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EFFECTS OF SOIL INJECTION OF LIQUID DAIRY MANURE ON THE QUALITY OF SURFACE RUNOFF

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ABSTRACT

Title: Effects of Soil Injection of Liquid Dairy Manure on the Quality of Surface Runoff

Liquid dairy manure has been injected on the soil contour to depths of 6 and 12 inches and applied to the surface of a Bluegrass sod and a bare tilled soil. Application rates of 9,250 gallons per acre were used. Runoff from 9-foot-square plots which were sprinkled at rates of 2.5 inches per hour on sod and 1.5 inches per hour on bare soil was collected and analyzed for various pollution parameters including COD, N, TS, TSS, pH, DO, and Fecal Coliform. The effects of pollutant yield in the runoff have been determined for various treatments.

Injection of the manure into the soil essentially eliminated any pollutant yield in the runoff from the test plots as compared with surface application. Also, injection tended to even the rate of pollutant loss in the runoff. Increasing the delay-time between application of liquid manure and the simulated rainfall event significantly decreased the yield of pollutants in the runoff. Repeated yearly applications of manure on sod reduced pollutant concentration in runoff and also reduced runoff rates. Test results indicate that pollutant concentration in runoff is a function of the concentration in the liquid manure and the total quantity of runoff.

Descriptors: Soil Contamination, Soil Management, Soil Moisture* Soil Treatment*, Soil Water, Soil Water Movement, Farm Wastes*, Injection*

CHAPTER I

INTRODUCTION

Approximately 38 million tons of manure are produced annually by domestic animals in Kentucky. Nationally, about 2 billion tons are produced. Because of recently enacted regulations by governmental agencies, most of the manure produced in centralized feeding operations is being placed on the land, both in the liquid and solid forms. The number of liquid manure handling systems being used in centralized feeding operations continues to increase, especially on dairy and swine operations. Some of the reasons that liquid manure systems are popular are 1) convenience, 2) labor saving, 3) timeliness of application of manures to land, and 4) availability of equipment to handle large volumes rapidly.

Most of the liquid manures are being spread on top of the soil or cover crop. However, because of public complaints about the odors and the attraction of insects by anaerobically digested liquid manures placed on the top of the soil, many animal producers are injecting these liquids into the soil either in slits formed by spring-tooth tillage bars or by plowing it down. This procedure essentially alleviates the odor and insect nuisances. Injecting also has the potential of reducing the quantity of pollutants which would be picked up by surface runoff and conveyed to lakes and streams. However, since more of the manures would be below the soil surface and not exposed to surface runoff, potentially more of the organic nitrogen present in the manure could be reduced to nitrate and find its way into ground water by percolating through the soil mantle. It was the purpose of the research conducted in this project to measure and quantatively evaluate the effects that injecting liquid manures into the soil have on the quality of surface runoff and the percolation of nitrates through the soil. The results can be used to provide information for developing recommendations for injecting liquid manure into soils to minimize the potential for pollution of surface and ground waters from this non-point source.

More specifically, the project objectives were:

1. To determine the effects of liquid manure application practices on the quality of surface runoff.
2. To determine the effects of liquid manure application practices on the quality of water percolating through the soil and the use of nutrients by crops.

The research conducted and the results obtained to satisfy objective 1 are the subject of this report. A report on the research conducted for objective 2 is presented separately.

CHAPTER II

RESEARCH PROCEDURE

Liquid manure from a predominately Holstein 100-cow dairy herd fed a typical dairy ration was stored under anaerobic conditions for periods up to 3 months. This liquid manure was injected into an established Bluegrass sod and into a tilled soil at 6- and 12-inch depths and applied to the surface of the soil. Test plots, 9-feet-square, were isolated with borders so that surface runoff water could be collected and analyzed for various pollutional (water quality) parameters. The treatment site was selected on a hillside and injections were made on the land contour in slits made with a spring-tooth tillage bar. The injection equipment used is commercially available and typical of that being employed by many farmers. Simulated rainfall was applied by sprinkler irrigation to control application rates, total volume applied, and time of application. Runoff was measured and a cumulative runoff hydrograph developed for test plots during the simulated rainfall event. Runoff tests were scheduled immediately following injection and preparation of the test plots and after delays of 1 and 7 days. All plots were covered during natural ranfall events during the testing period.

TEST PROCEDURE

The liquid dairy manure used in all tests was obtained from one of two 82,000-gallon storage tanks at the University of Kentucky, Coldstream Dairy Farm located 10 miles north of Lexington. The manure was mixed and pumped into a 2,300 gallon liquid manure wagon made by Badger Manufacturing Company of Kaukauna, Wisconsin. The wagon is equipped with three spring-tooth injection tools located behind the wagon and spaced 3 feet apart. Liquid manure is pumped from the wagon through tubing and deposited behind the injection tool at a point near the bottom of the silt made by the tool in the soil. The depth of the slit is controlled by hydraulic cylinders used to raise and lower the injection tool carriage frame.

The rate of injection was calibrated by placing a known quantity of liquid manure in the wagon and determining the distance of travel required to empty the wagon. The travel speed required to deposit 17 gallons of manure in 9 feet of travel in 3 silts, spaced 3 feet apart was determined. The wagon was pulled at this speed for all injections. The value of 17 gallons per 9-foot-square plot was chosen to provide elemental nitrogen at a rate of approximately 150 pounds per acre. This nitrogen application rate would be typical of that used in many farming practices. A sample of the liquid manure injected for each three-plot series of tests was collected for chemical and microbiological analysis.

Injections were made parallel to the contour of the land in the test area. An individual test sequence at a given injection depth would require the preparation of three 9-foot-square test plots, one each for the runoff test immediately following application (0-day delay) and one each for the 1-day delay and 7-day delay tests. Since each test plot was 9 foot wide, liquid manure was injected for approximately 35 to 40 feet along the contour. Borders were placed around each of the three plots to isolate the 9-foot-square runoff area. Approximately 2 hours was required to prepare a plot for testing. Therefore, the start of the 0-day delay test was actually 2 to 3 hours after injection of the manure. The 0- and 7-day delay test plots were covered to eliminate natural rainfall on these plots. This test series was replicated three times for each injection depth.

Surface applications were made by manually applying 17 gallons of manure to the plots. After application, the test procedures were identical to the injection plots described before. Each test series was replicated three times.

Three control plots which received no manure application were tested to determine the background levels of the various pollutional parameters measured.

Placement of the plots in the test area for the 1975 experimental program is shown in Figure 2-1. The slope of the plots varied from 2 to 5%.

The 6-inch deep injection and surface application tests were repeated in triplicate in 1976 on Bluegrass sod in a test area immediately adjacent to the 1975 test area. The 12-inch injection tests were not repeated. The 6-inch injection and surface application plots for the 1975 tests were retreated in both 1976 and 1977.

The 1975 test area was plowed, disked, and leveled after the 1977 reapplication tests as described above were completed. This plowed area was used for replicated 6-inch injection and surface application tests on plowed bare soil. Again, the injection procedures described for the 1975 experiments were used for these tests including testing of control plots.

RUNOFF TEST PROCEDURES AND FACILITIES

Runoff from each test plot was collected in a trough which spanned the entire width of the downhill end of the plot. A ditch was dug across the end of the plot to accommodate the trough with care being taken to make a smooth, straight cut at the edge of the plot. A special cutting guide was used to insure this straight, smooth edge. It consisted of sheet metal cutting tools which were inserted into a long angle iron guide which was placed across the end of the plot as illustrated in Figure 2-2. The sheet metal cutters were driven into the ground to a depth of 6 to 8 inches to cut the edge. The ditch was then opened and the cutting tool installed in the ditch in a horizontal position as illustrated in Figure 2-3. The sheet metal cutting tools were then driven horizontally into the uphill edge of the ditch for a distance of 2 or 3 inches. A horizontal slit was thus formed 1 to 2 inches below the soil surface. The collecting trough was then installed in the ditch with the lip of the trough inserted into the slit approximately 2 inches as illustrated in Figure 2-4.

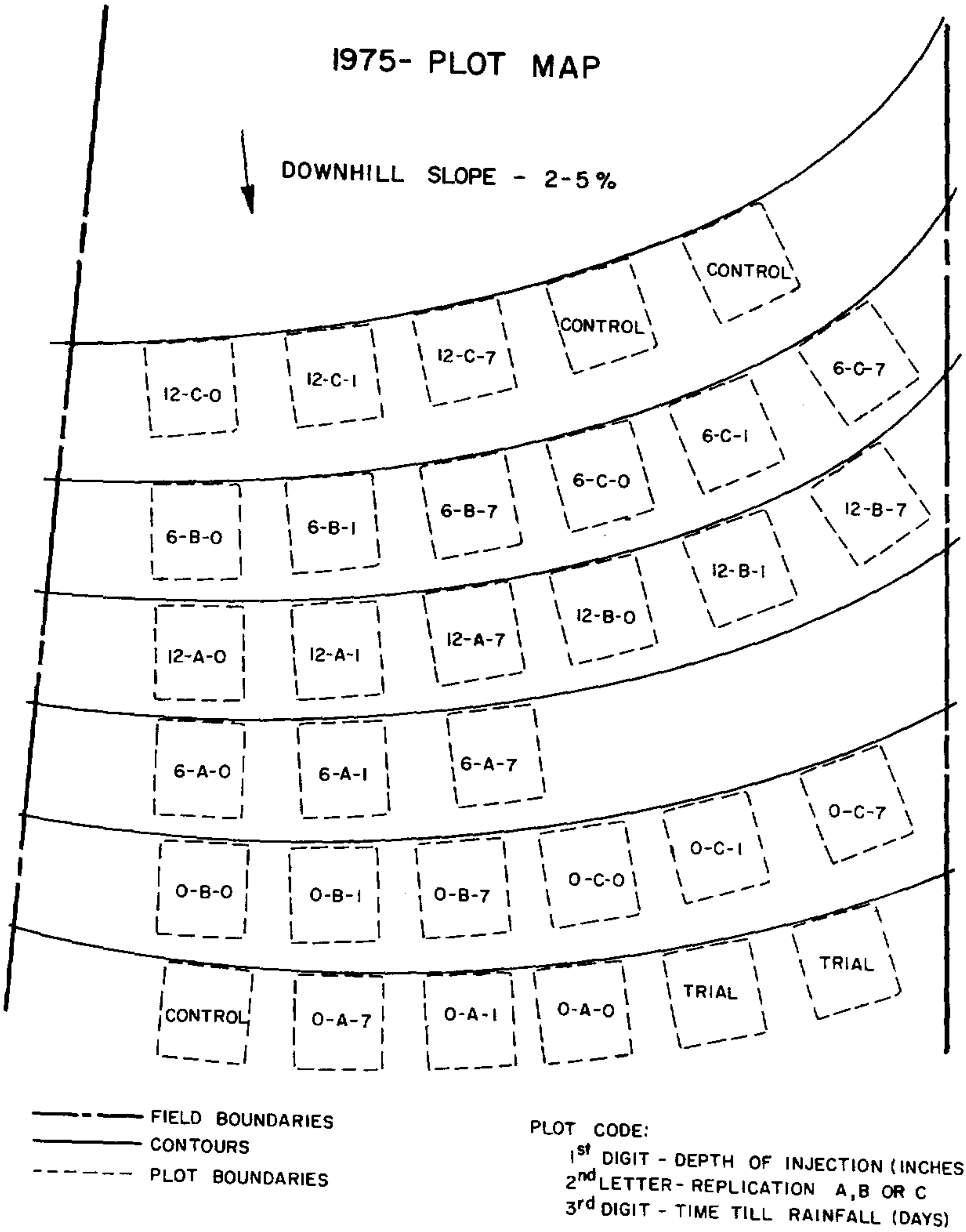


Figure 2-1. Plot map for 1975 manure application tests.

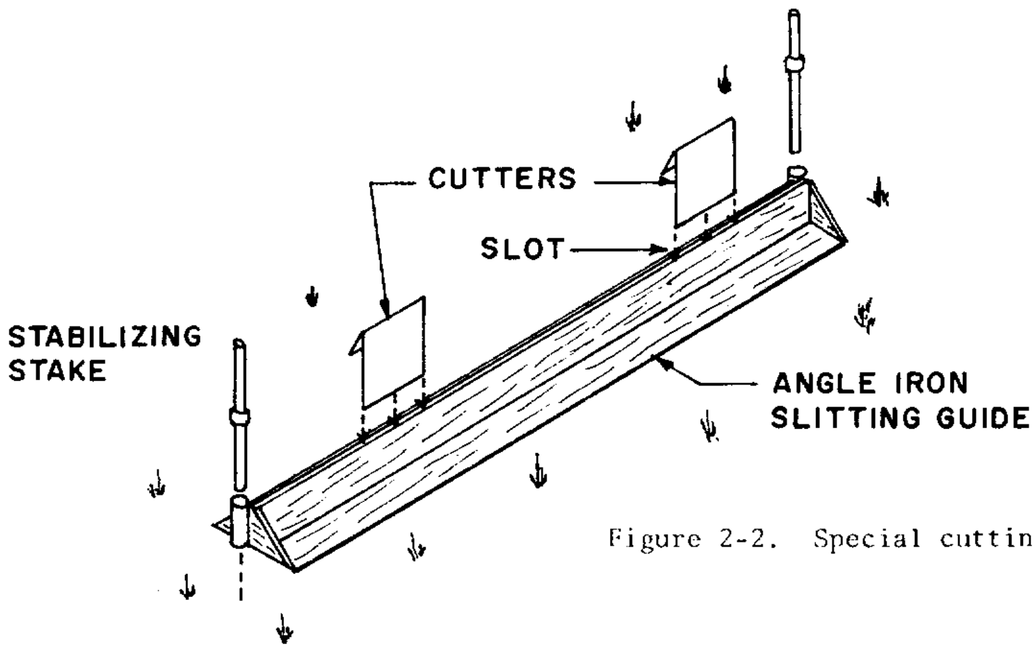


Figure 2-2. Special cutting tool.

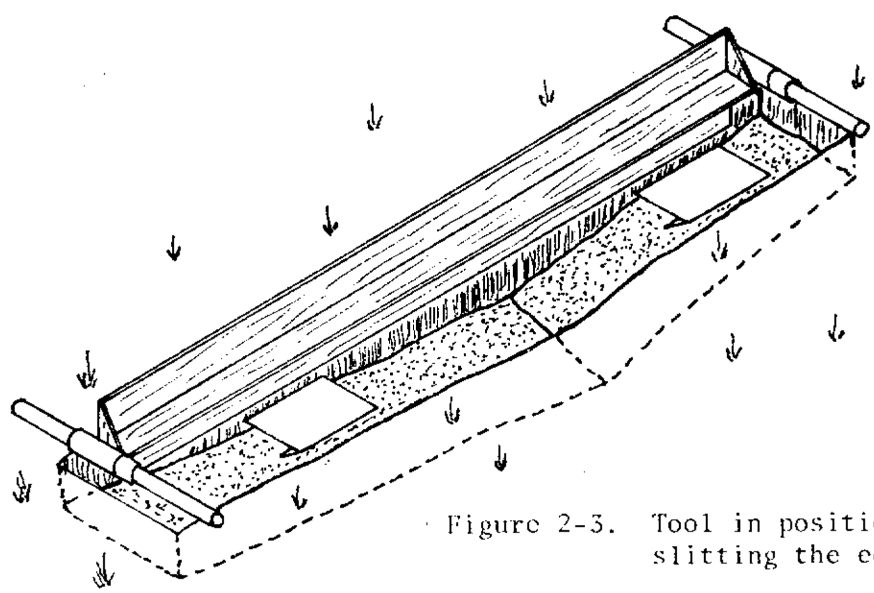


Figure 2-3. Tool in position for slitting the edge.

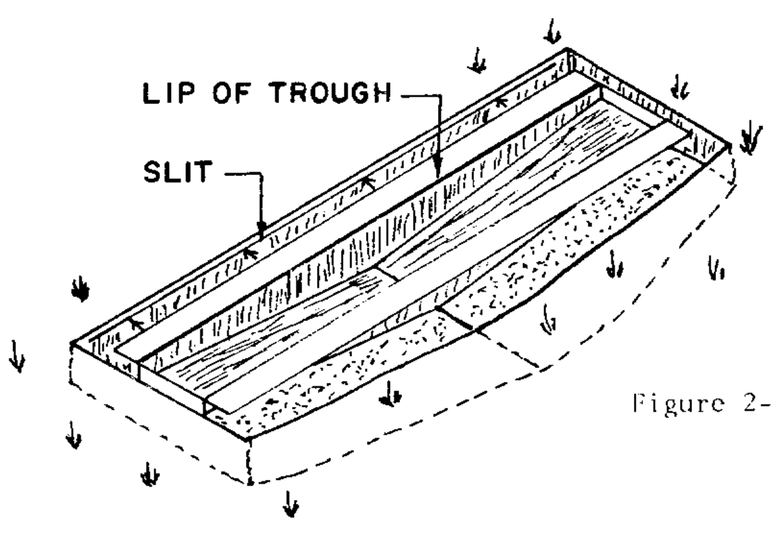


Figure 2-4. Trough being positioned in ditch.

The collection though was shaped so that water collected in the trough would flow to the middle (lengthwise). A pump was attached to the drainage hole as indicated in Figures 2-5 and 2-6. The level of runoff water in the trough was controlled with a float switch which activated the pump. When approximately 1 liter of runoff collected in the trough, the float switch would activate the pump and the sample would be pumped into a measuring cylinder. This cylinder, shown in Figure 2-7, was also equipped with a float switch which activated when the measuring cylinder filled to a level of 1 liter. Activation of the float switch in the measuring cylinder deactivated the trough pump and opened a valve on the measuring cylinder. The runoff sample from the measuring cylinder was drained either into a sample jar or a disposal pipe.

The cylinder float switch indexed an event counter which recorded the number of liters of runoff from the plot. This made it possible to obtain samples for chemical and microbiological analysis after selected amount of runoff had been collected. Usually 1 liter samples were collected at counts 1, 20, 40, 60, 100, and 150 liters. The time span between each measuring cylinder drainage event was recorded either manually with a stop watch or automatically with an event marker. Samples were sometimes collected at other counts. For example, some injection plots did not yield any runoff and others only several liters during extended periods of testing. For the latter situation, all runoff was collected for analysis. One injection plot which was sprinkled for approximately 48 hours and received over 120 inches of water did not have any runoff.

The pH and dissolved oxygen content of the collected runoff samples were determined immediately upon collection during the first two years of testing. Collected samples were placed in a portable cooler for holding during transport to wet laboratory facilities.

Each 9-foot-square test plot was bordered on three sides by sheet-metal plot borders as illustrated in Figure 2-8. The plot borders were driven about 3 inches into the soil for the surface application

Figure 2-5. Trough and drainage system

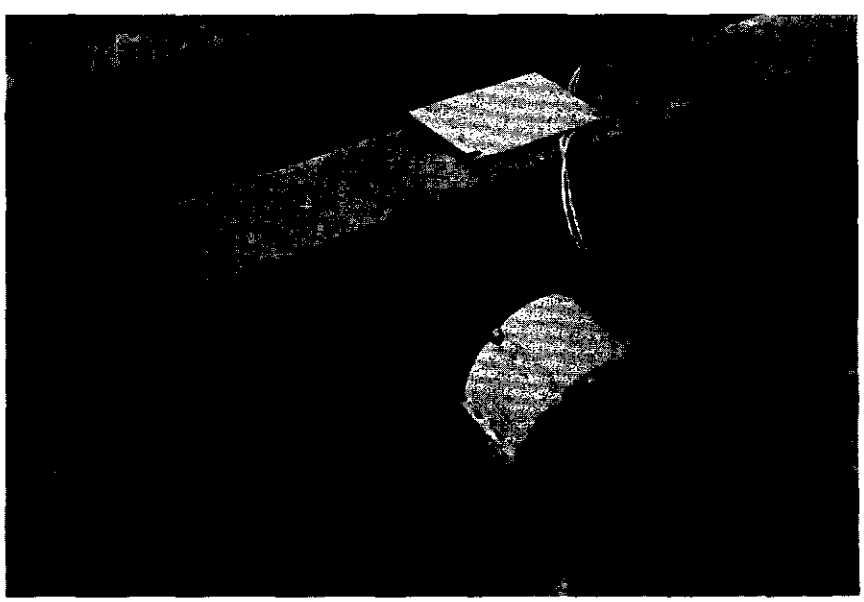


Figure 2-6. Drainage pump.

PICTURE OF COLLECTION APPARATUS

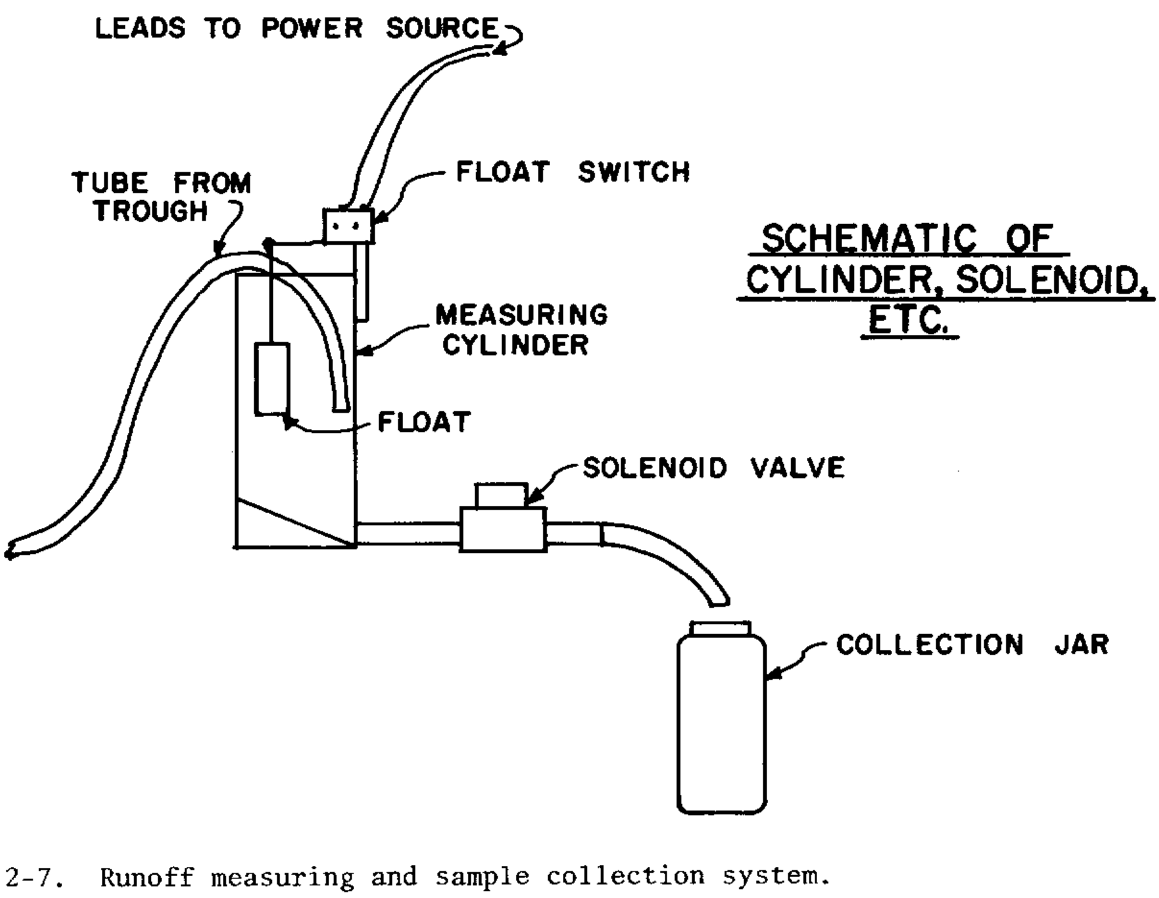
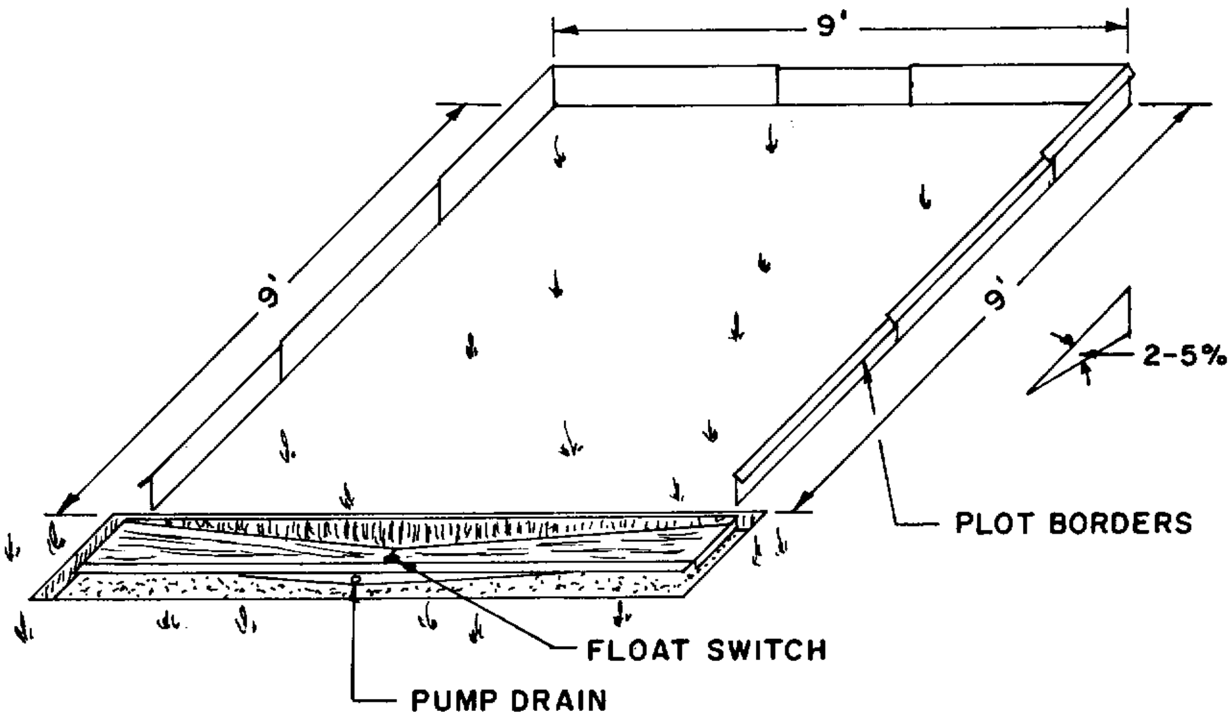
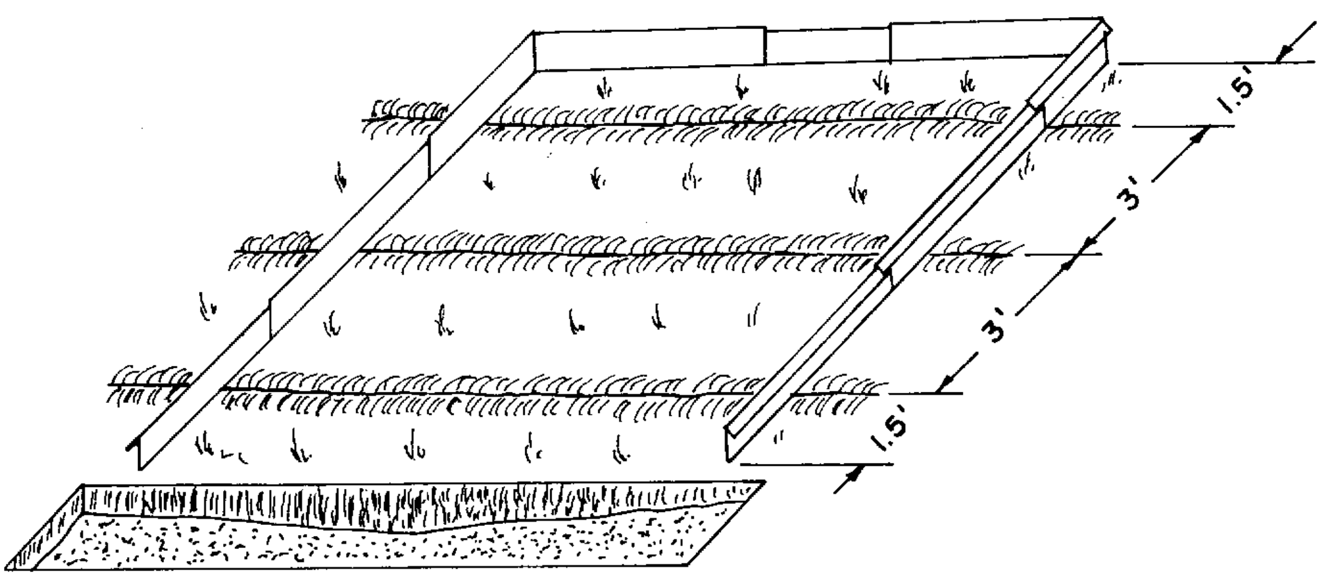


Figure 2-7. Runoff measuring and sample collection system.



SURFACE PLOT WITH TROUGH IN PLACE



INJECTION PLOT SHOWING ORIENTATION OF SLITS

Figure 2-8. Plot layout.

and control plot tests and about 6 inches for the injection plots. The 6-inch depth used for the injection plots was necessary to prevent runoff from leaving the plot laterally through the injection slits. The plot borders were used to isolate the plots and divert all runoff from the simulated rainfall falling on the inside of the plot borders to the collection trough. The borders also prevented any simulated rainfall falling outside the plot borders from entering the collection trough. The collection trough was covered with a sheet metal roof to prevent any simulated rainfall from falling directly into the trough.

Plots were covered at the time of testing with a portable plastic-covered building (greenhouse) to eliminate natural rainfall on the plot. The greenhouse shown in Figure 2-9 also prevented drifting and distortion of the sprinkler patterns by eliminating wind currents. The 1- and 7-day delay plots were covered with plot covers as shown in Figure 2-10 between the time of manure application and testing.

A sprinkler system was used to provide simulated rainfall at a rate of 2.5 inches per hour for the grassed plots and 1.5 inches per hour for the bare soil plots. The system was arranged as shown in Figure 2-11. The sprinkler pattern was adjusted periodically to improve even distribution by collecting water in jars placed at nine different locations over the plot for a given time period. Total application rate was determined by averaging the water collected in all jars. A pressure regulator was used to adjust water flow rate and maintain constant pressure at the sprinklers.

LABORATORY ANALYSIS

Runoff samples were tested using standard laboratory procedures. Chemical Oxygen Demand was determined using a potassium dichromate in sulfuric acid solution as the oxidizing agent and standard ferrous ammonium sulfate for titration as outlined in Standard Methods etc., 13th ed. Total Nitrogen was determined by the Kjeldahl method, again as described in Standard Methods etc., 13th ed. Standard tests from

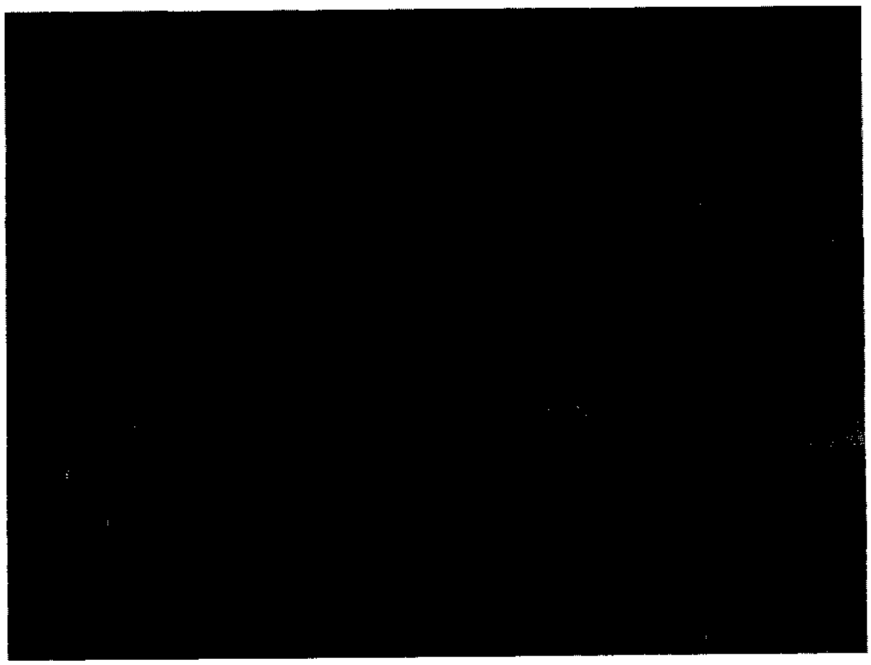


Figure 2-9. Greenhouse.

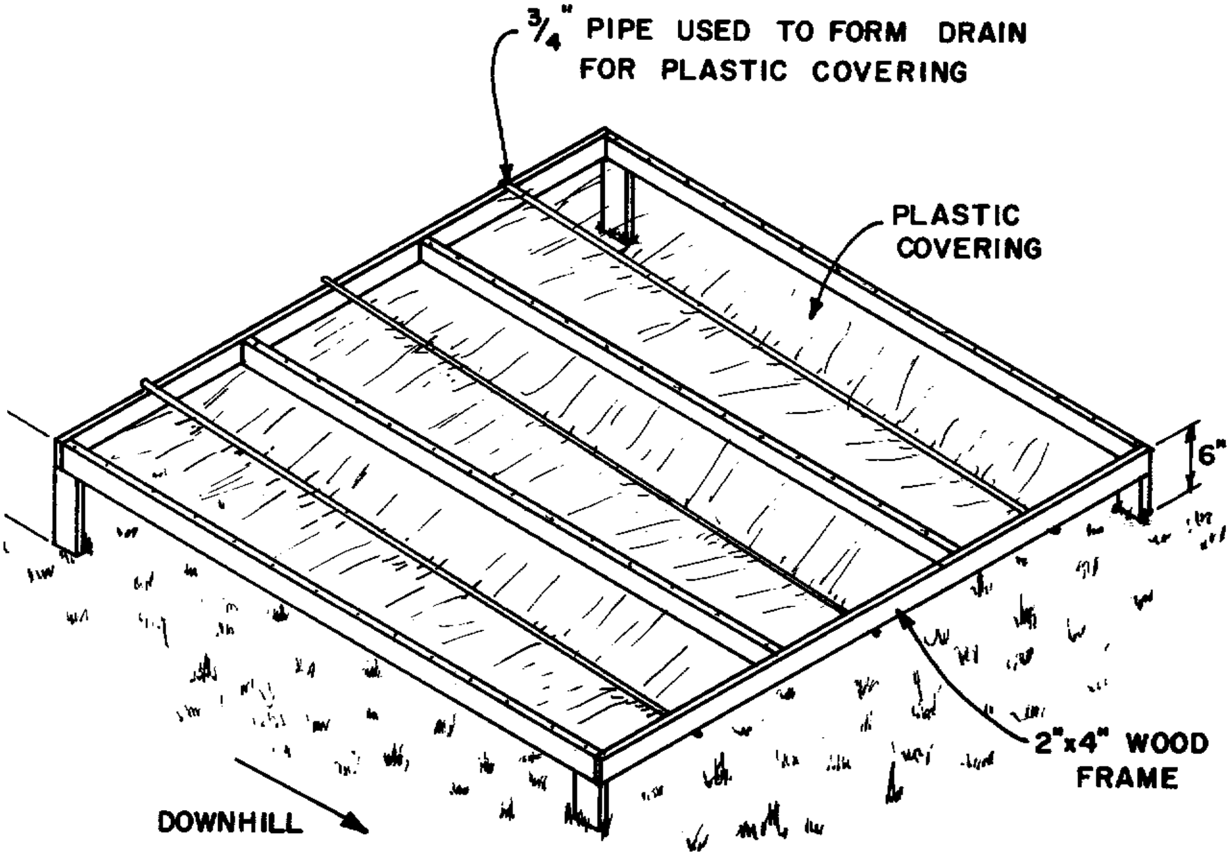


Figure 2-10. Plot cover.

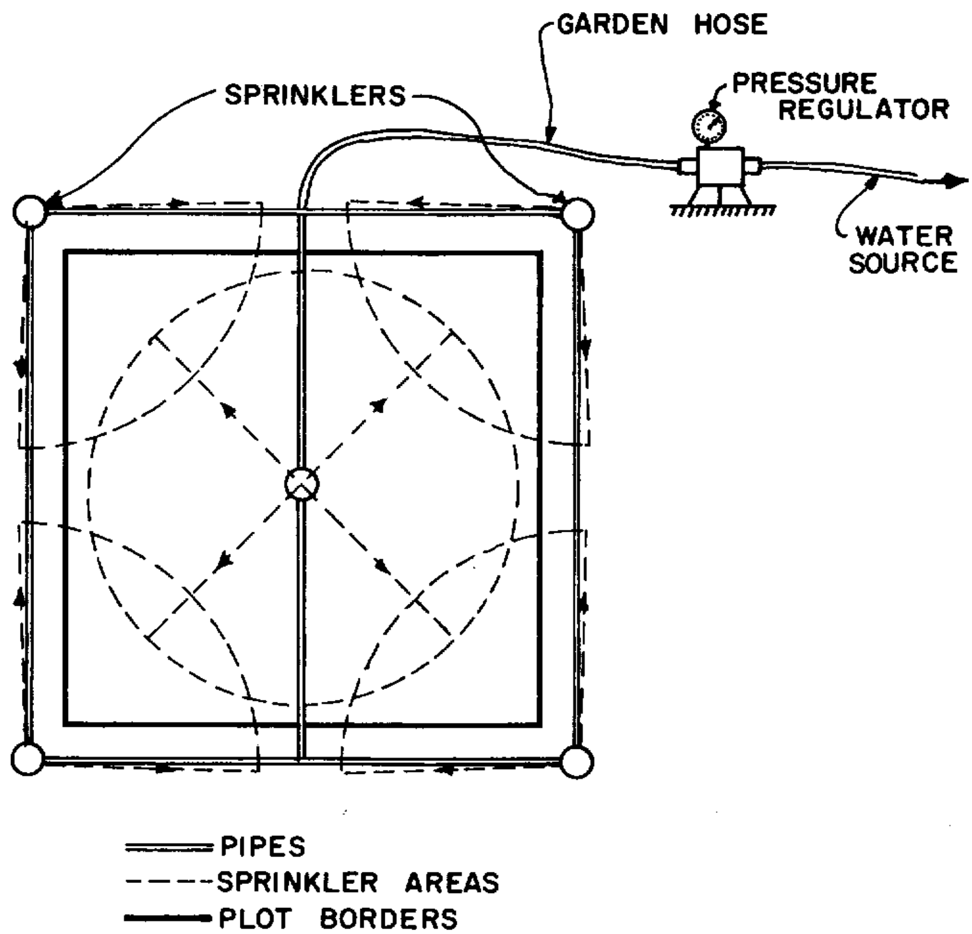


Figure 2-11. Plan view of sprinkler system.

this reference were also used for Total Solids, Suspended Solids, and Fecal Coliforms.

CHAPTER III

DATA AND RESULTS

The major objectives of this research were to determine the effects of (1) injection versus surface application, (2) injection depth, and (3) delay between the time of application and a rainfall event on the quantity of pollution (water quality) parameter in the runoff from a sodded area receiving liquid dairy manure. Time and resources also permitted a 6-inch injection and surface application test series to be conducted on a bare tilled soil although this was not one of the original major objectives of the project.

Seventy-six tests were conducted as part of this research project. There was no runoff from approximately 10% of the test plots, most of these being 7-day delay and injection tests. Some of the other plots yielded less than the 150 liters of the desired runoff during an application period of 4 to 6 hours of simulated rain. The no-runoff condition was generally associated with the injected plots, however, there were several surface application plots which also produced no runoff. Observations indicated that these plots contained small areas where ponding occurred. The same effect was more obvious with the injection plots where ponding occurred in the injection slit and on the uphill side of the soil ridge made by the injection tool.

A problem was encountered with soil erosion with the series of test performed on tilled bare soil. During several tests at simulated rainfall application rates of 2.5 inches per hour, the collection trough filled with sediment and fouled the proper operation of the collection trough float-switch and pump. For this reason application rates for bare soil tests were reduced to 1.5 inches per hour.

DATA

The data collected is presented in graphical form in Figures 3-1 through 3-30. The data points on the graphs generally represent the average values measured for three replications. Whenever a data point represents less than three replications, it is indicated as a solid point. The graphs are displayed in a way to compare the 0-, 1-, and 7-day delay effects. The average concentration of the pollutants in the manure applied to the plots is indicated on each graph. Table 3-1 indicates the order of data presentation.

INJECTION VERSUS SURFACE APPLICATION

The data for surface application, Figure 3-1 through 3-13, and injection, Figures 3-14 and 3-30, show that comparatively, injection essentially eliminates pollution in the runoff. Runoff from the 0-delay injected plots contained only slightly greater to less quantities of each pollution parameter than runoff from the control plots while 1- and 7-day delays were generally lower than the 0-day delay. A dramatic illustration of this can be shown by comparing the COD in the first runoff sample from the 0-day delay plots for surface and 6-inch injection plots in Figures 3-1 and 3-14, respectively. There is an approximate 72-fold decrease in the PPM of COD. Similarly, there is a 90-fold decrease in N (Figures 3-4 and 3-17), an 18-fold decrease in TS (Figures 3-7 and 3-20), a 33-fold decrease in TSS (Figure 3-10 and 3-23), and a 290-fold decrease in Fecal Coliform (Figures 3-13 and 3-26). The foregoing comparisons are made without subtracting background (control) levels. If background levels are subtracted, the magnitude of the decreases are much higher. For example, there would be a 175-fold decrease in COD.

INJECTION DEPTH

Comparison of the 1975 data for the 6-inch injections; Figures 3-14 through 3-23; with the 12-inch injection; Figures 3-27 through 3-30; indicate essentially no difference in the levels of COD, N, TS, or TSS in the runoff. In both cases, levels are essentially equal to background levels. Twelve inch injections were discontinued after the 1975

Table 3-1. Order of Data Presentation

Figure No.	Pollution of Parameter	Injection Depth	Test Year	Surface
1	COD	Surface	1975	Sod
2	COD	Surface	1976	Sod
3	COD	Surface	1977	Bare
4	N	Surface	1975	Sod
5	N	Surface	1976	Sod
6	N	Surface	1977	Bare
7	TS	Surface	1975	Sod
8	TS	Surface	1976	Sod
9	TS	Surface	1977	Bare
10	TSS	Surface	1975	Sod
11	TSS	Surface	1976	Sod
12	TSS	Surface	1977	Bare
13	Fecal C	Surface	1975	Sod
14	COD	6"	1975	Sod
15	COD	6"	1976	Sod
16	COD	6"	1977	Bare
17	N	6"	1975	Sod
18	N	6"	1976	Sod
19	N	6"	1977	Bare
20	TS	6"	1975	Sod
21	TS	6"	1976	Sod
22	TS	6"	1977	Bare
23	TSS	6"	1975	Sod
24	TSS	6"	1976	Sod
25	TSS	6"	1977	Bare
26	Fecal C	6"	1975	Sod
27	COD	12"	1975	Sod
28	N	12"	1975	Sod
29	TS	12"	1975	Sod
30	TSS	12"	1975	Sod

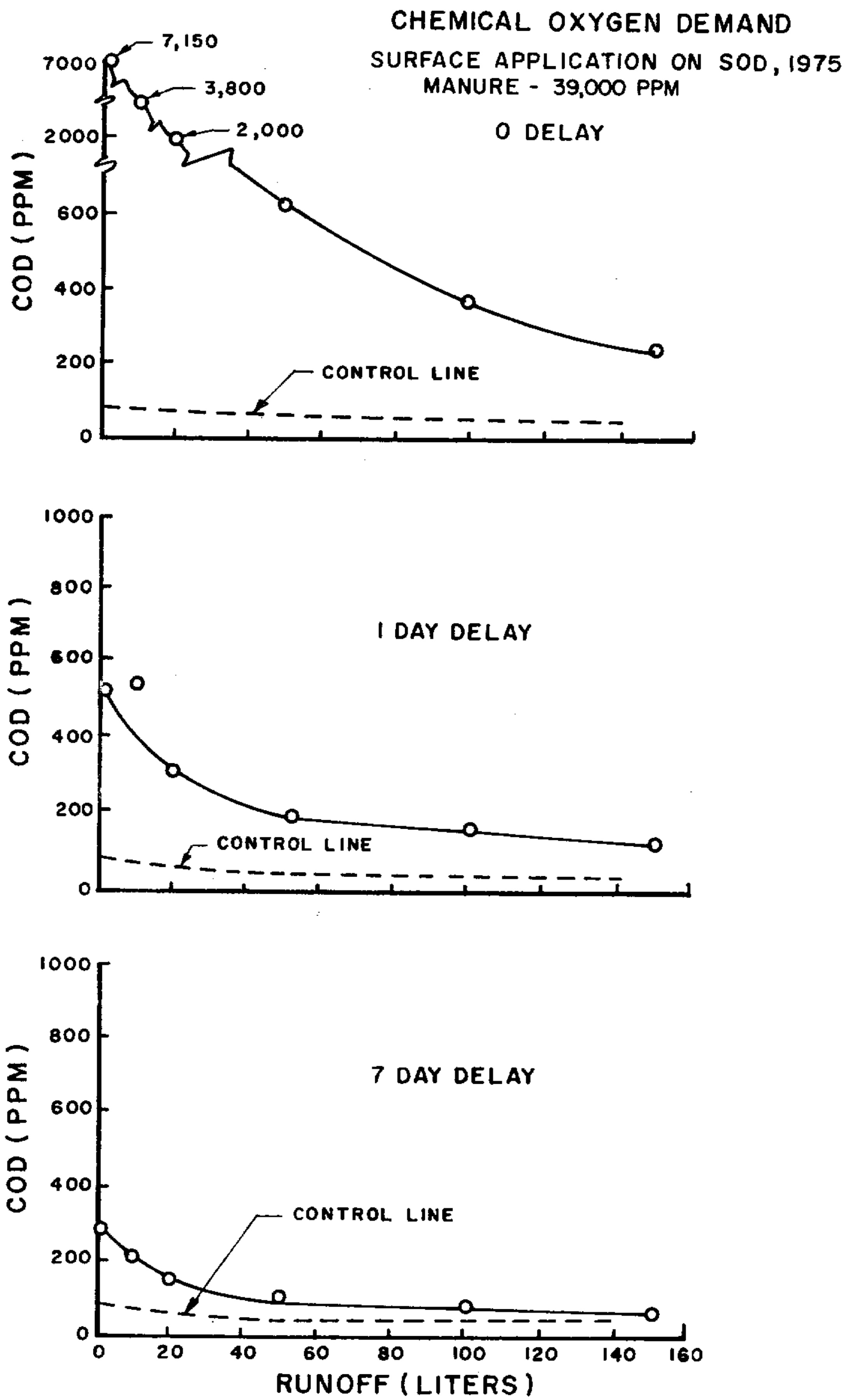


Figure 5-1. Chemical oxygen demand, surface application on sod, 1975.

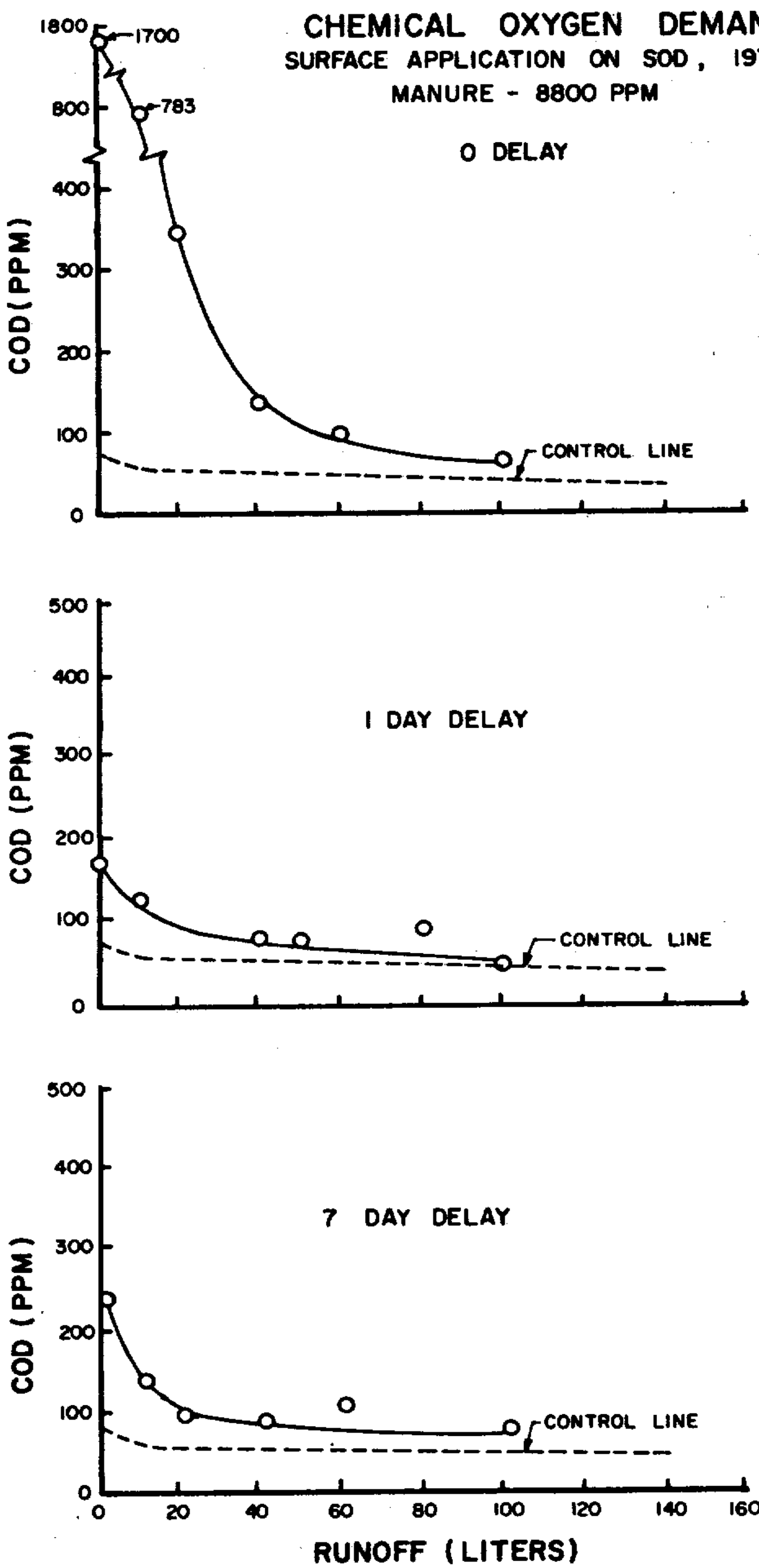


Figure 3-2. Chemical oxygen demand, surface application on sod, 1976.

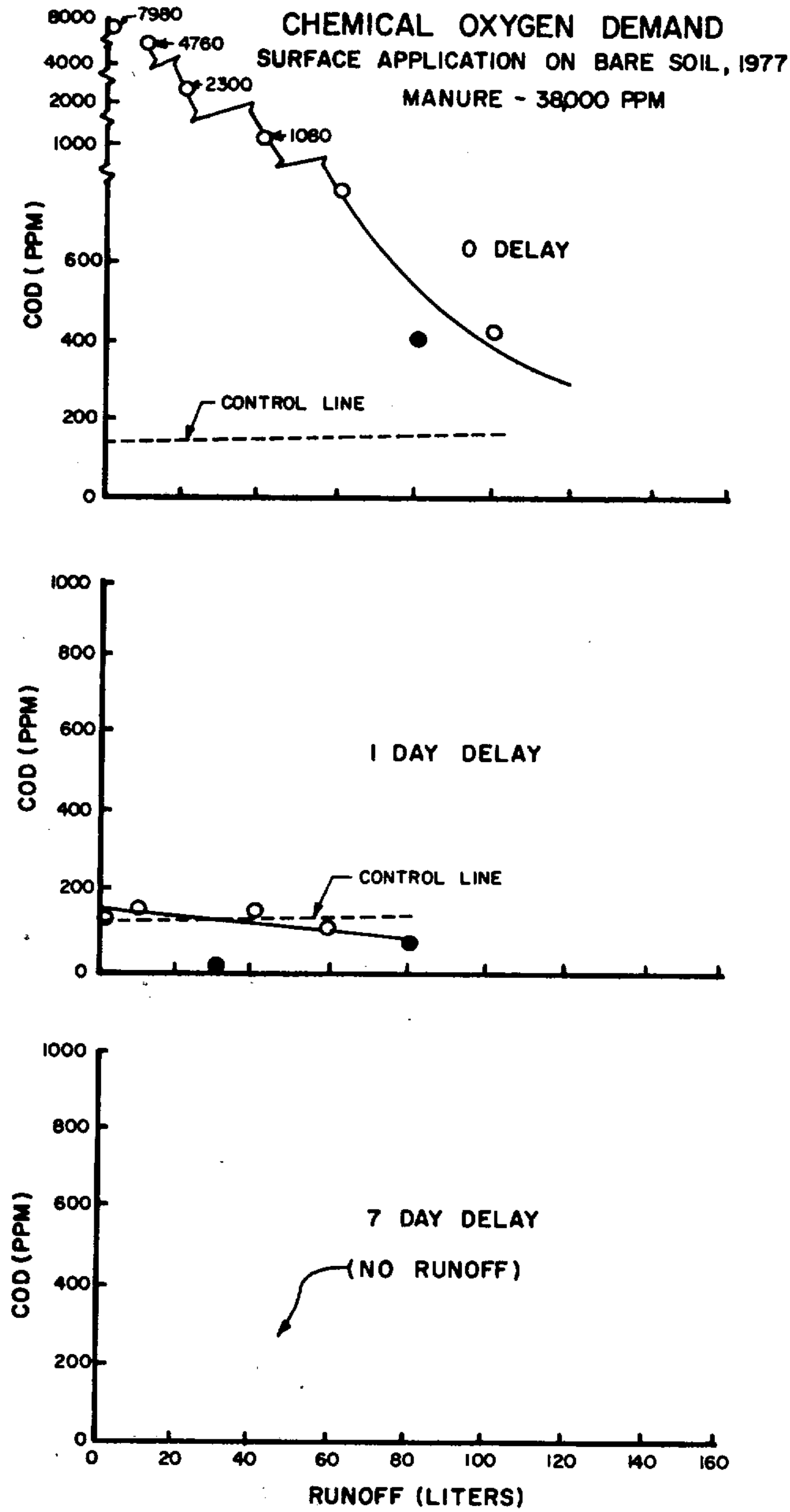


Figure 3-3. Chemical oxygen demand, surface application on bare soil, 1977.

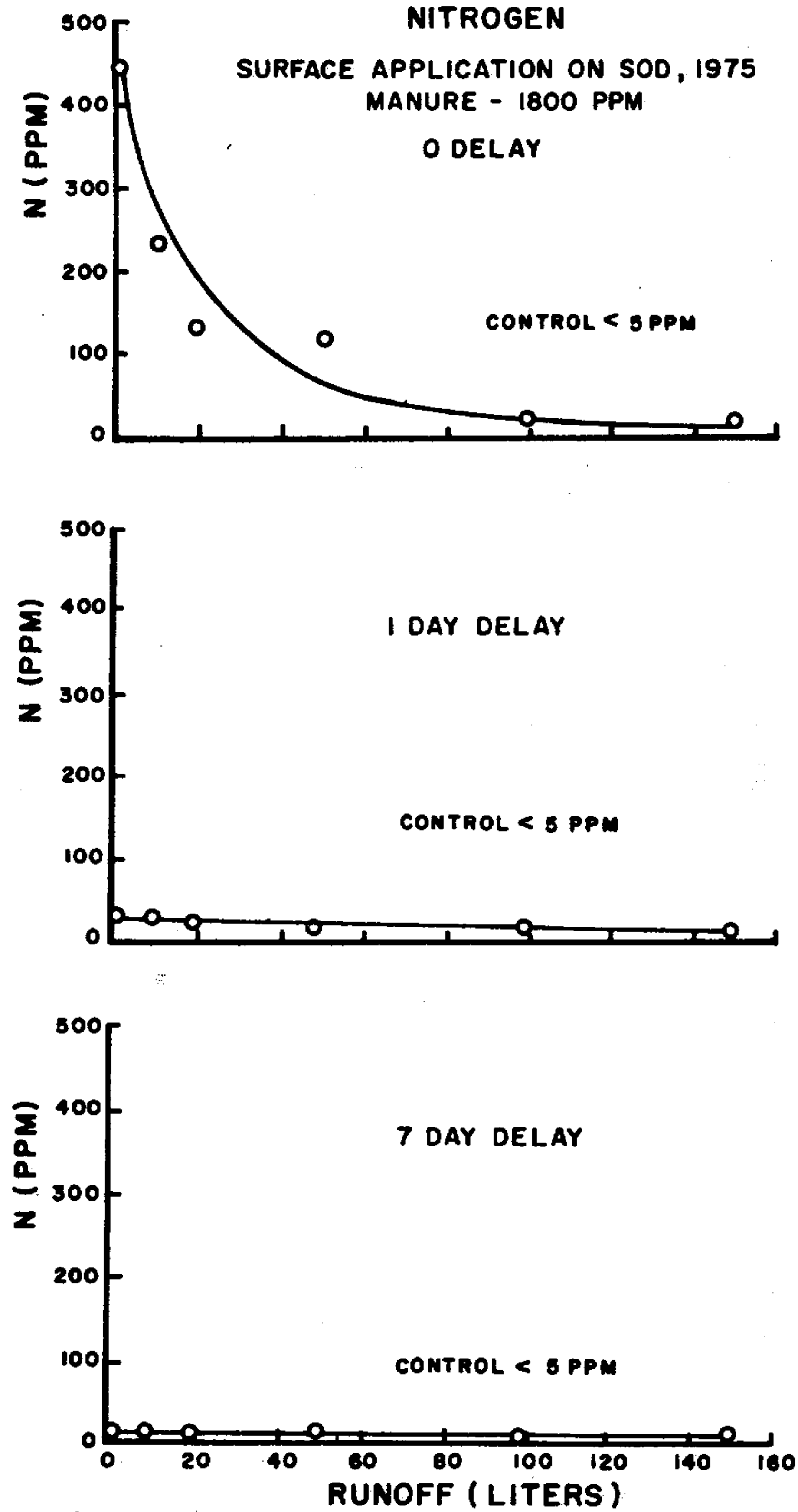


Figure 3-4. Nitrogen, surface application on sod, 1975.

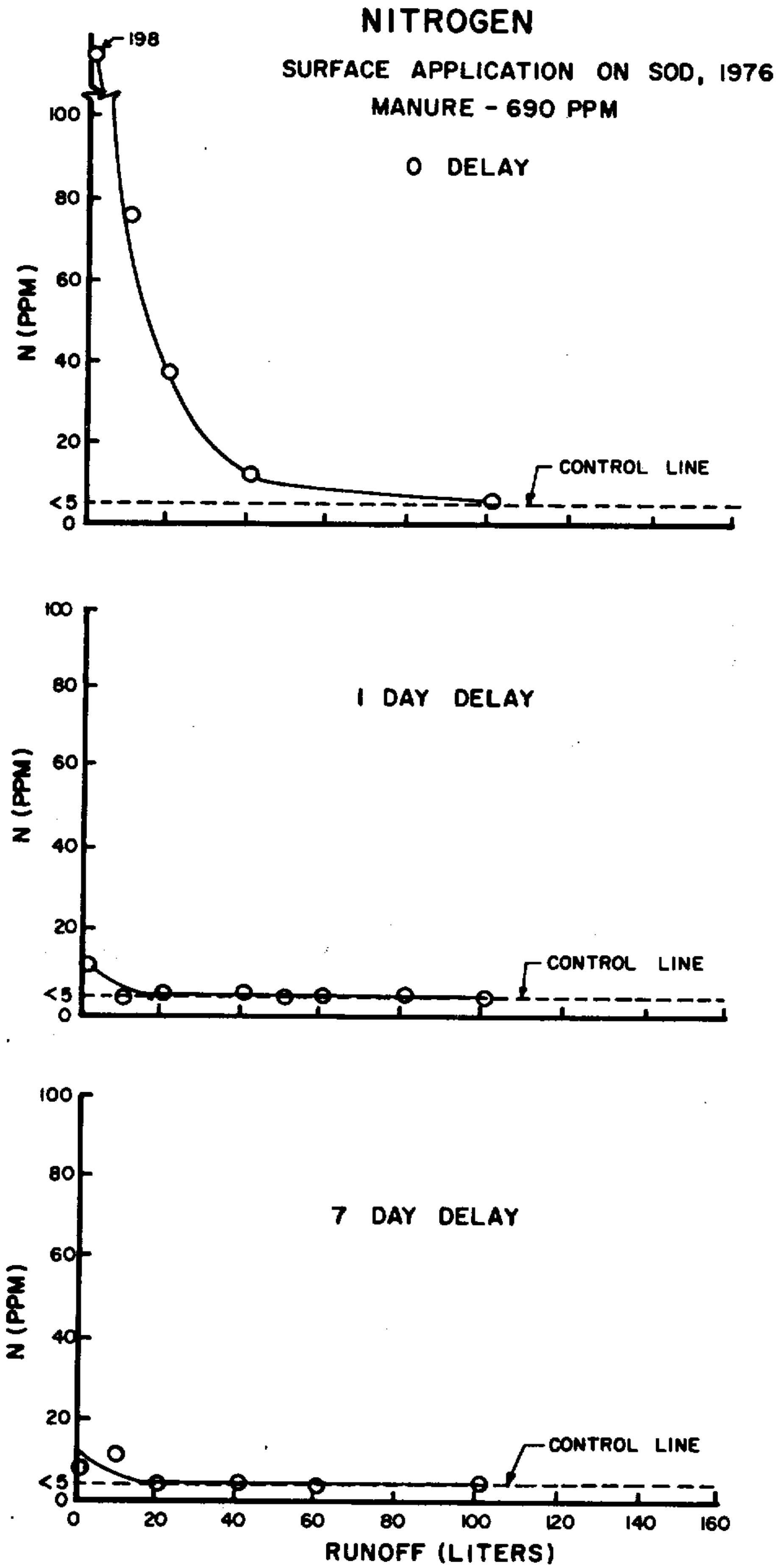


Figure 3-5. Nitrogen, surface application on sod, 1976.

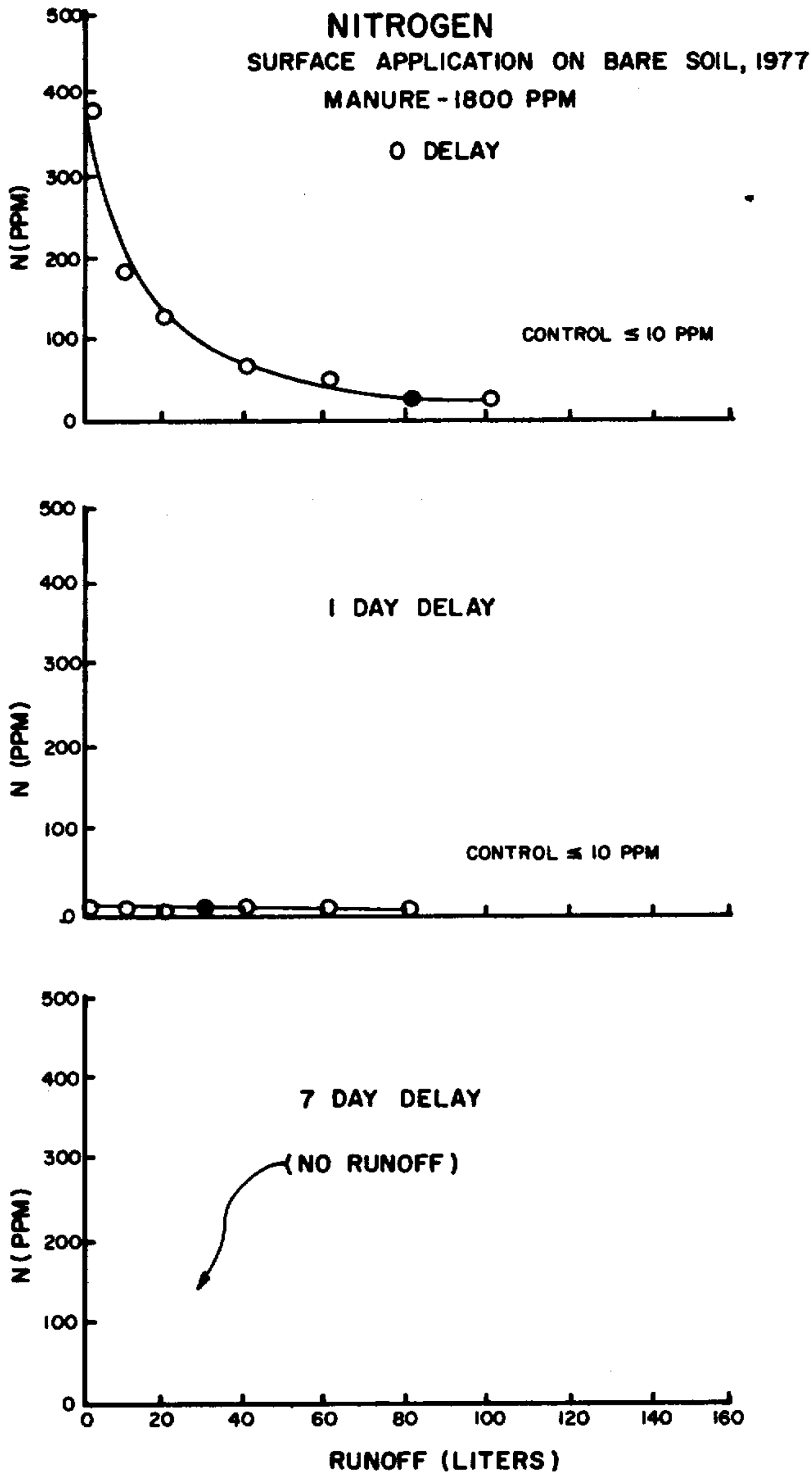


Figure 3-6. Nitrogen, surface application on bare soil, 1977.

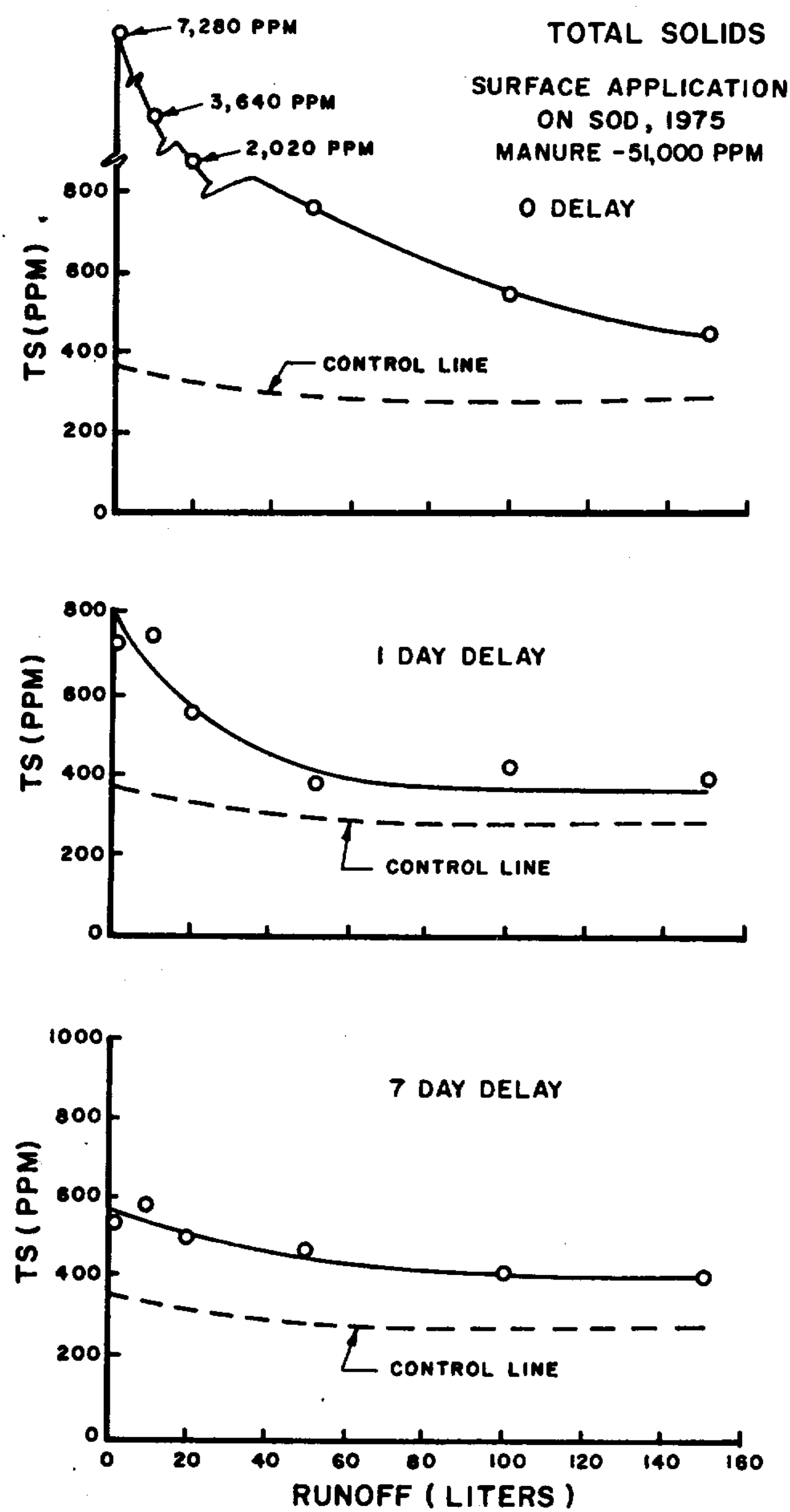


Figure 3-7. Total solids, surface application on sod, 1975.

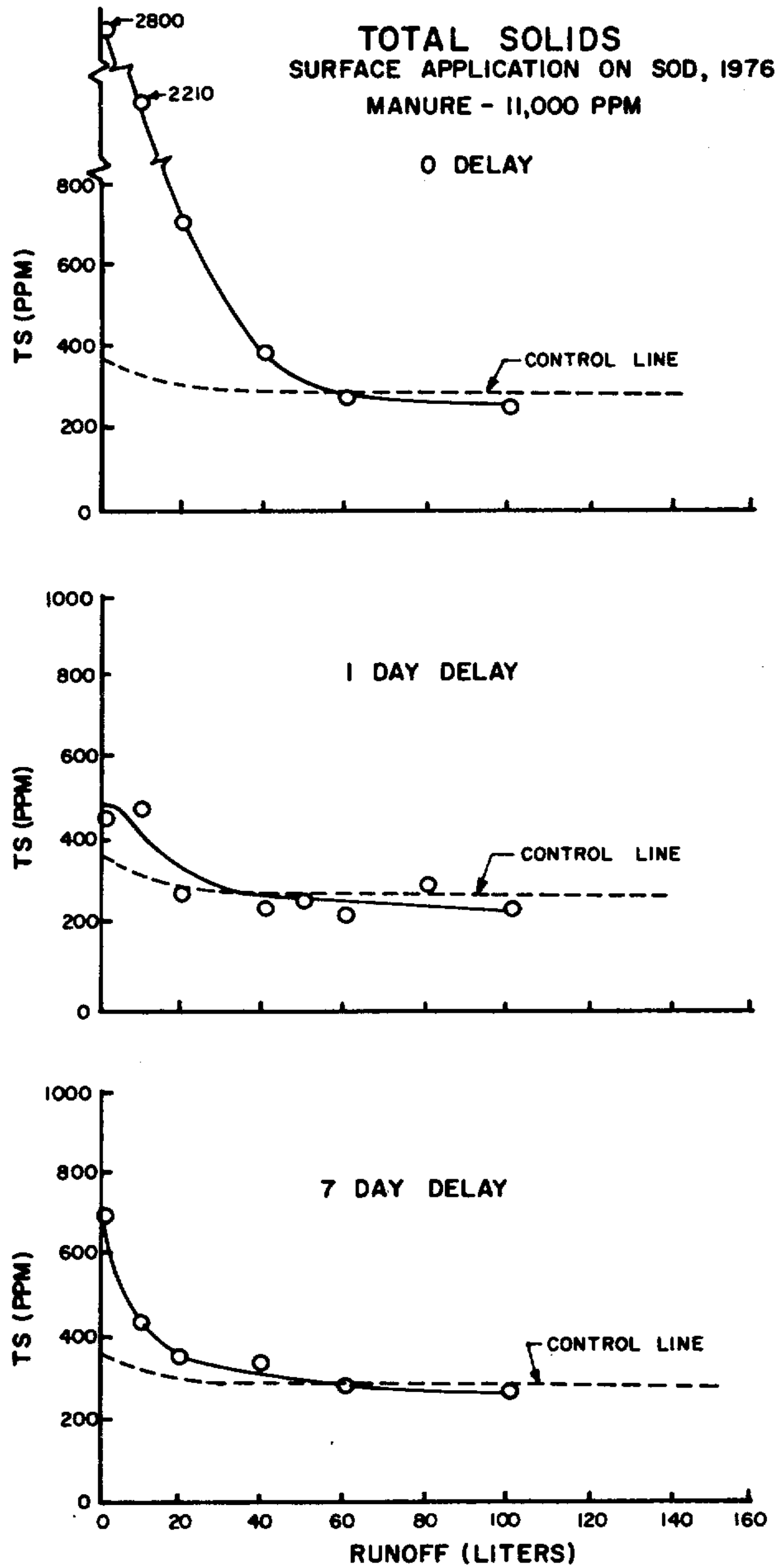


Figure 3-8. Total solids, surface application on sod, 1976.

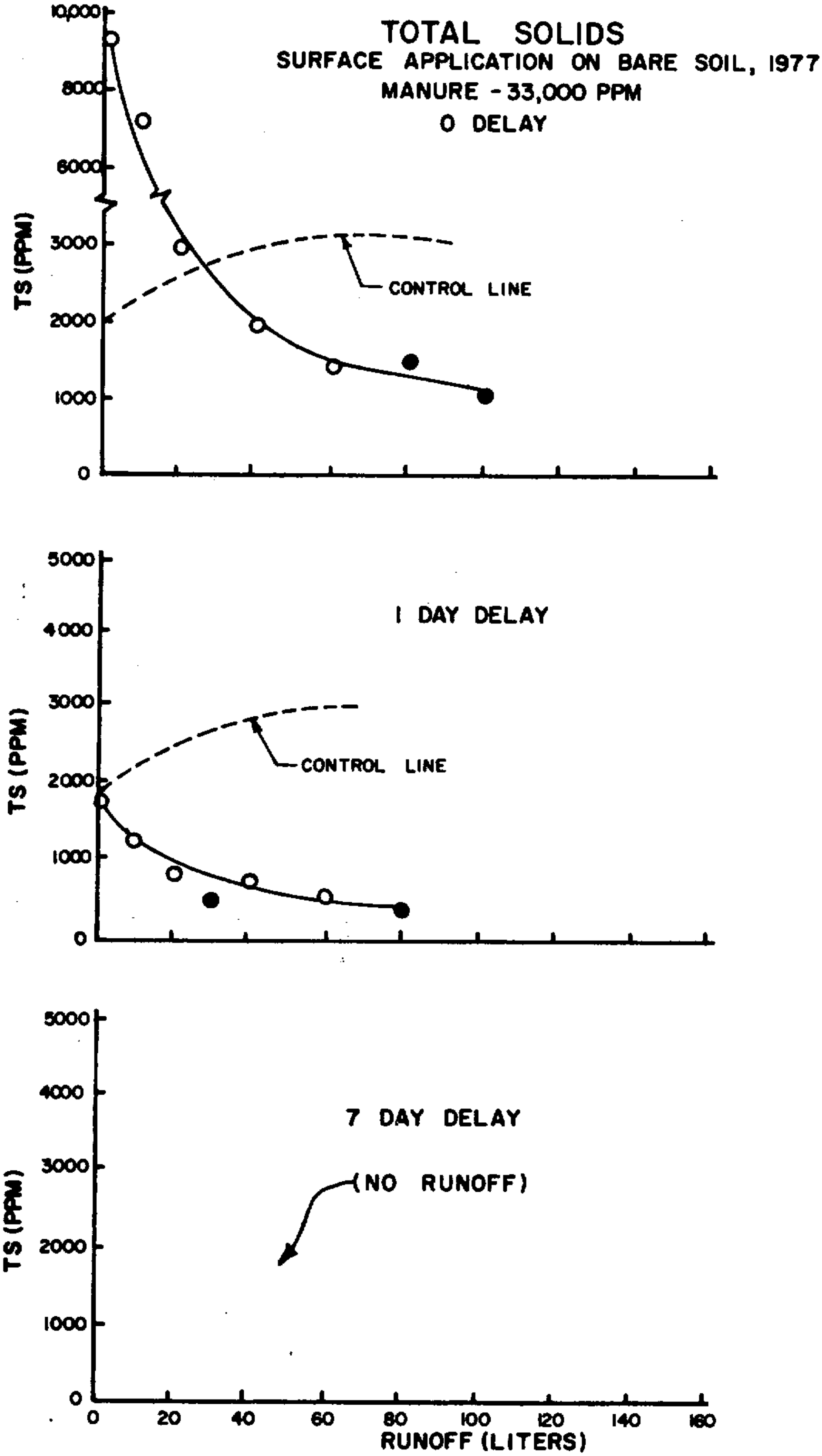


Figure 3-9. Total solids, surface application on bare soil, 1977.

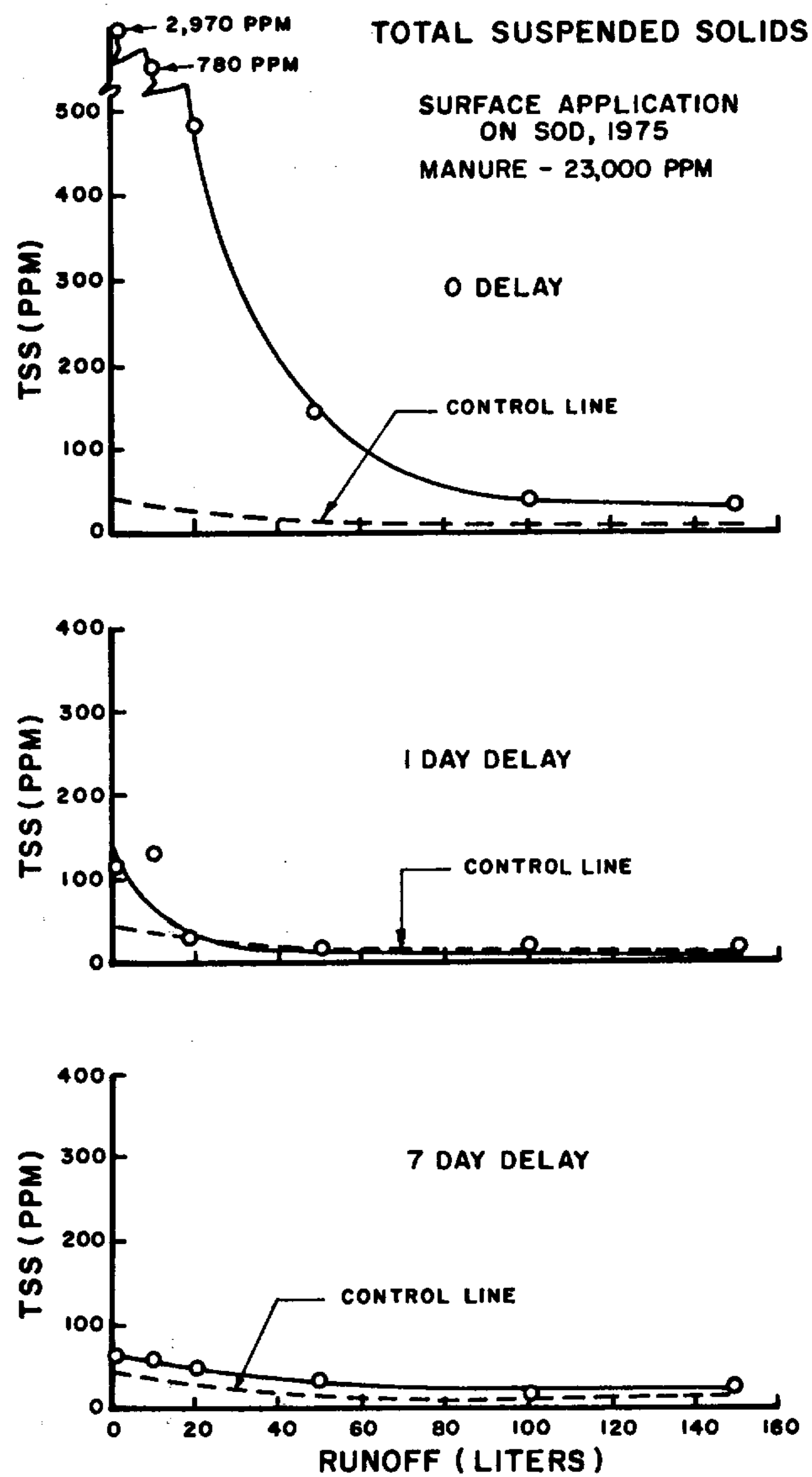


Figure 3-10. Total suspended solids, surface application on sod, 1975.

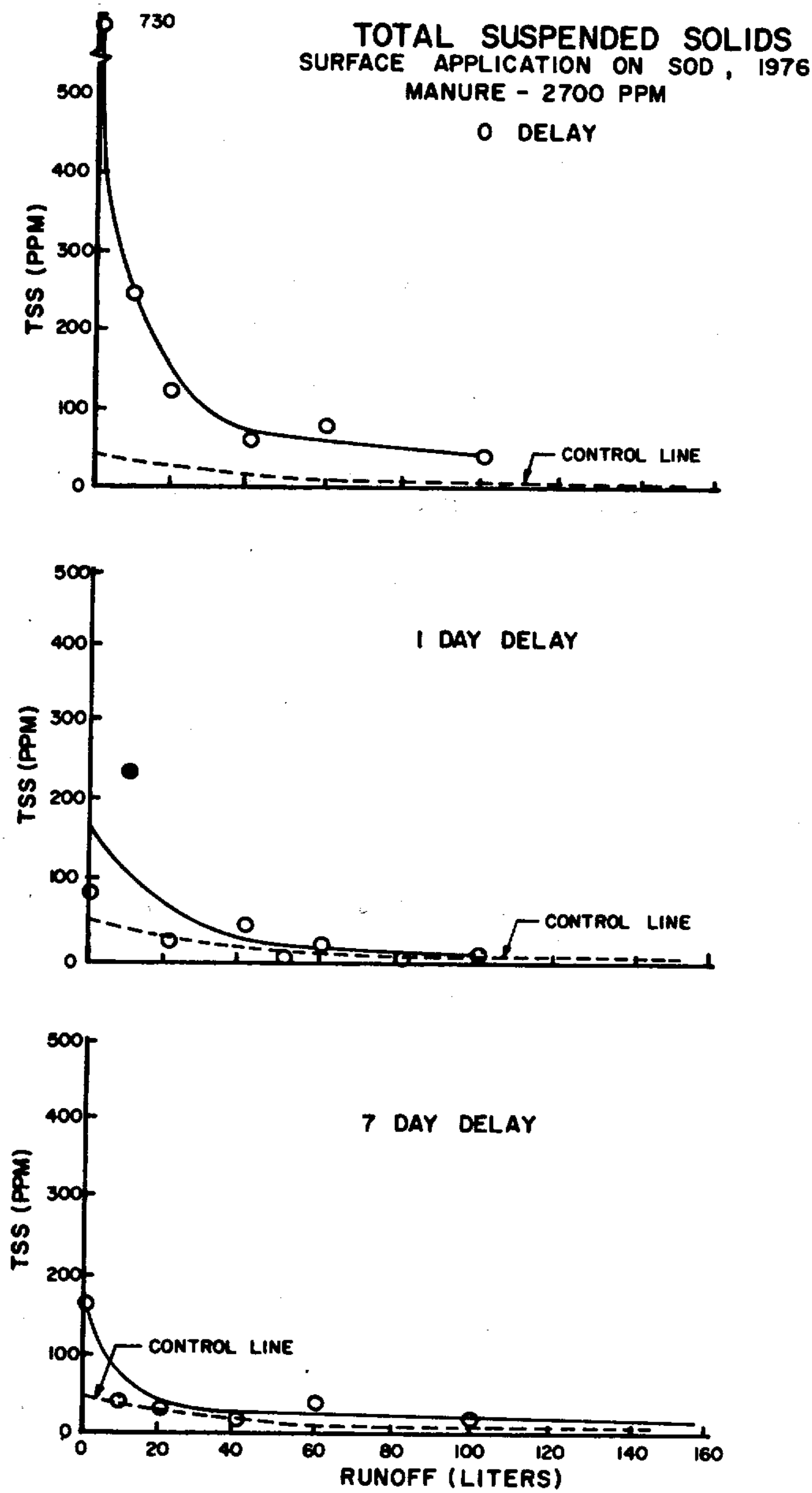


Figure 3-11. Total suspended solids, surface application on sod, 1976.

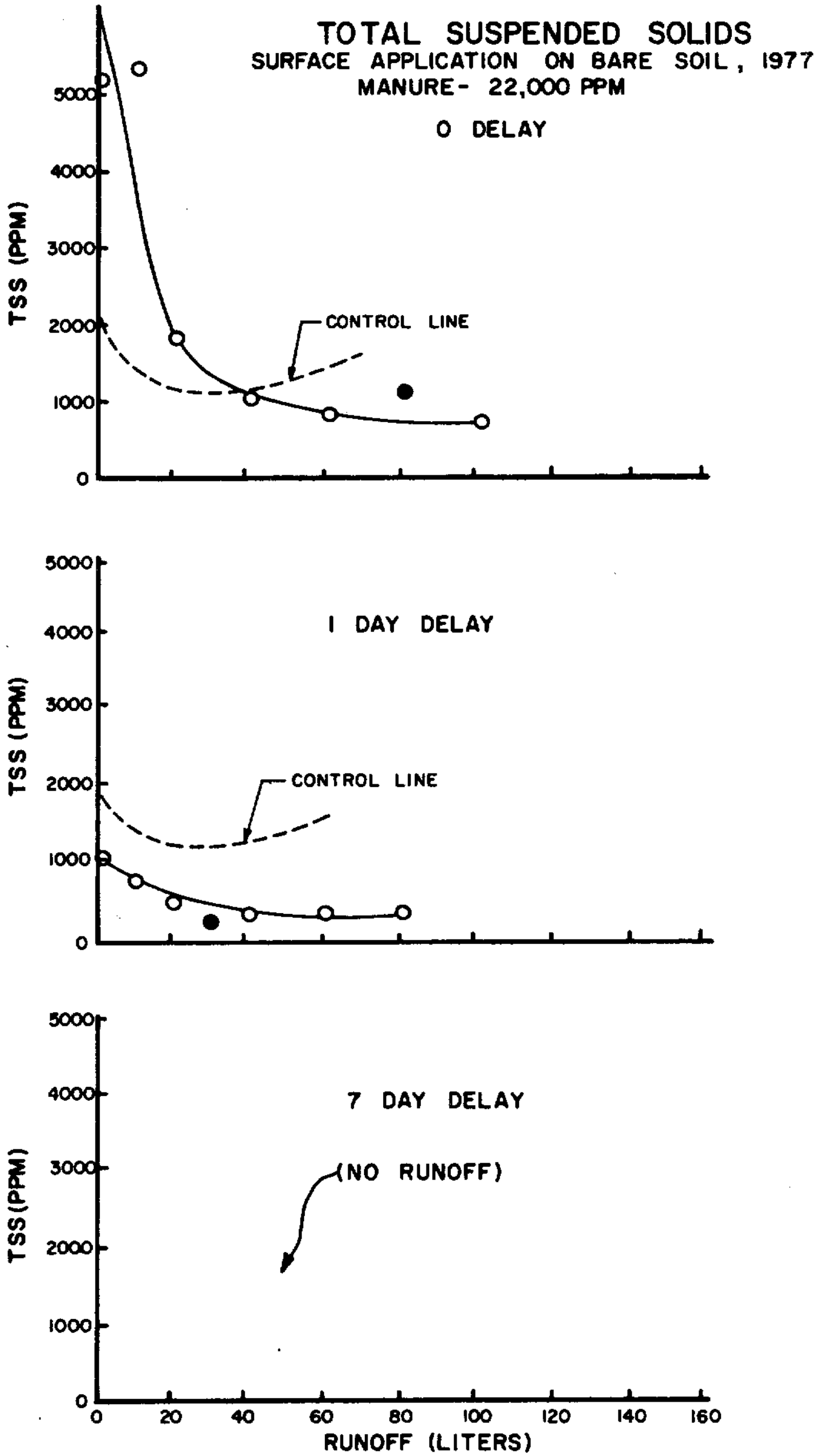


Figure 3-12. Total suspended solids, surface application on bare soil, 1977.

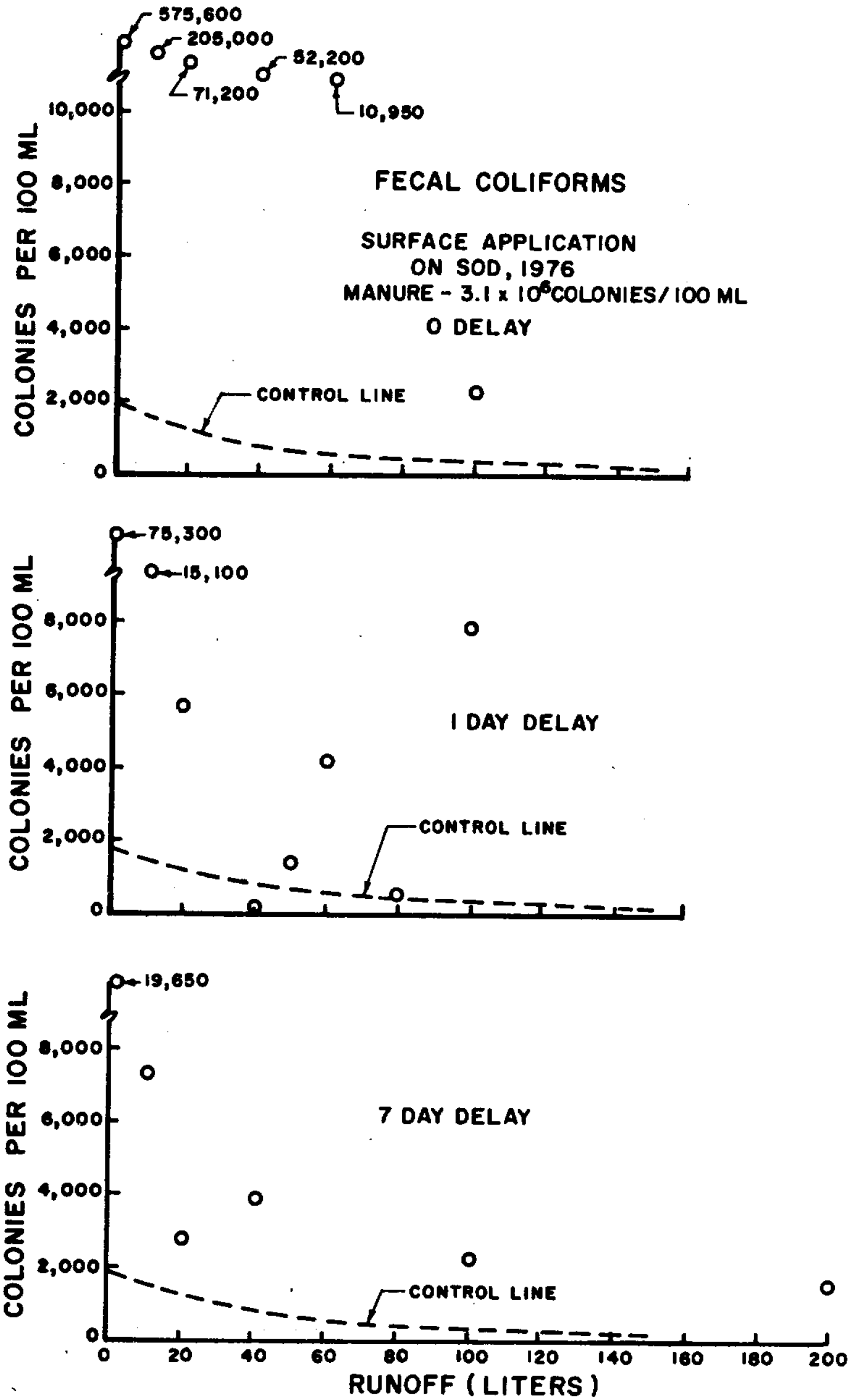


Figure 3-13. Fecal coliforms, surface application on sod, 1976.

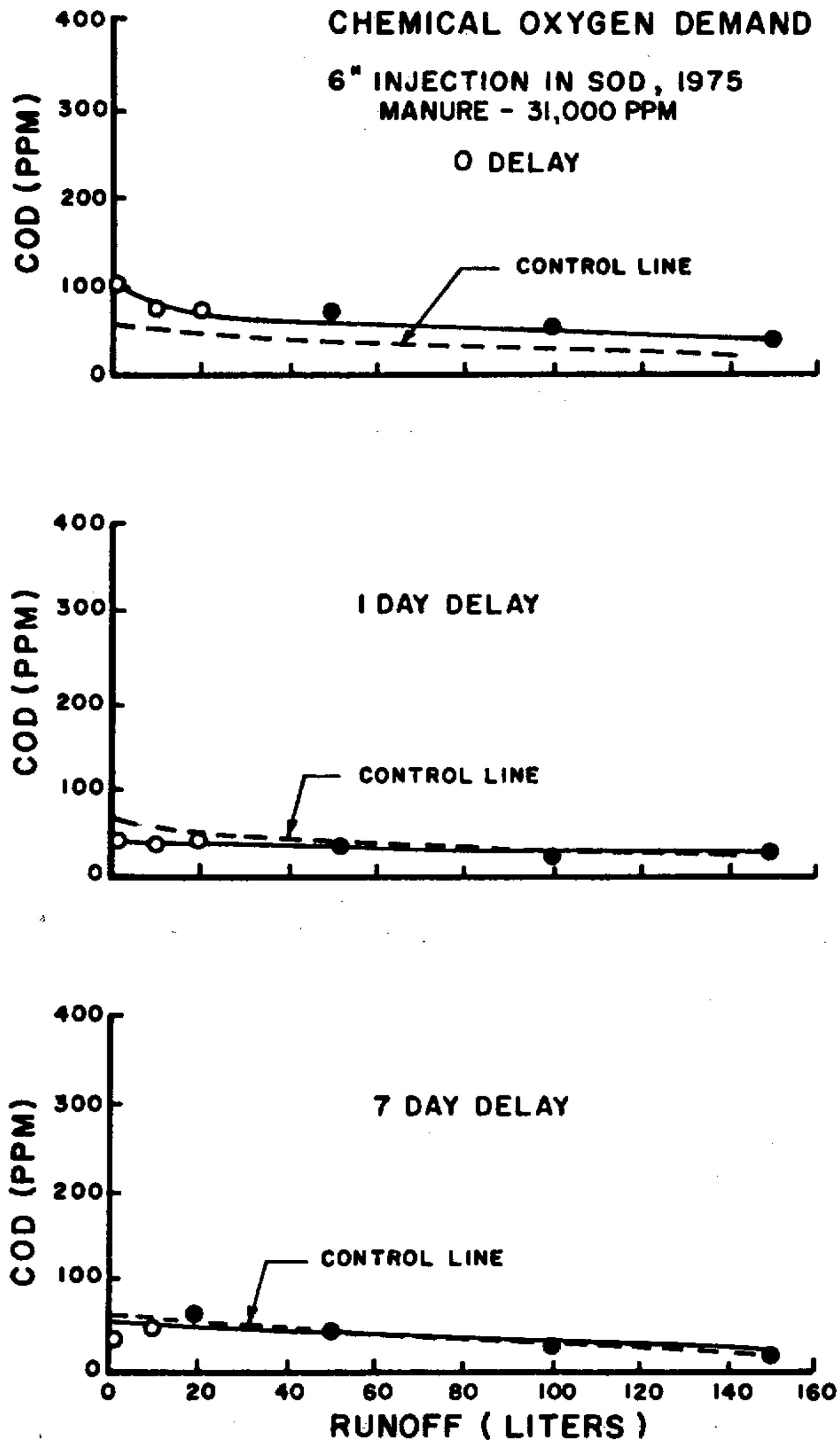


Figure 3-14. Chemical oxygen demand, 6" injection in sod, 1975.

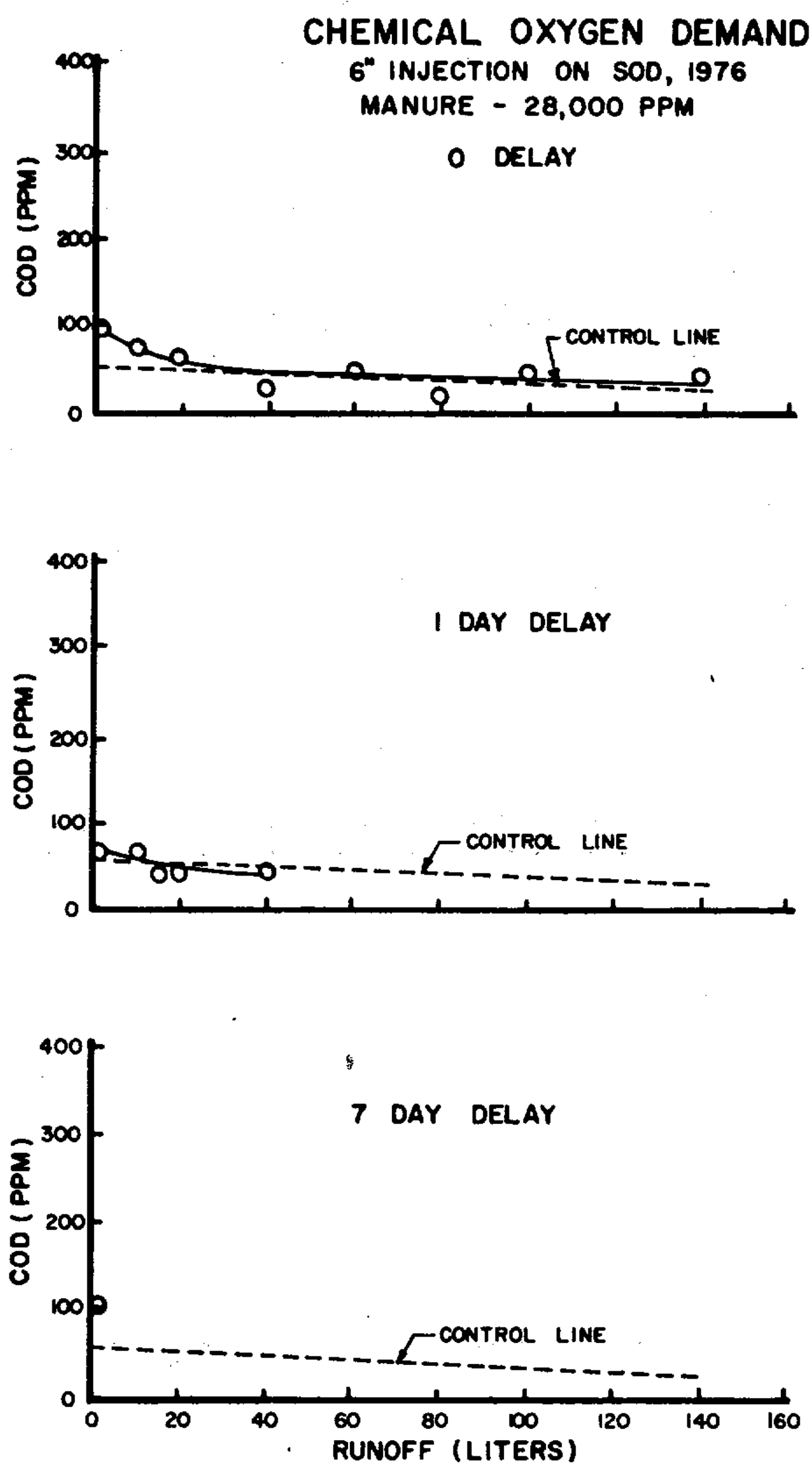


Figure 3-15. Chemical oxygen demand, 6" injection on sod, 1976.

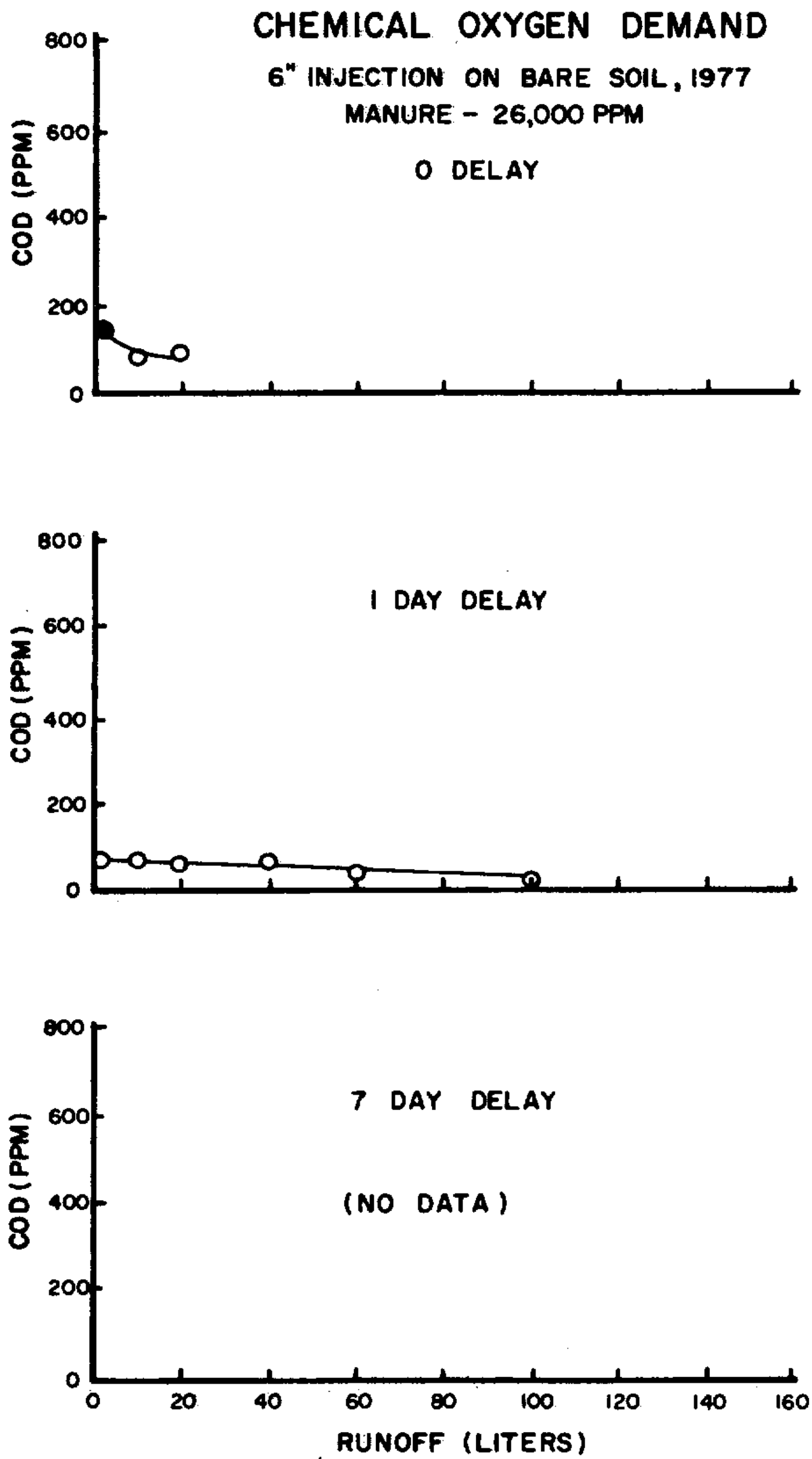


Figure 3-16. Chemical oxygen demand, 6" injection on bare soil, 1977.

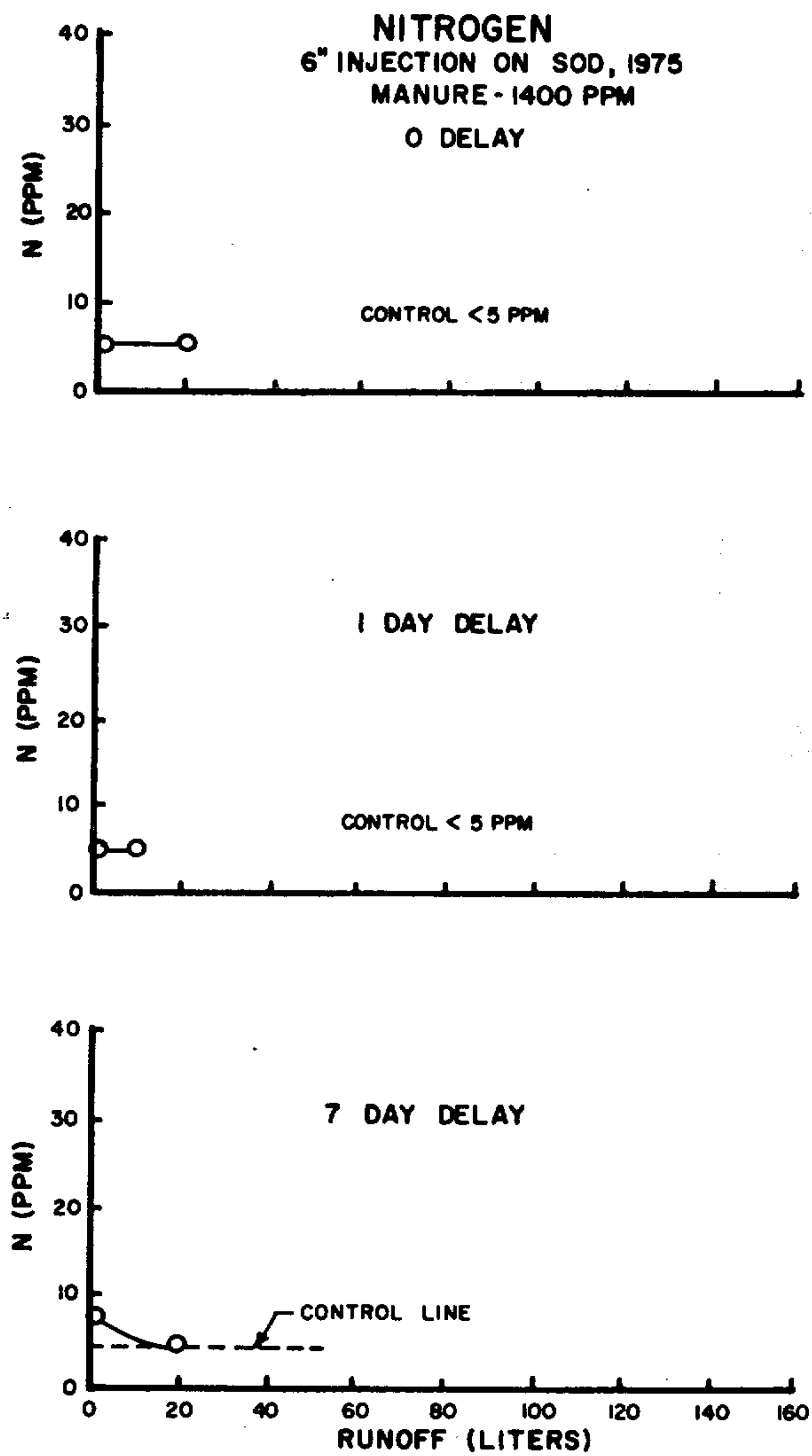


Figure 3-17. Nitrogen, 6" injection on sod, 1975.

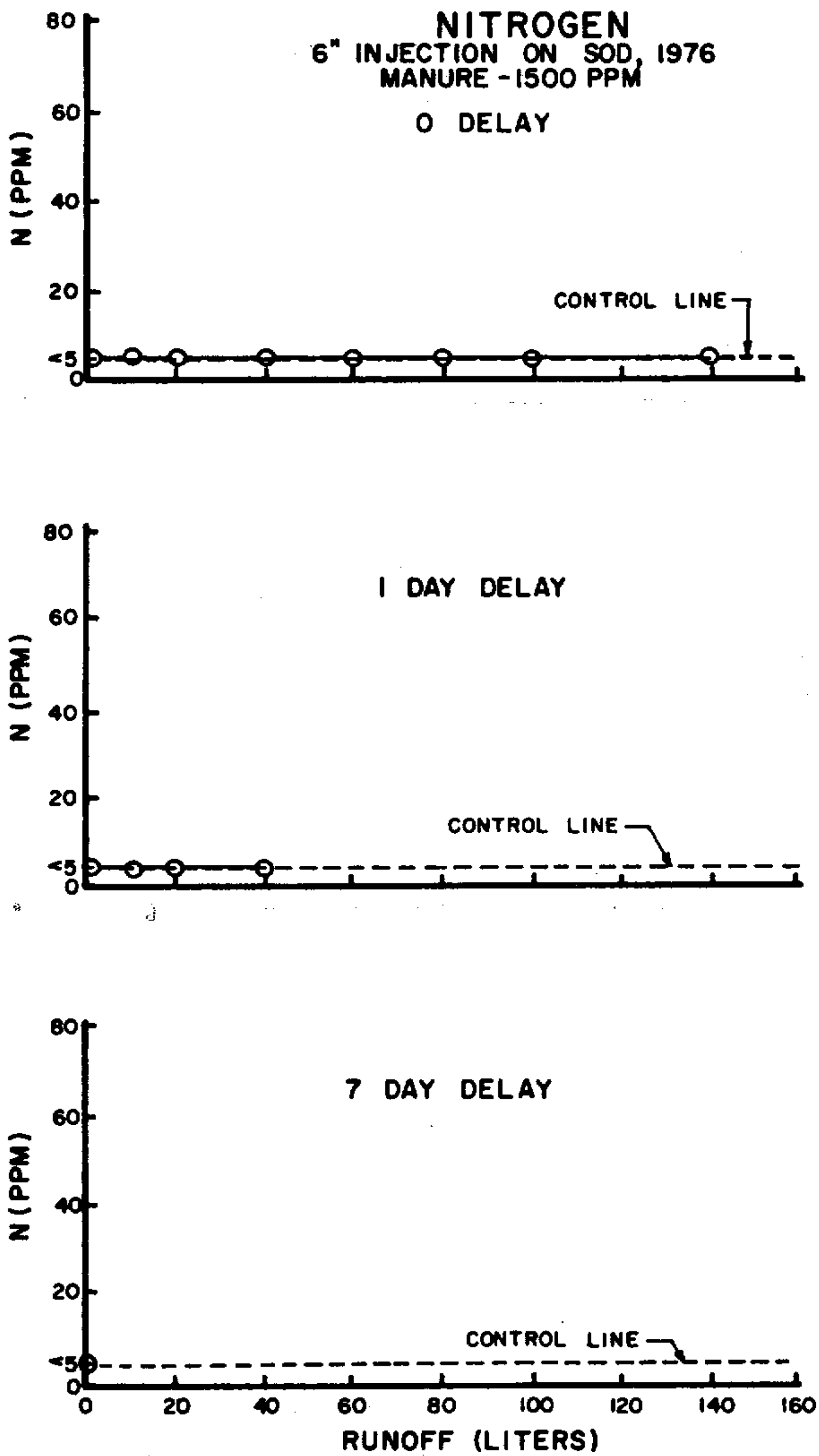


Figure 3-18. Nitrogen, 6" injection on sod, 1976.

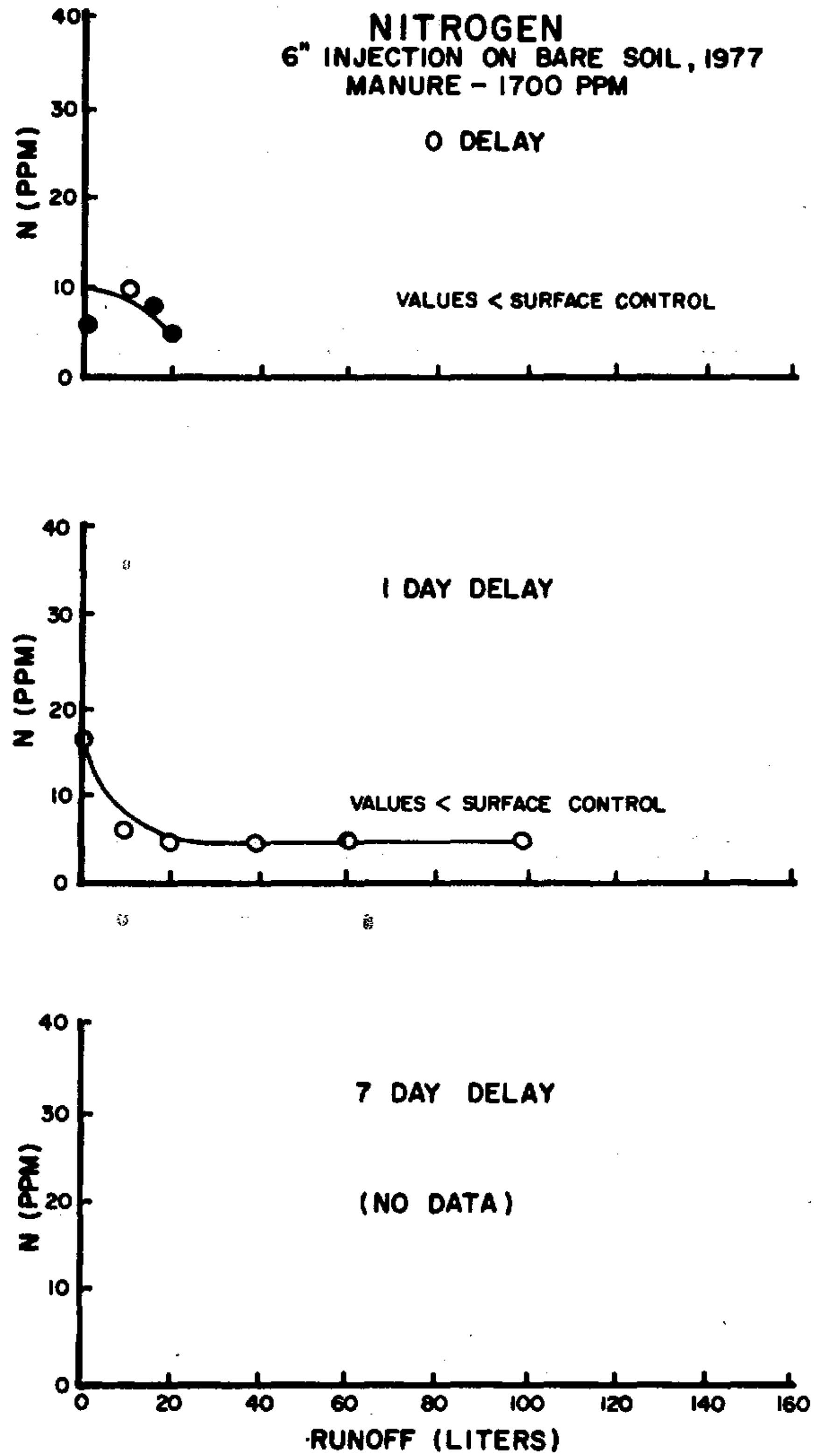


Figure 3-19. Nitrogen, 6" injection on bare soil, 1977.

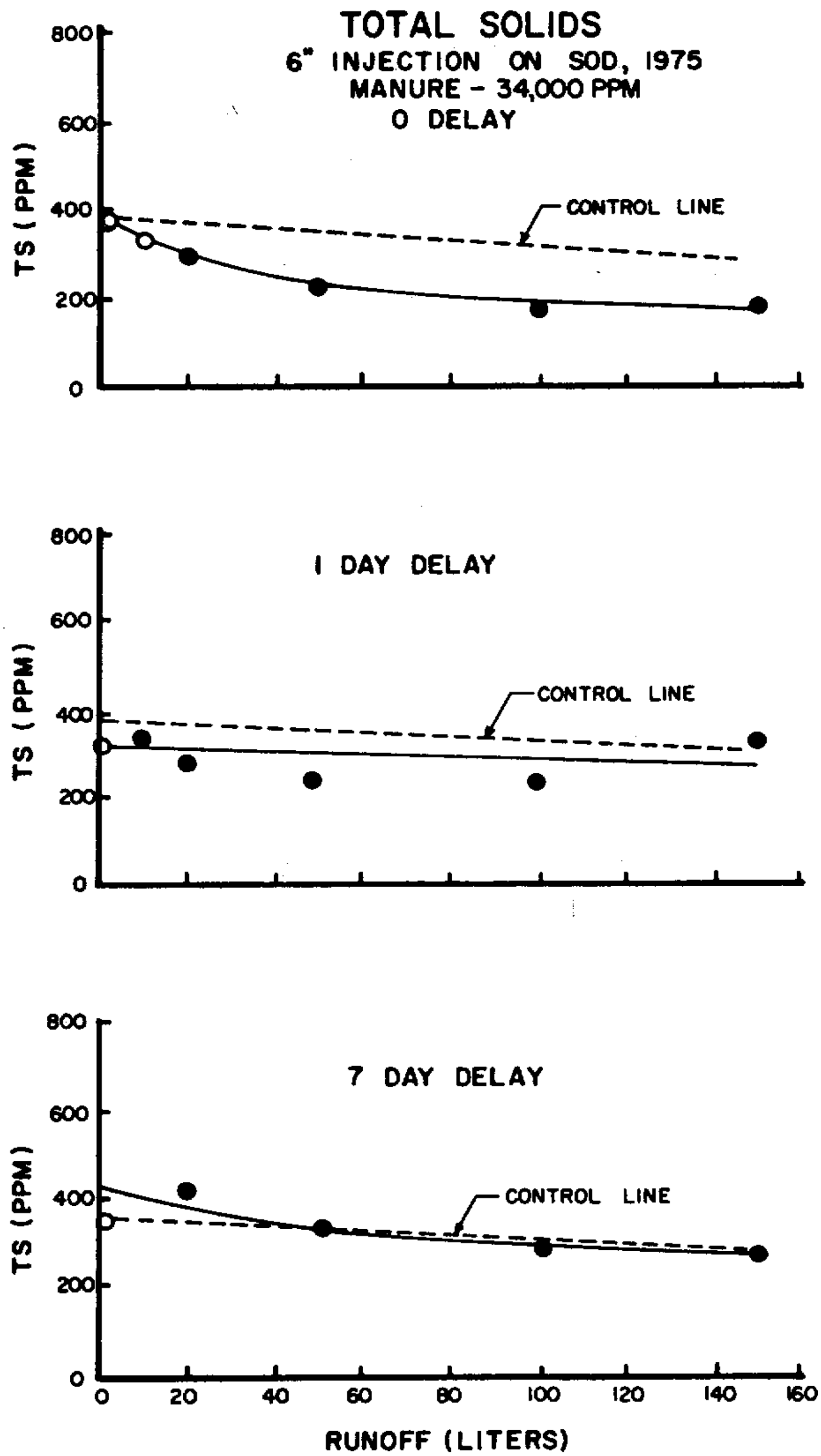


Figure 3-20. Total solids, 6" injection on sod, 1975.

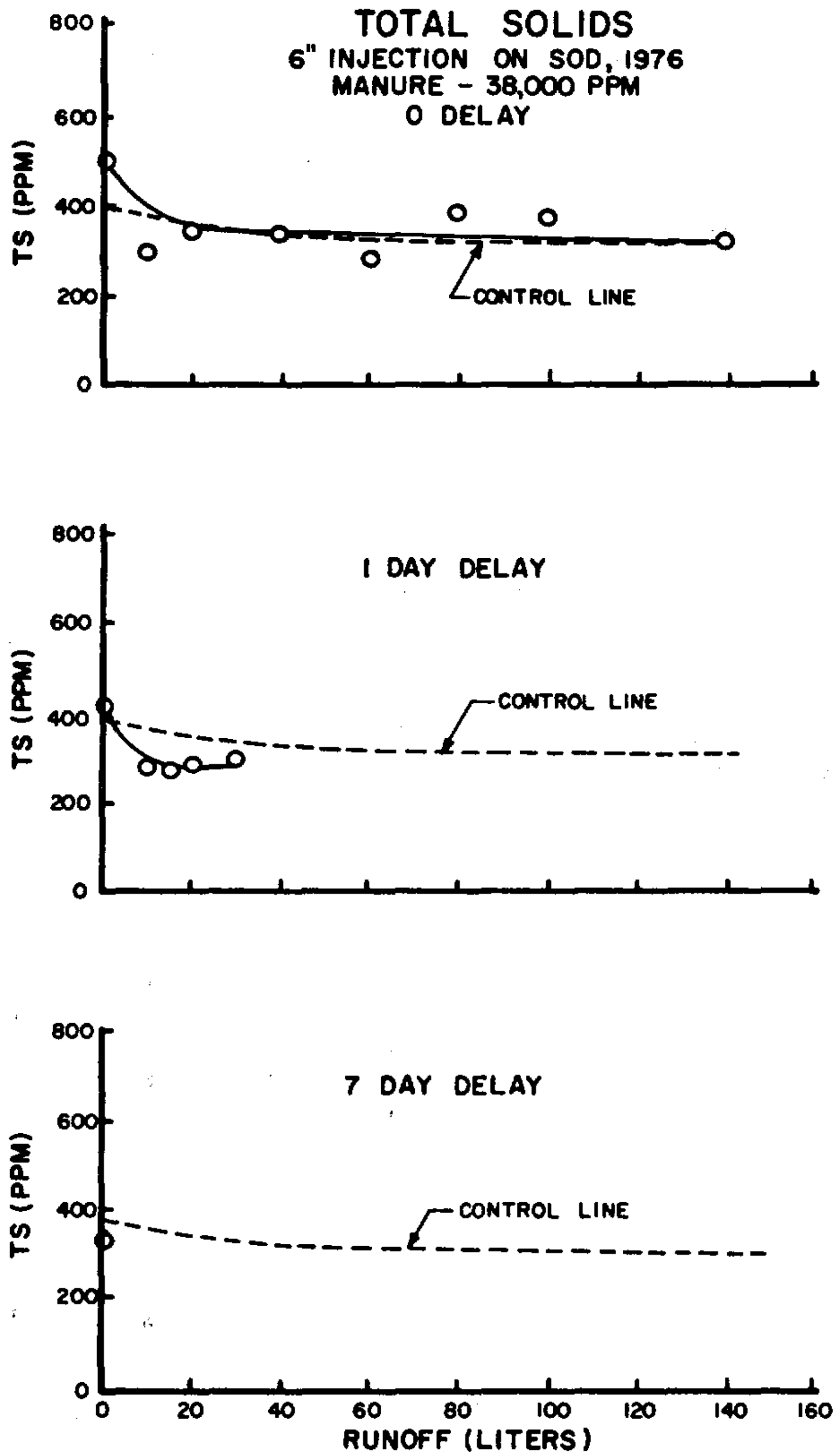


Figure 3-21. Total solids, 6" injection on sod, 1976.

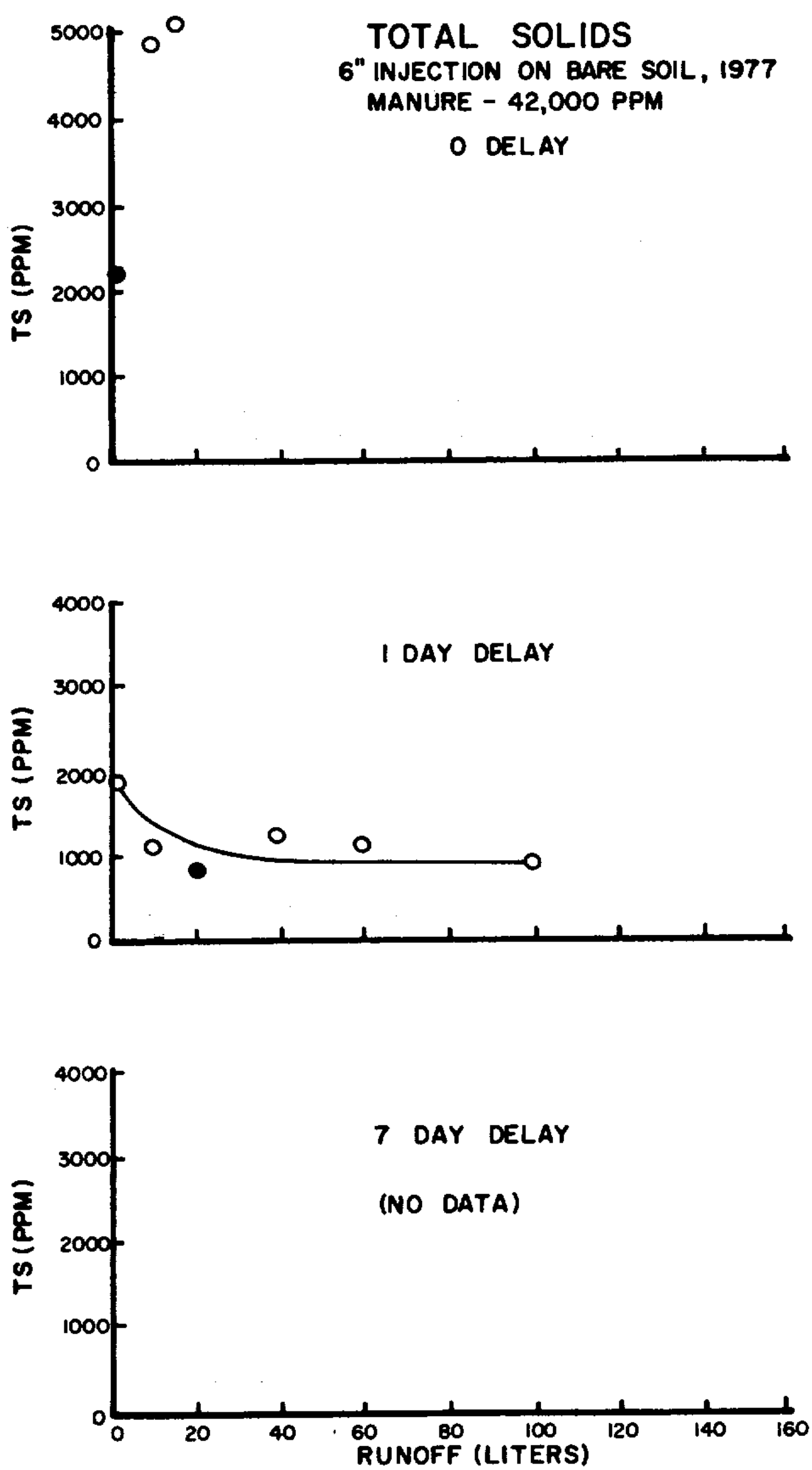


Figure 3-22. Total solids, 6" injection on bare soil, 1977.

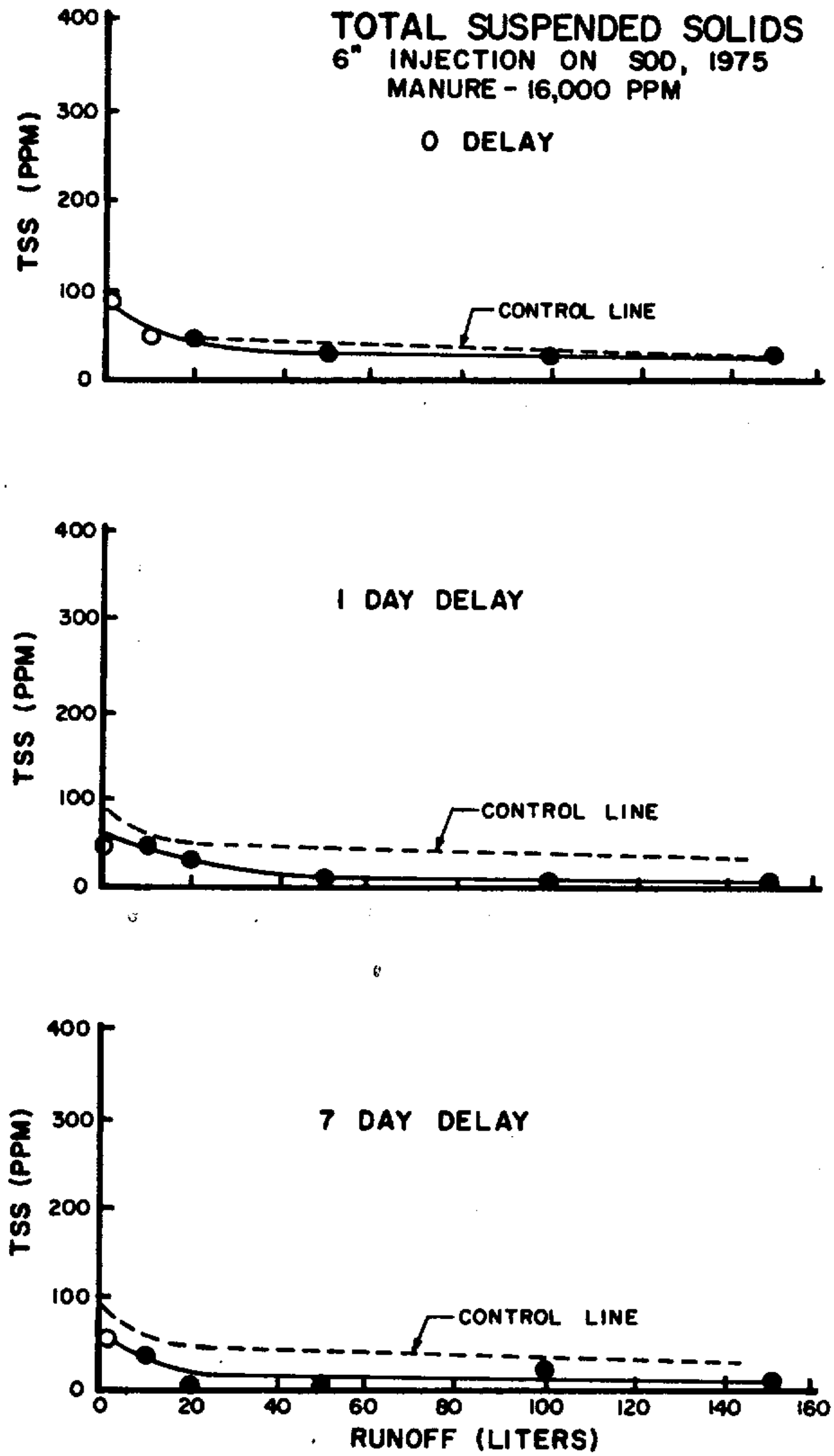


Figure 3-23. Total suspended solids, 6" injection on sod, 1975.

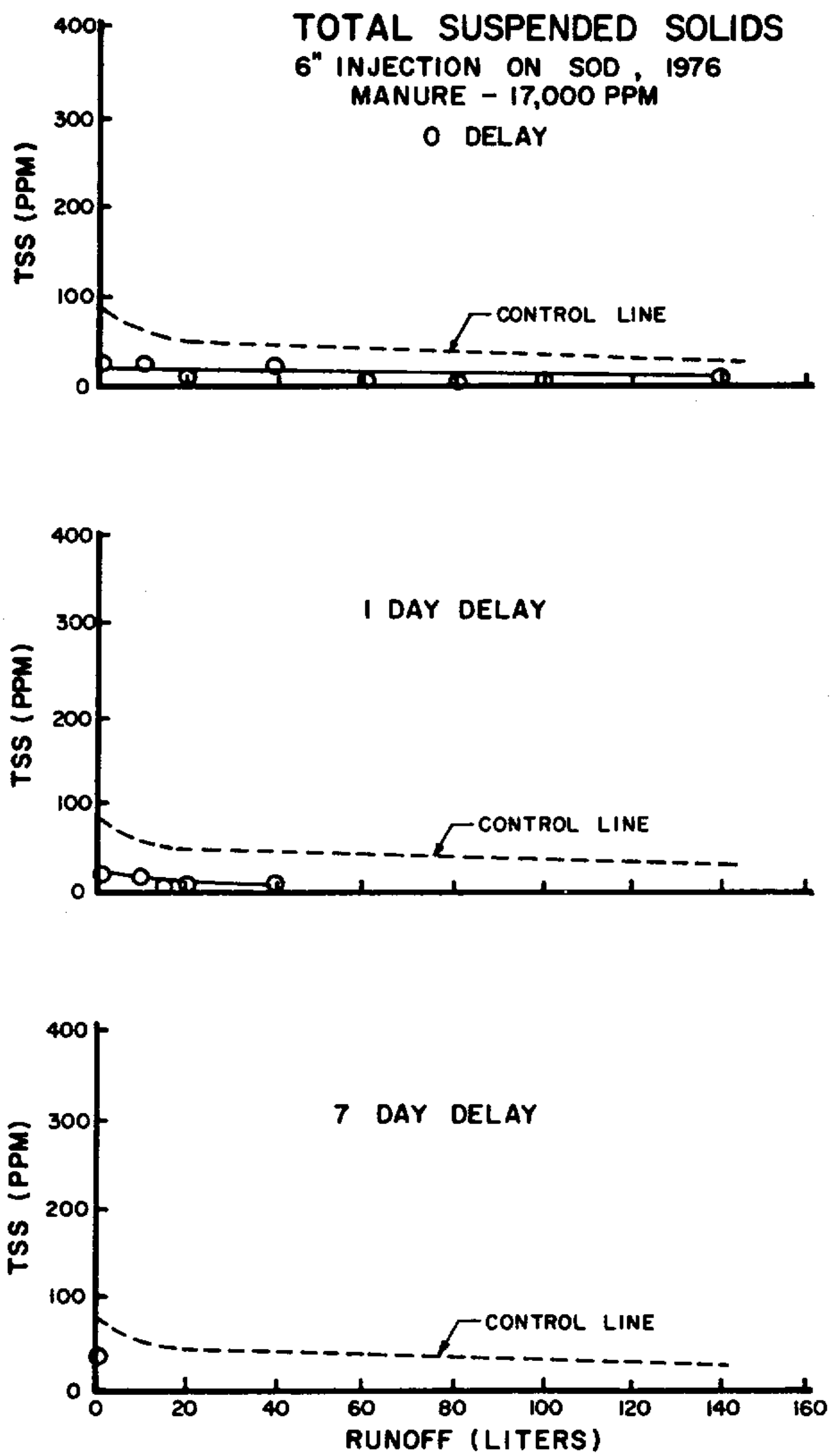


Figure 3-24. Total suspended solids, 6" injection on sod, 1976.

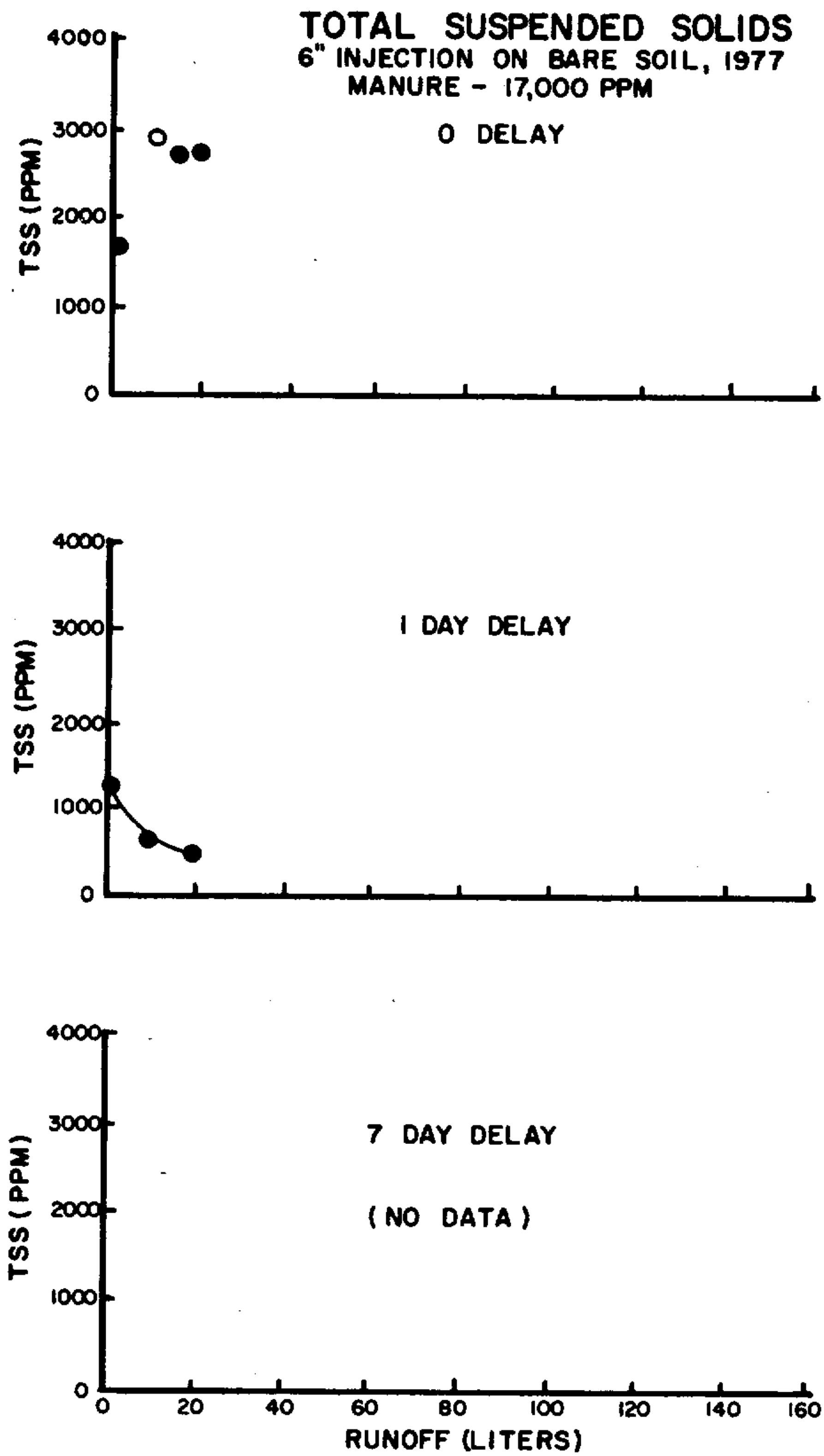


Figure 3-25. Total suspended solids, 6" injection on bare soil, 1977.

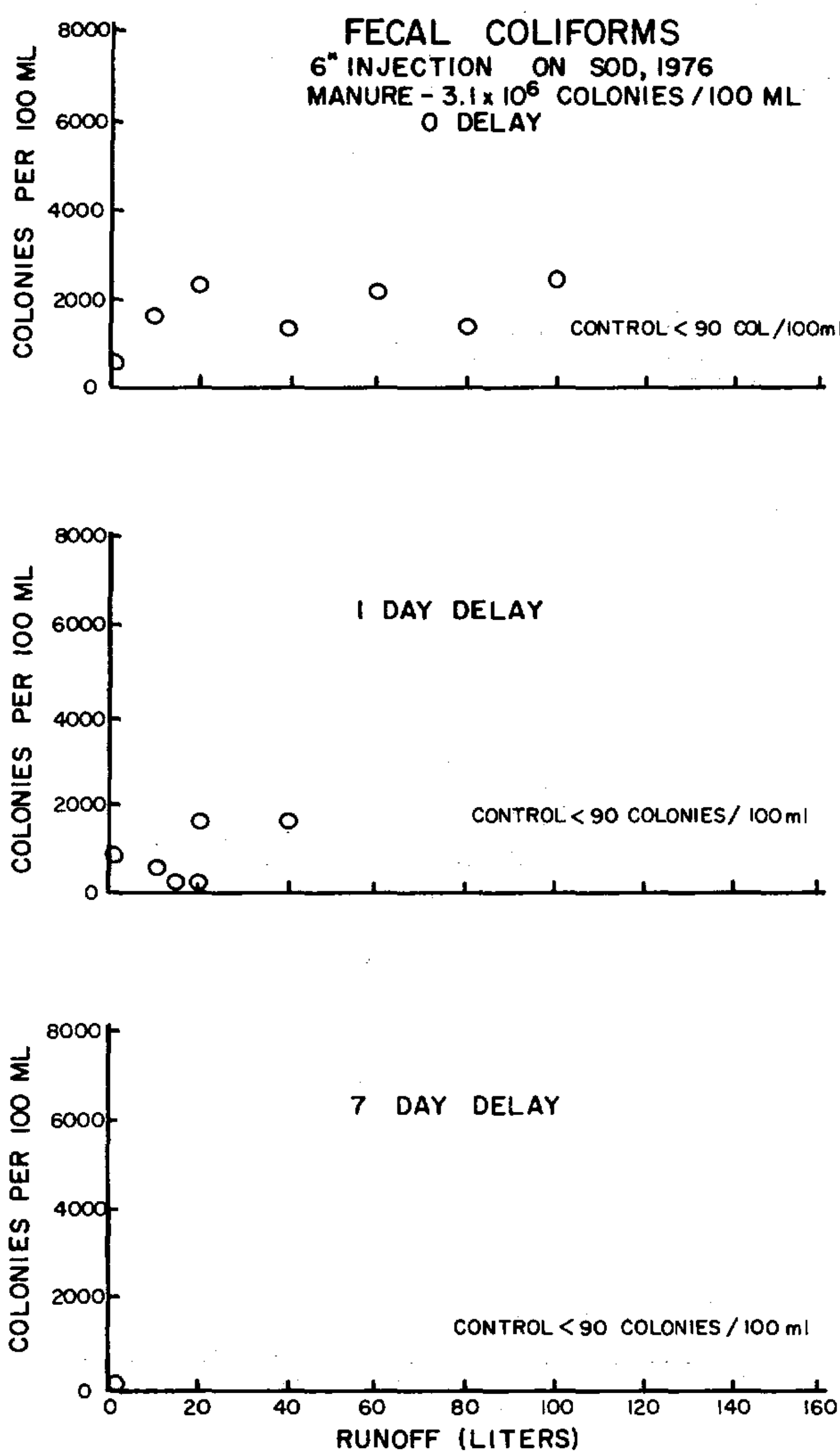


Figure 3-26. Fecal coliforms, 6" injection on sod, 1976.

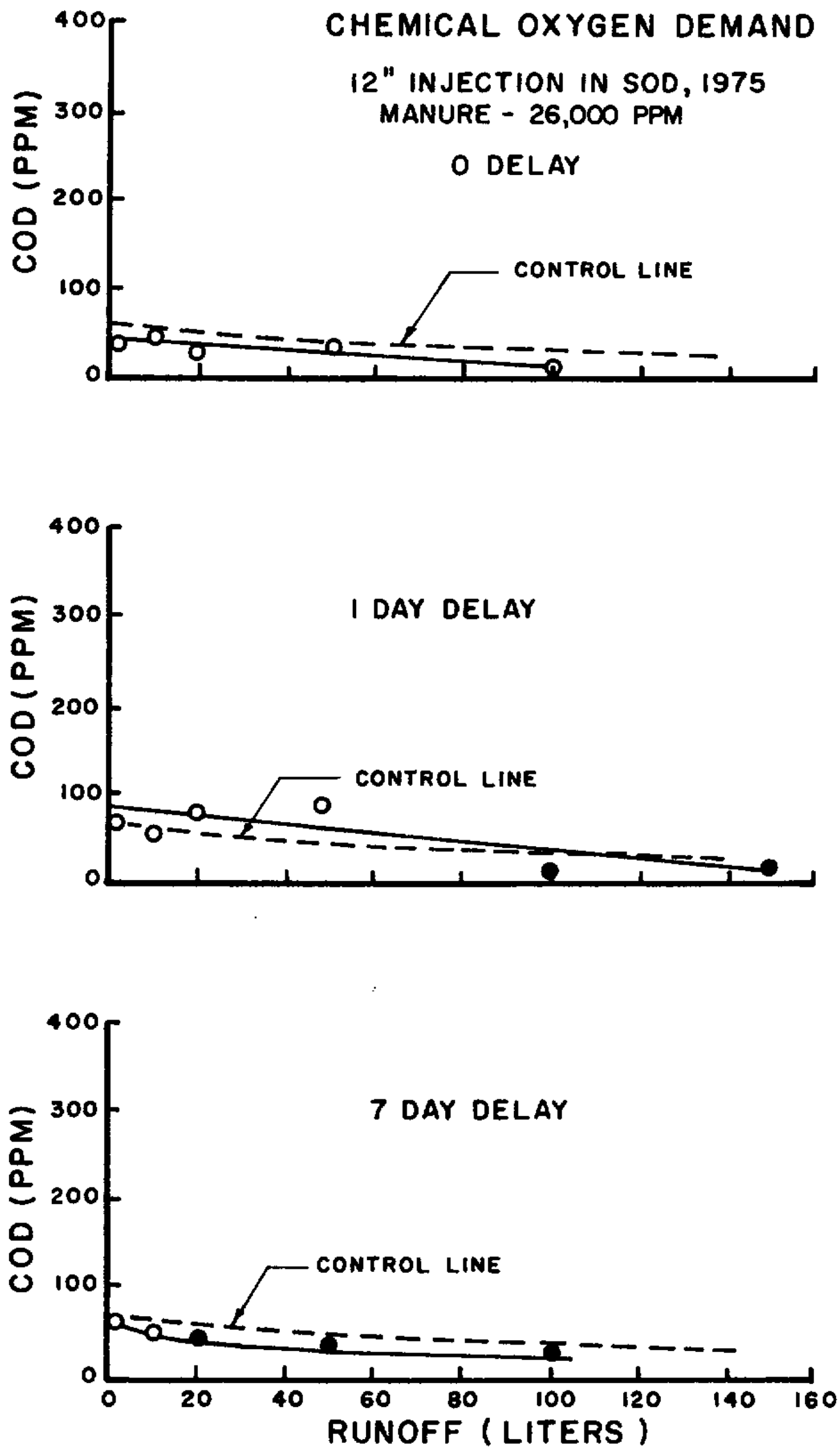


Figure 3-27. Chemical oxygen demand, 12" injection in sod, 1975.

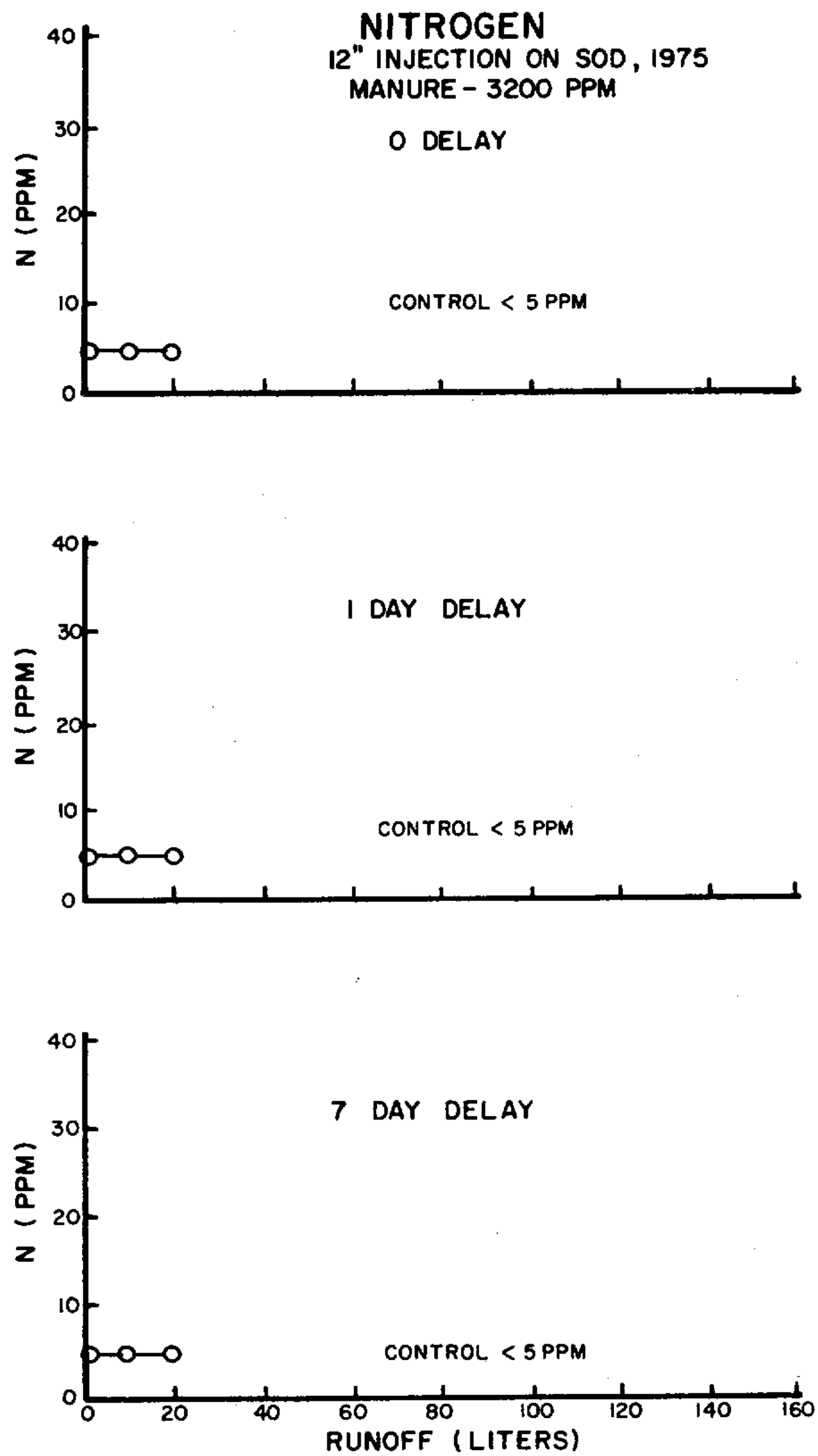


Figure 3-28. Nitrogen, 12" injection on sod, 1975.

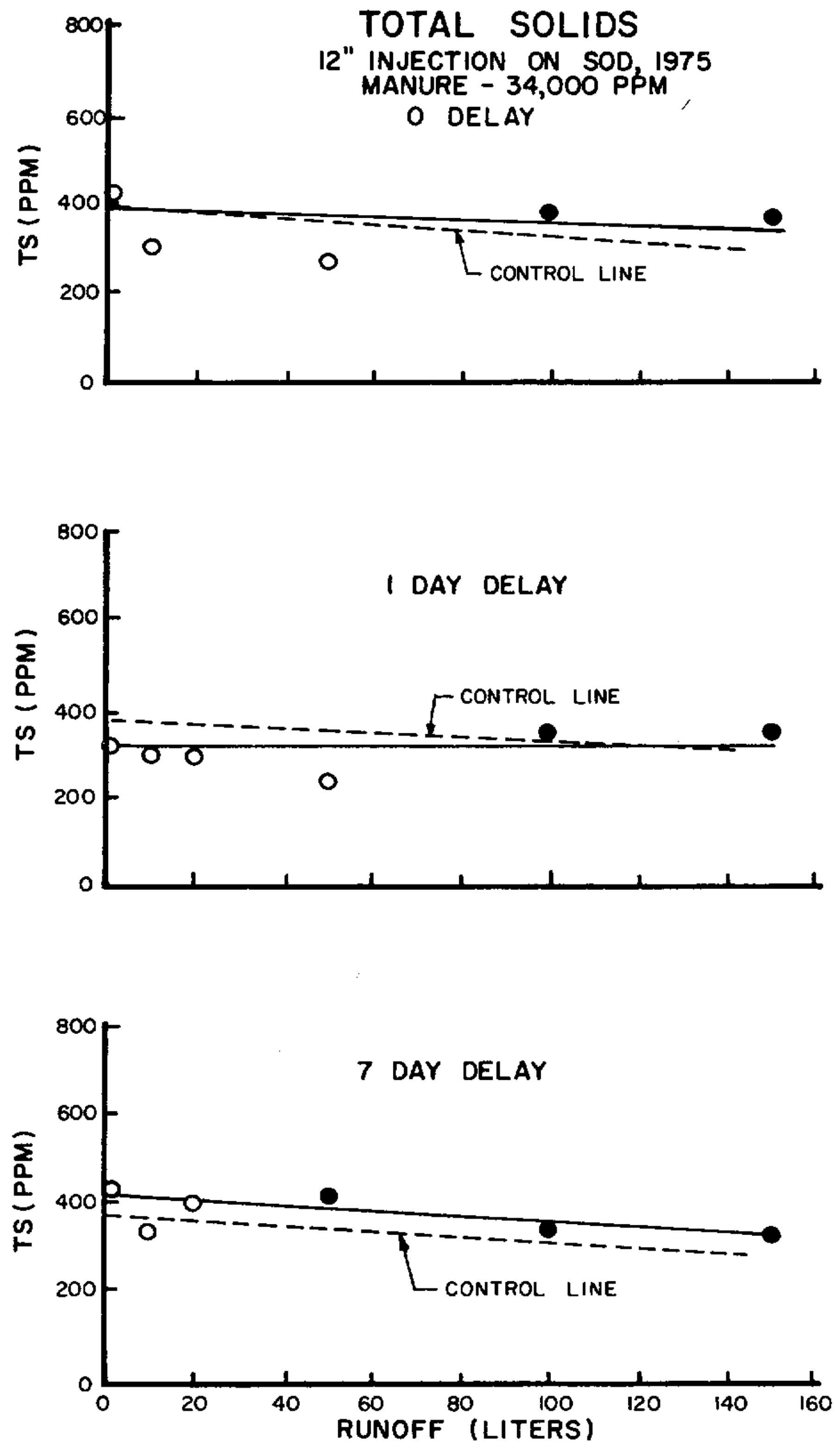


Figure 3-29. Total solids, 12" injection on sod, 1975.

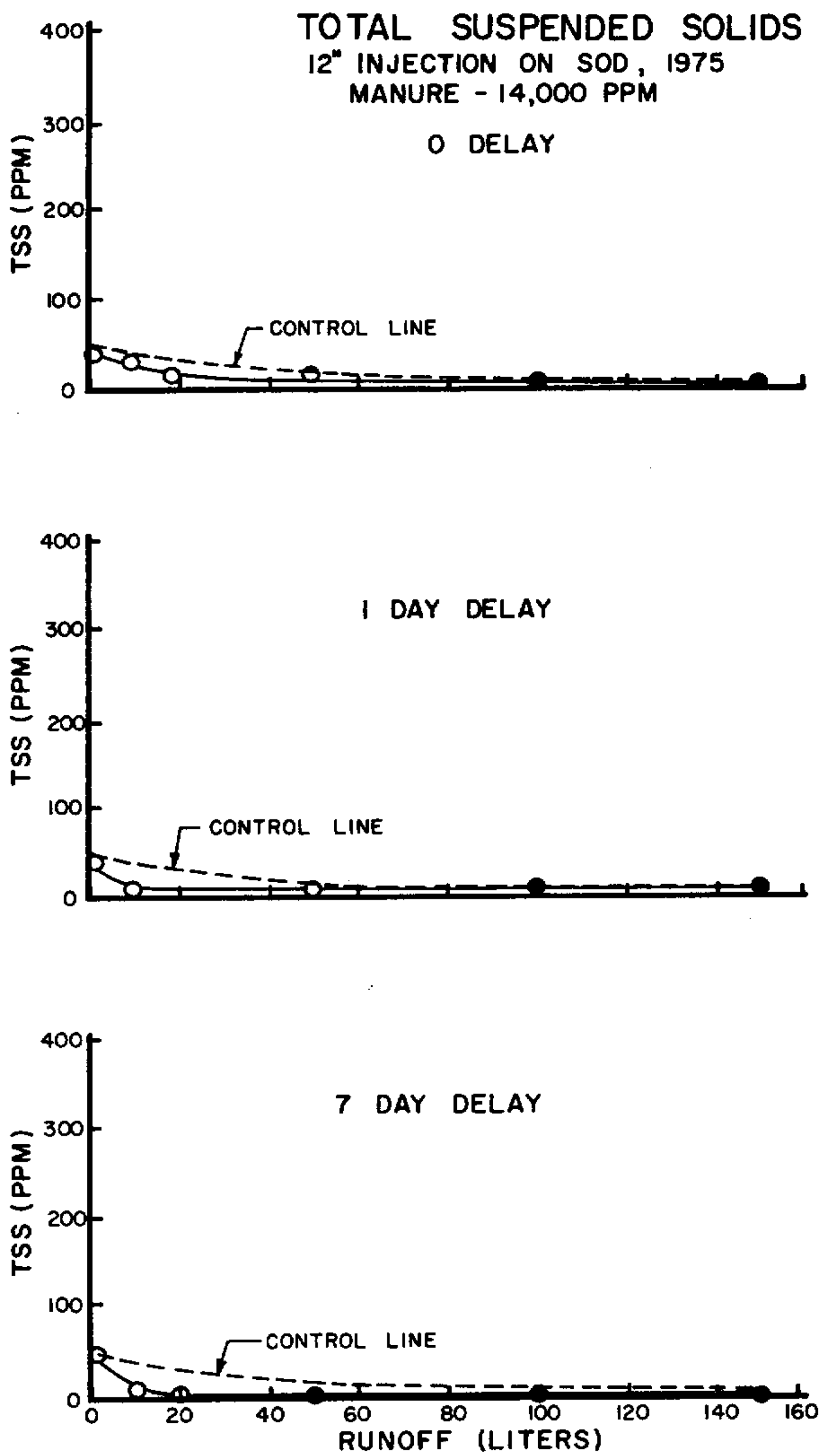


Figure 3-30. Total suspended solids, 12" injection on sod, 1975.

testing program because of this fact.

DELAY BETWEEN TIME OF APPLICATION AND RAINFALL

It is apparent from the data presented in Figures 3-1 through 3-30 that a delay between the time of manure application and a rainfall event greatly reduces the concentration of pollution parameters in the runoff. This is most evident from the data obtained for surface applications, Figures 3-1 through 3-13, since injection itself caused a drastic reduction in pollution parameters in the runoff. A 1-day delay between manure application and a rainfall event reduced the pollutant concentration in the runoff by at least 80% and in some cases by 97% as compared with 0-day delay tests. A 7-day delay tended to further decrease the pollutant concentration in the runoff as compared to the 1-day delay, but this effect was not pronounced. These effects will be further illustrated later with the data presented in a different format.

REPEATED APPLICATIONS

Liquid manure was injected to a depth of 6 inches and applied to the surface of sod on the same plot for 3 consecutive years. The 1975 injection plots which were reinjected in 1976 and again in 1977 yielded no runoff during the last 2 years. This was apparently caused by roughness and ponding behind the ridges formed by the effect of multiple disruption of the soil with the injection tynes. Plots receiving repeated surface applications did produce runoff all three years as indicated in Figure 3-31. The data in Figure 3-31 is presented as a percentage of the total pollutant which was applied to the plot per liter of runoff. This approach was used to compare and normalize the data since the liquid manure applied in different years contained different concentrations of the pollutant parameters, even though the same quantity, 17 gallons, was applied each year. The concentration of the pollutant (water quality parameter) in the liquid manure applied to the plots are indicated on the graph in each of the Figures 3-1 through 3-30. The data shows that the concentration of pollutants in the runoff

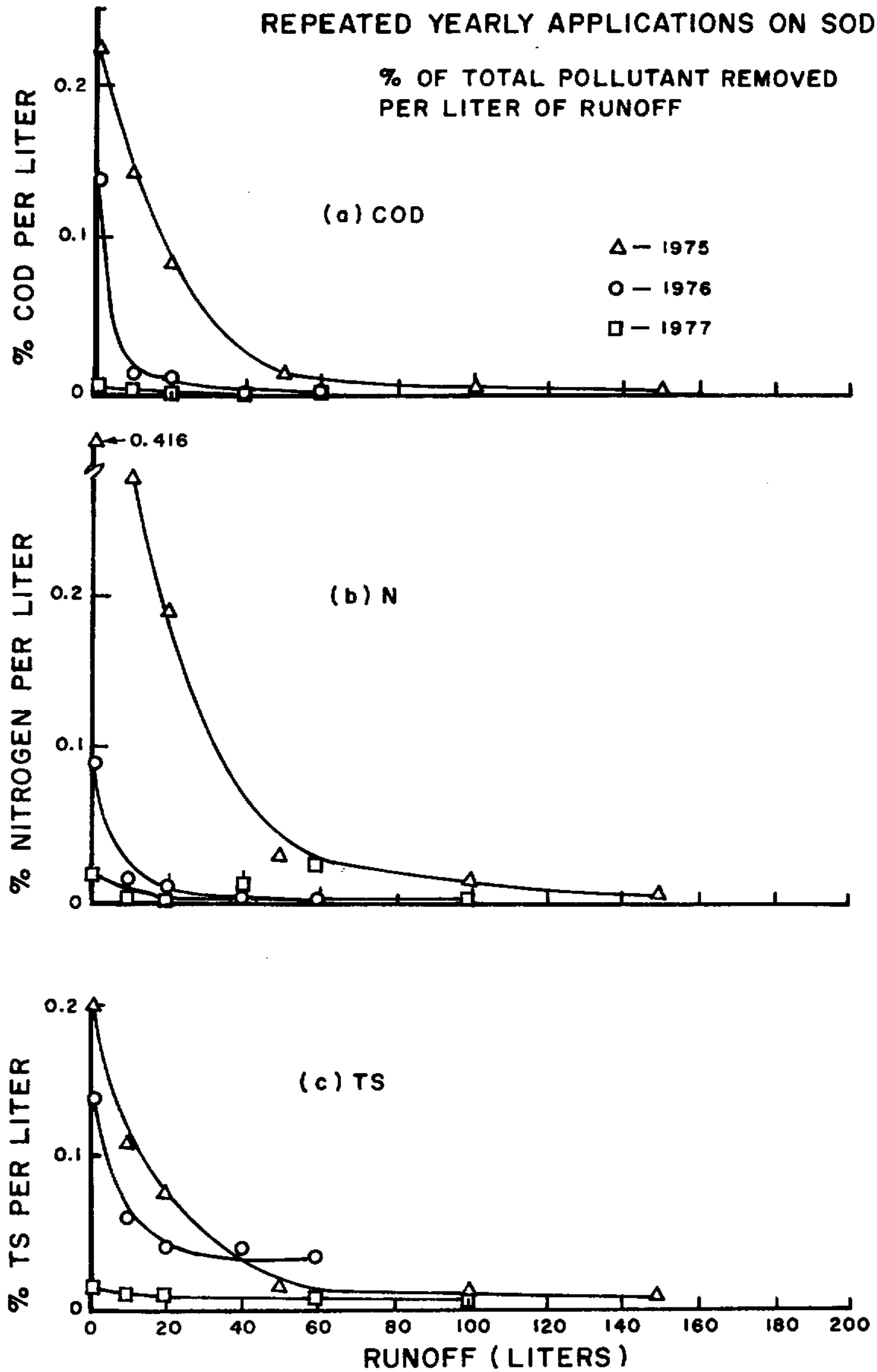


Figure 3-31. Repeated yearly applications on sod.

decreased with each additional yearly application. Since the soil was not disrupted when receiving surface application, this effect possibly results from increased soil permeability because of the addition of organic matter to the soil both in the form of manure solids and cut-grass when the plots were mowed. The plots were not grazed during the three year test periods and no forage was removed. It could also be the result of improved vegetative growth resulting from the addition of plant nutrients.

BARE SOIL TESTS

The major portion of the 1977 test program was conducted on bare soil. The simulated rainfall application rate for these tests was reduced from 2.5 to 1.5 inches per hour because of the higher rates of runoff which are characteristic of a bare soil as compared to sod and because of erosion and sedimentation problems with the higher application rates.

The results obtained for these tests are presented in Figures 3-3, 3-6, 3-9, 3-12, 3-16, 3-19, 3-22 and 3-25. These results are characteristic of similar tests conducted on sod. The data for all 3 years of testing are presented in Figures 3-32 and 3-33 as the percentage of the total pollutant which was applied to the plot with background levels of the pollutant parameter, as determined by the control tests, subtracted from the pollutant yield.

The results of the 0-day delay tests are given in Figure 3-32. The percent of pollutant yield per liter from sodded and bare plots are quite similar. Differences between sod and bare soil are much greater with the 1-day delay tests as shown in Figure 3-33. The total COD yield from 0-day delay plots is approximately 8 times greater than the yield from 1-day delay plots on sod. The same comparison for bare soil indicates that yield for 0-day delay is approximately 60 times greater than that from 1-day delay plots. As shown in Figure 3-33, runoff from the bare soil generally contained a much lower percentage of pollutant than the runoff from sod after a 1-day delay. Results for the 7-day delay

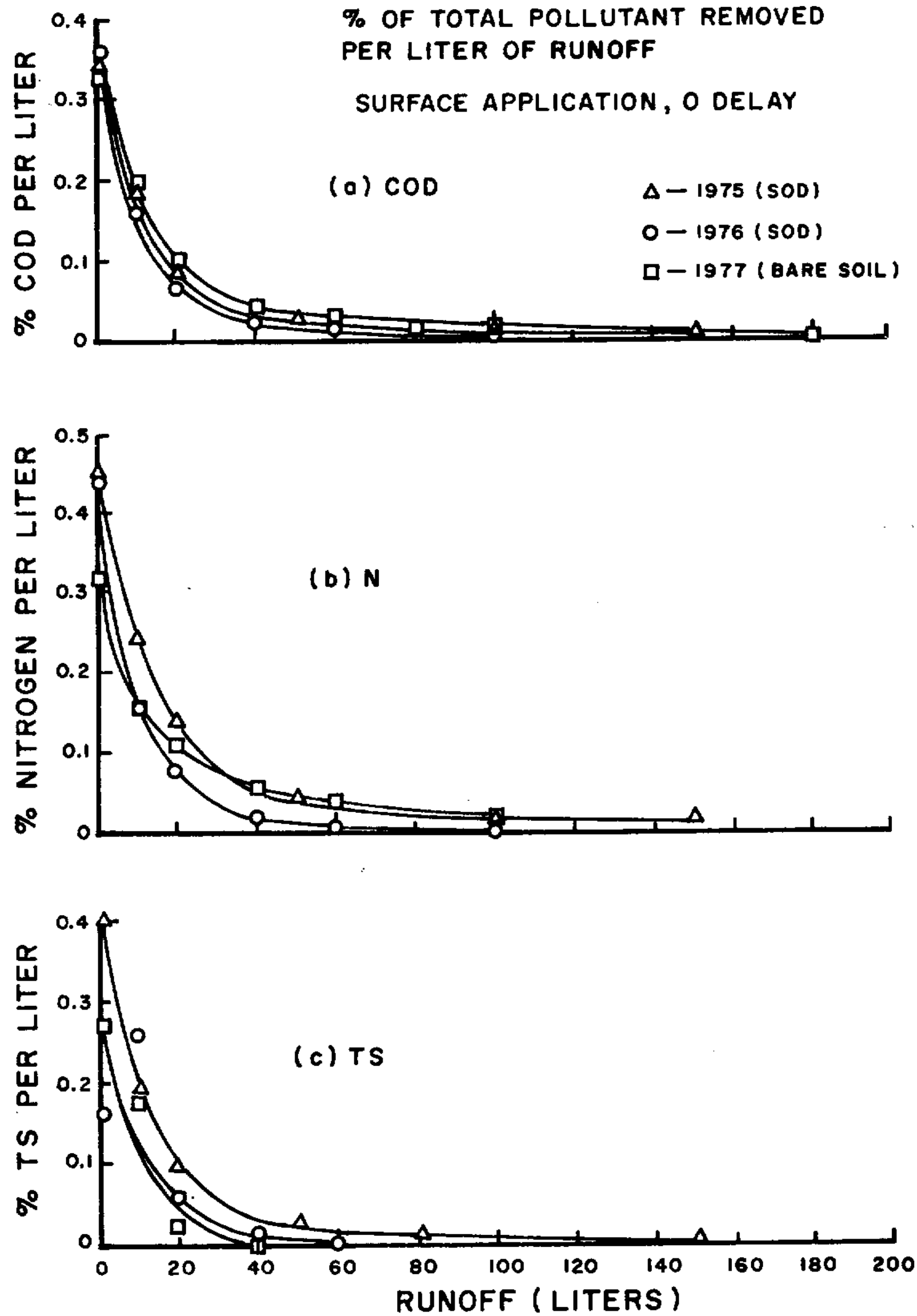


Figure 3-32. Percent of total pollutant removed per liter of runoff, surface application, 0 delay.

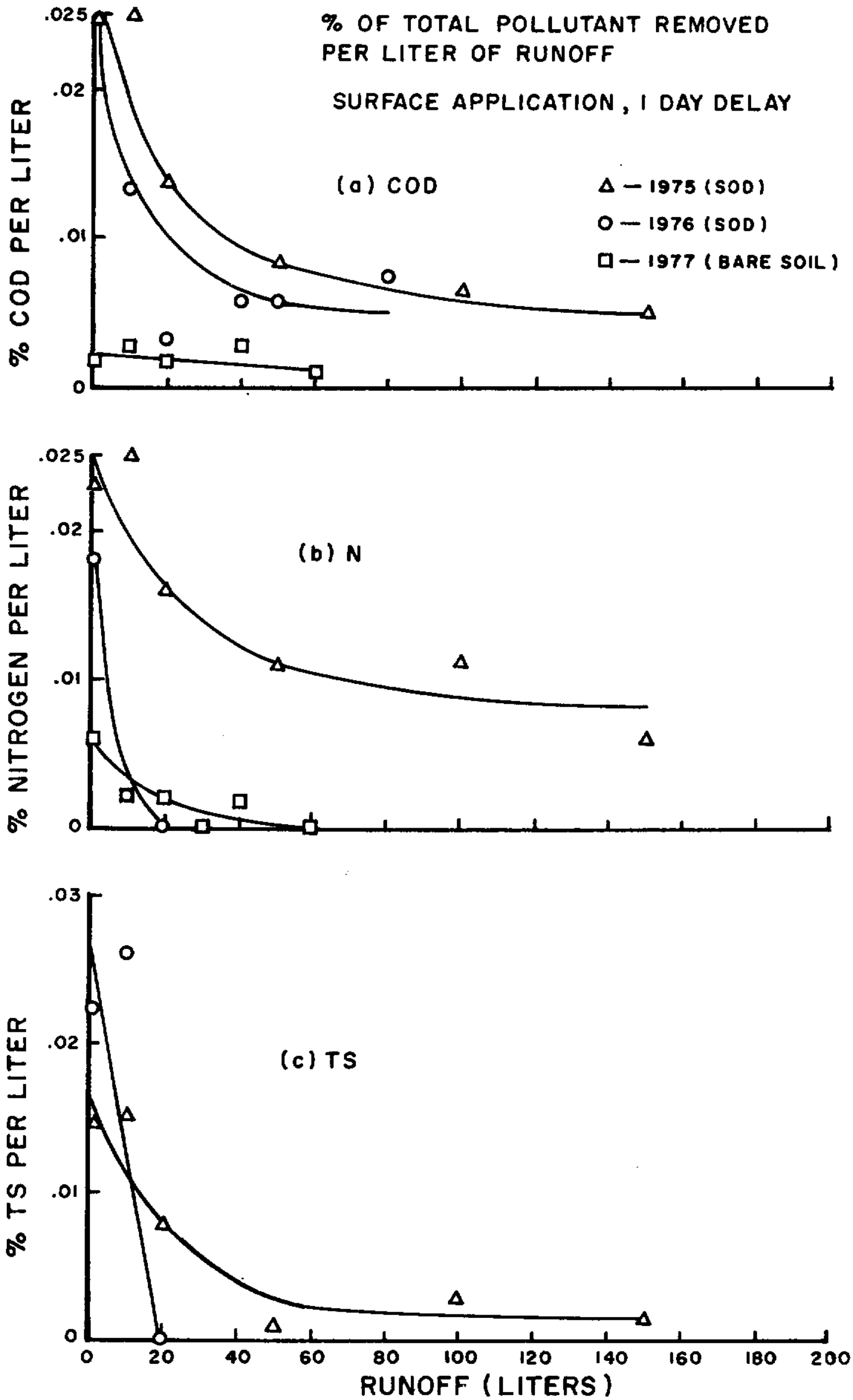


Figure 3-33. Percent of total pollutant removed per liter of runoff, surface application, 1 day delay

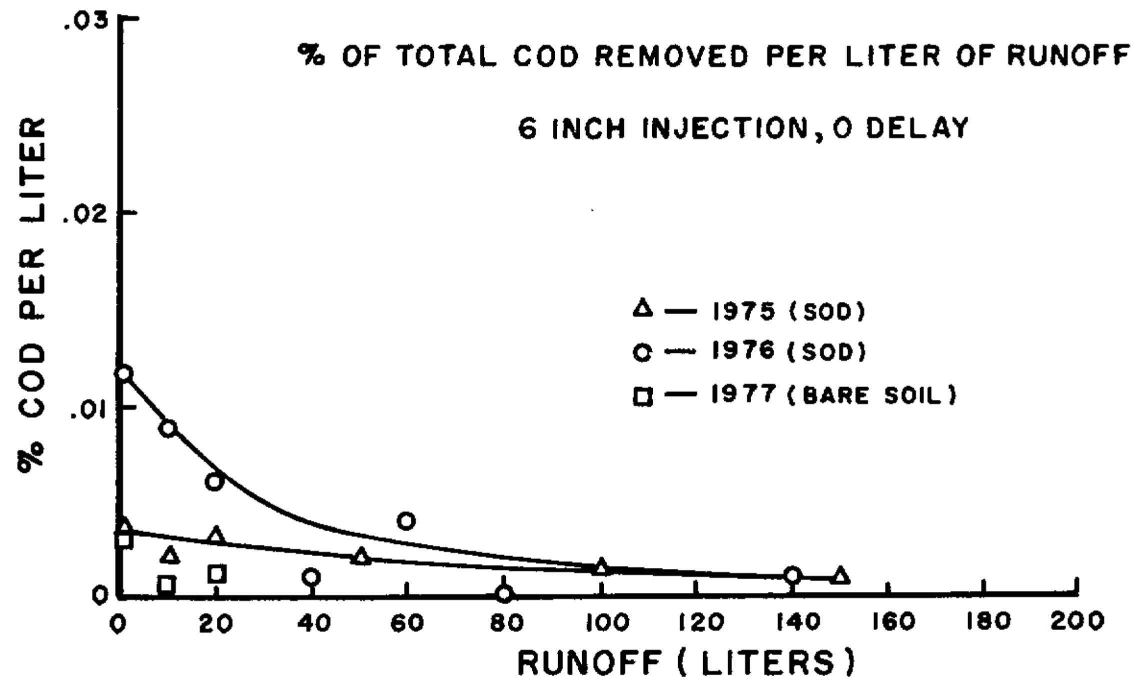


Figure 3-34. Percent of total COD removed per liter of runoff, 6 inch injection, 0 delay.

are not plotted because of their similarity to the 1-day delay results.

The data for the 0-day delay given in Figure 3-32 were fitted to a power equations. The resulting equations are:

$$COD = 0.4955\ R^{-0.6838}$$
$$N = 0.5788\ R^{-0.6729}$$
$$TS = 0.5177\ R^{-0.7962}$$

where:

COD - Percent of COD applied/liter of runoff
N - Percent of N applied/liter of runoff
TS - Percent of TS applied/liter of runoff
R - Liters of runoff.

The regression coefficients (r^2) for the equations were 0.95, 0.97, and 0.91, respectively.

The results for COD for the 0-day delay, 6-inch injection is presented in a similar manner in Figure 3-34. The pollutant yields are quite small being less than 10% of the yield from 0-day delay plots.

CUMULATIVE POLLUTION YIELD

The experimental results on cumulative pollution parameter yield from the test plots are presented in Figure 3-35 and 3-36 for surface application and 0- and 1-day delays, respectively. The cumulative yield is given as a percentage of total pollutant yield versus the percentage of total runoff from the test plots for each years data. Approximately 50% of the pollutant yield from the test plots was in the first 20% of the total runoff. The percent of total COD yield in the percent of total runoff is very nearly the same for both sod and bare soil (Figure 3-35a).

Approximately 80% of the total COD and TS yield was in the first 30% of the runoff (Figure 3-35a and 3-35c) whereas 45% of the first runoff was required to remove 80% of the total N (Figure 3-35b). This indicates that the N is picked up by the water at a somewhat slower rate. For the 1-day delay tests as shown in Figure 3-36, as much as 75% of the total runoff was required to remove 80% of each pollutant. This data show that the rate of pollutant removal is much slower after a 1-day delay as compared to 0-day delay.

The percentage of total COD removed is presented as a function of percent of total runoff for the 6-inch injection, 0-day delay tests in Figure 3-37. Approximately 55% of the total runoff was required to remove 80% of the total pollutant yield from the injected plots (Figure 3-37) as compared with only 30% of the total runoff for surface application (Figure 3-35a). Therefore, not only did injection slow the rate at which the runoff picked up the COD (comparative results given in Figure 3-32a and Figure 3-34), it also reduced the percentage of total COD removed by at least a factor of 17 in the first 100 liters of runoff. The time required to produce a given amount of runoff from the injected plots receiving simulated rainfall at a rate of 2.5 inches per hour is longer than for the surface-applied plots. This shows that not only was there less total COD in the runoff from injected plots as compared with surface applied plots, but also more simulated rainfall was required to remove the COD.

CUMULATIVE RUNOFF HYDROGRAPHS

The cumulative runoff hydrographs shown in Figure 3-38 were developed for surface application and 6-inch injections to supplement the data presented in the previous sections. They are based on a simulated rainfall rate of 2.5 inches per hours from the 9-foot-square plots. Each data point shown on the graphs represents the average of three replications.

Increasing the time of delay between application of manure and rainfall significantly reduce the rate of runoff as indicated by the slope of the lines. Also, injection reduced the rate of runoff. For 0-day delay, the rate of runoff from the injected plots was less than half of that from surface application. For the 1-day delay plots, the reduction factor is greater than 12. No runoff was obtained from the

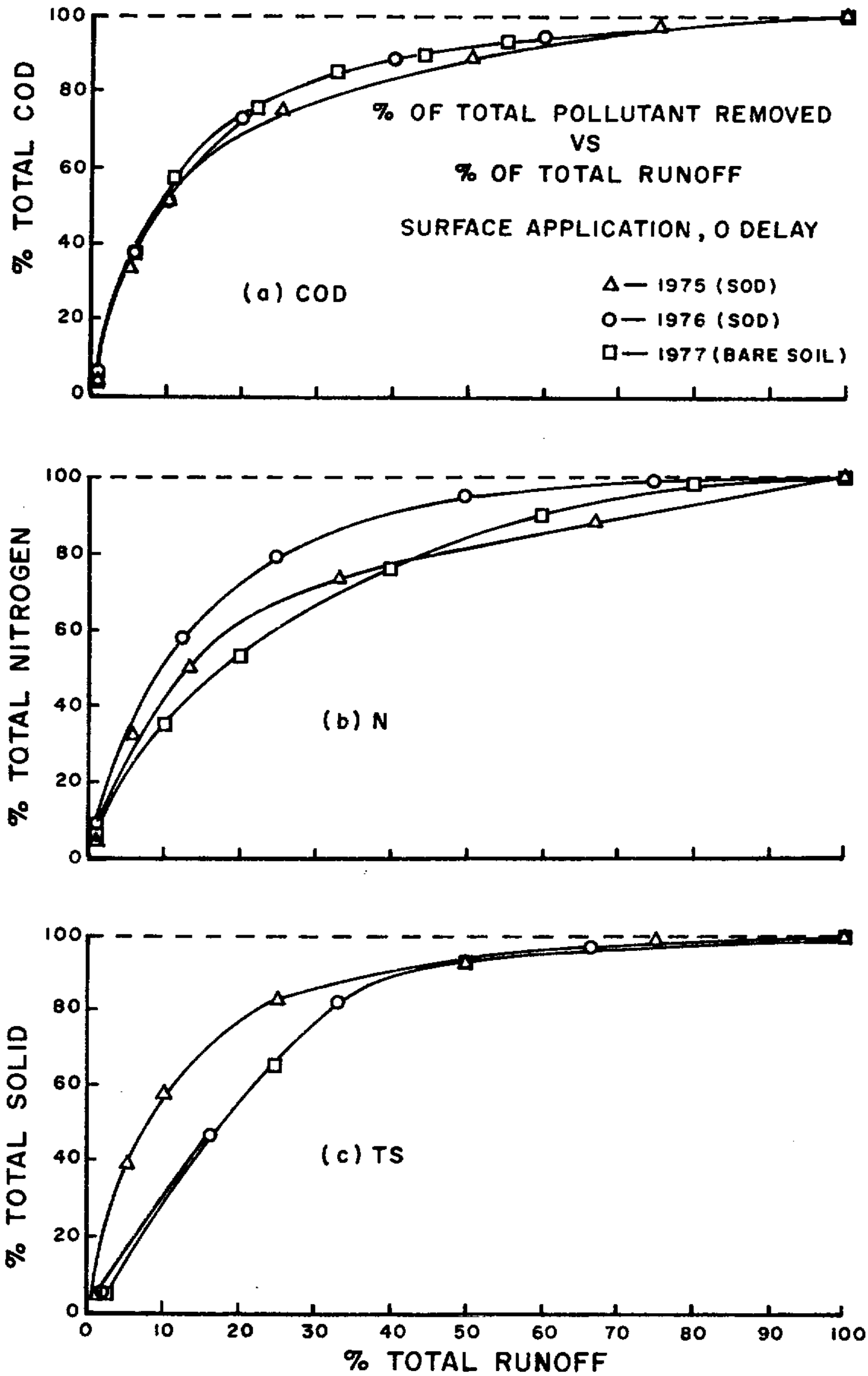


Figure 3-35. Percent of total pollutant removed vs percent of total runoff, surface application, 0 delay.

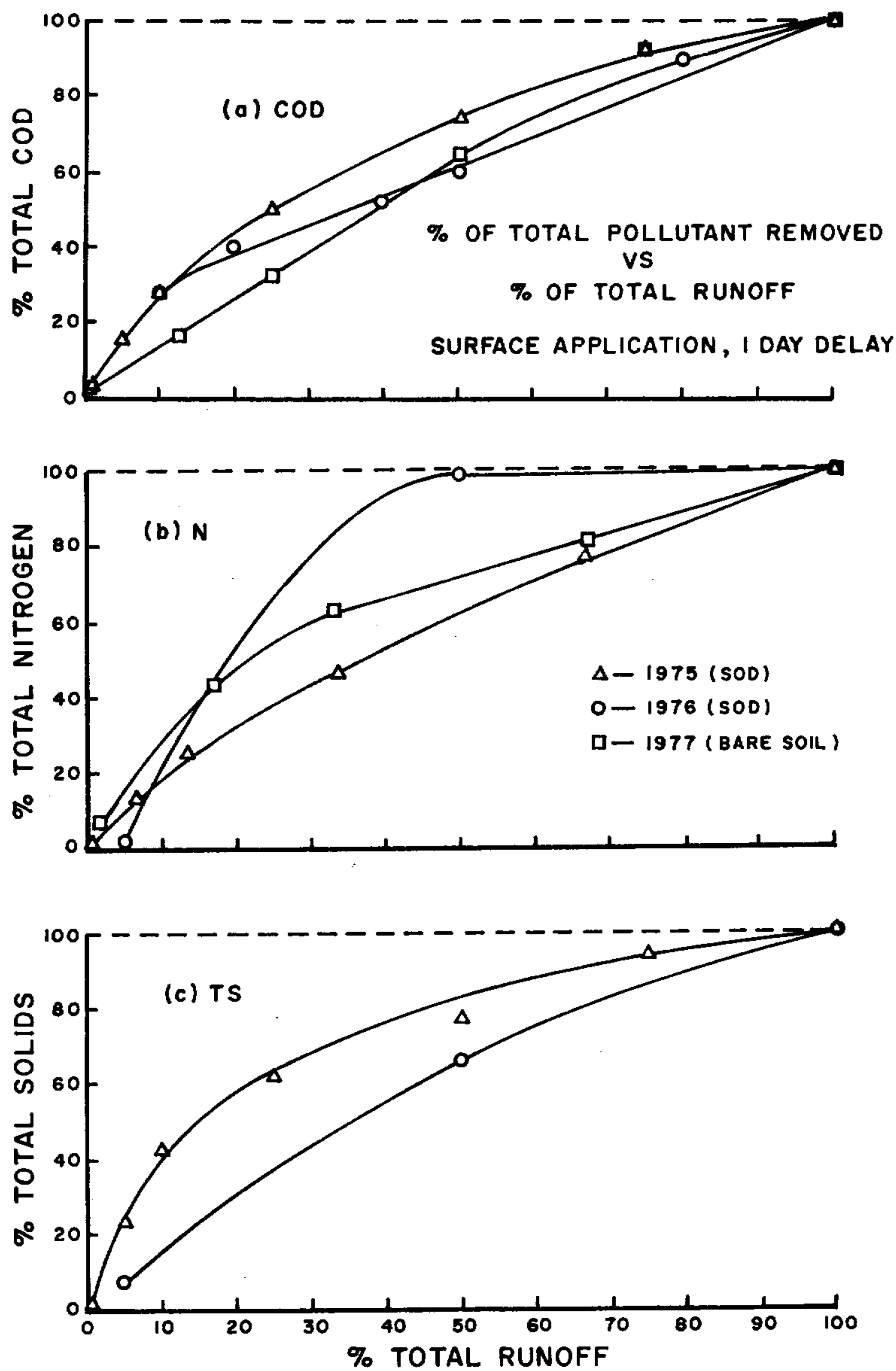


Figure 3-36. Percent of total pollutant removed vs percent of total runoff, surface application, 1 day delay.

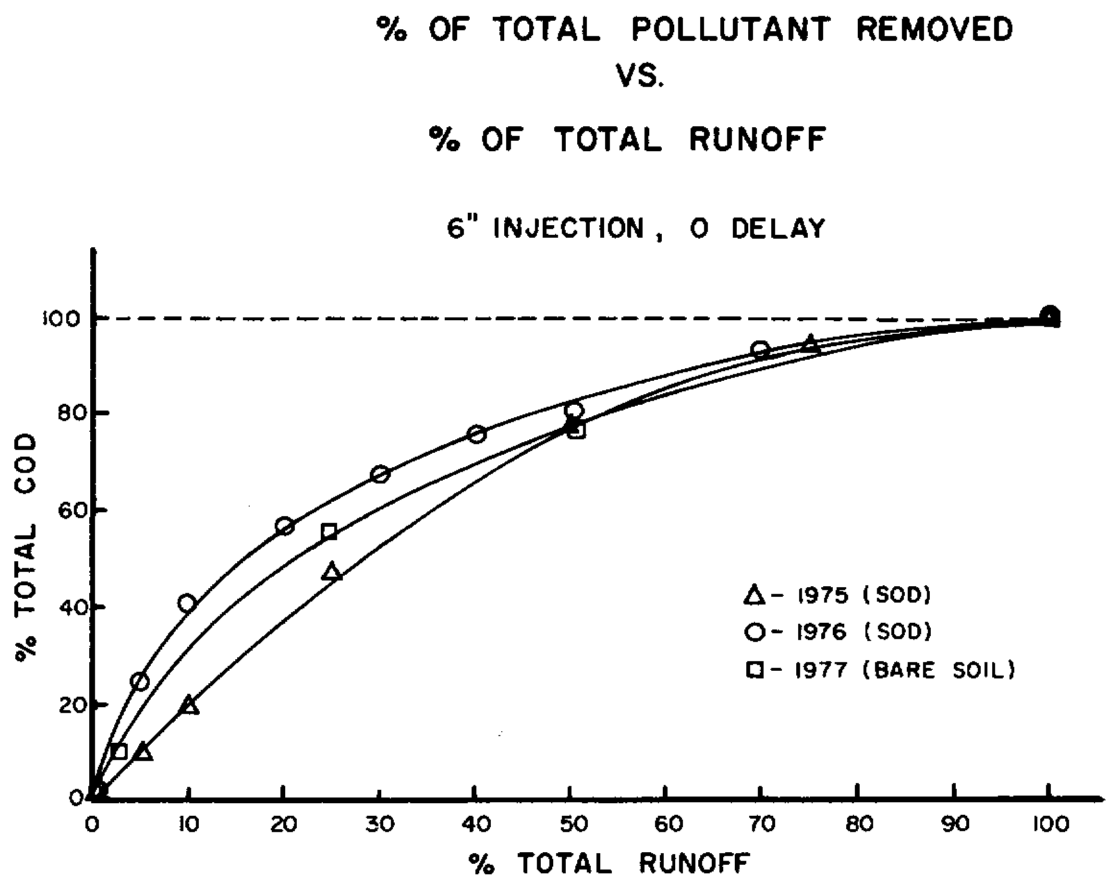


Figure 5-37. Percent of total pollutant removed vs percent of total runoff, 6" injection, 0 delay.

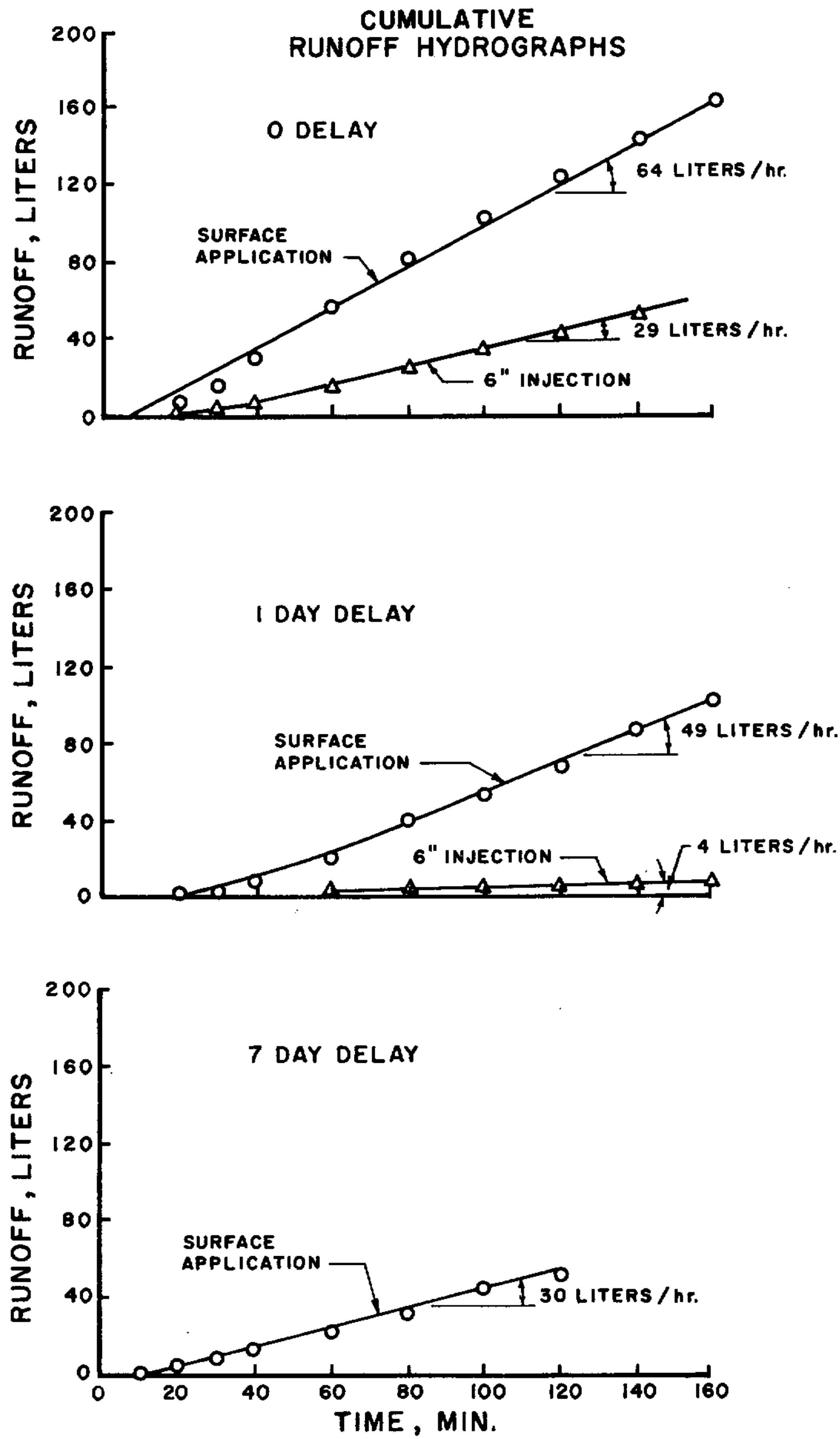


Figure 3-38. Cumulative runoff hydrographs.

injected plots with 7-day delay.

DISSOLVED OXYGEN AND pH

The DO and pH of each sample of runoff collected for laboratory analysis was measured in the field immediately after it was collected for all plot tests in 1975 and 1976. These measures were compared to those for the water being applied to the plots. Very little difference was found between the water as applied and the runoff. There was a slight increase in pH with an increase in the concentration of the pollutant in the runoff. The majority of the pH values were in the range of 6.9 to 7.6, although the range extended from 6.0 to 8.4.

SOIL CHARACTERIZATION

The soil at the test site was a deep, well-drained, dark brown silty loam in the 0 to 12 inch deep layer, changing to a finer textured reddish brown silty clay loam to silty clay in the 12 to 24 inch deep layer, and to red silty clay with a slight gray to yellow tint in the 24 to 48 inch deep layer. The hydraulic conductivity of the top layer ranged from 2.1 to 2.9 inches per hour. The soil correlates with the Soil Conservation Service (SCS) classification as a Maury silt loam which is found extensively in the central Bluegrass region in Kentucky. This soil has a medium organic content and acidity and is naturally fertile. The root zone is deep and the moisture-supplying capacity is high. It can be worked throughout a wide range of moisture contents without crusting or clodding.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Liquid dairy manure has been injected on the soil contour to depths of 6 and 12 inches and applied to the surface of a Bluegrass sod and a bare tilled soil. Application rates of 9250 gallons per acre were used to supply approximately 150 pounds of elemental nitrogen per acre. Runoff from 9-foot-square plots which were sprinkled at rates of 2.5 inches per hour on sod and 1.5 inches per hour on bare soil was collected and analyzed for various pollution parameters including COD, N, TS, TSS, pH, DO, and Fecal Coliform. The effects on pollutant yield in the runoff have been determined for various treatments.

Injection of the manure into the soil essentially eliminated any pollutant yield in the runoff from the test plots as compared with surface application. For example, the concentration of COD in the first liter of runoff from sodded plots receiving surface application followed immediately by simulated rainfall was 72-fold greater than the first liter of runoff from 6-inch injected plots. Likewise the total COD yield in the first 100 liters of runoff was 17 times greater for surface applied plots than the 6-inch injection plots. Similarly, for bare soil the first liter of runoff contained approximately 80 times as much COD as the first liter of runoff from injected plots. The depth of injection had essentially no effect on pollutant yield for 6- and 12-inch injection depths at the application rate used in these experiments.

Injection tended to even the rate of pollutant loss in the runoff. Approximately 55% of the total runoff was required to remove 80% of the total pollutant yield from the injected plot as compared with only 30% of the total runoff for surface application. Further, the rate of runoff from injected plots was less than one-half the rate from surface-applied plots.

The delay time between application of liquid manure and the simulated rainfall event had a significant effect on the yield of the pollution parameters in the runoff. A 1-day delay reduced the concentration by at least 80% and in some cases as much as 97%. A 7-day delay tended to further reduce the pollutant concentration in the runoff, but the effect was not pronounced as compared with the 1-day delay. A 1-day delay was more effective in reducing pollutant concentration in runoff from bare plots than for sodded plots. A 1-day delay also reduced the rate at which the pollutant was picked-up by the runoff. Approximately 75% of the total runoff was required to remove 80% of the total pollutant yield after a 1-day delay whereas only 30% of the total runoff was required to remove 80% of the total pollutant yield with 0-day delay. A 1-day delay also reduced rate of runoff by a factor of 12 as compared with no delay.

Repeated yearly applications of manure on sod reduced pollutant concentration in the runoff from test plots. Injected plots receiving manure applications for 3 consecutive years produced no runoff during the latter 2 years. Plots receiving surface application produced runoff each of the 3 years, but the concentration of pollutants was reduced each consecutive year. For example, the total COD in the first 100 liters of runoff for the first year of application was more than 5 times as much as the total yield for the second year. The concentration of COD in the runoff for the third year was essentially zero.

Measurements of pH and DO in runoff from test plots indicate little or no change in these parameters as compared with the water applied to the plots.

The results of the experiments performed for this project indicate that pollutant concentration in runoff from plots receiving surface applications is a function of the concentration of the pollutant in the manure and the total quantity of runoff from plots. Equations for predicting the percentage of the total pollutant load applied to the soil in each liter of runoff have been developed as a function of the total runoff. These equations were found applicable to both sodded and bare soil where simulated rainfall was applied immediately following liquid manure application.

REFERENCES

Standard Methods for the Examination of Water and Wastewater, 13 edition. 1971. American Public Health Association, 1015 Eighteenth St., N.W., Washington, D.C. 20036. pp. 874