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ABSTRACT

DISPOSAL OF HOUSEHOLD WASTEWATER IN SOILS OF HIGH STONE CONTENT

Two experimental septic tank filter fields were constructed with built-in monitoring equipment in Nixa soils. These soils contain many chert fragments and a fragipan about 60 cm deep which restricts downward water movement and is the design-limiting feature.

The standard filter field (76 cm deep) was built into the fragipan and the modified standard filter field (30 cm deep) was placed above it. During 30 months' observation, the modified standard performed better than the standard filter field. Maximum rise of effluent in the standard and modified standard came within 11 and 19 cm of the soil surface, respectively.

Performance of these systems indicates filter fields should be designed to function during climatic stresses, i.e. when the soil has a maximum hydraulic load and surfacing may occur. Filter fields should be designed to withstand a stress period of specified intensity. The filter fields in this study were observed under less than normal stress. Therefore, their long range performance is less clear.

Our observations indicate that filter field performance is related more to rates of water movement than to stone content. Major influences on filter field performance are rates and directions of water movement, stress period intensity, designs, and construction techniques.

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KEYWORDS - Septic Tank Systems/Filter Fields/Soil Adsorption Systems/Effluent Renovation/Septic Tank Effluent Treatment/Fragiudults/Loamy-Skeletal Soils/Soils-Stony/Climatic Stress Periods.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The movement of people from urban areas to suburban areas, small towns, and rural areas has created several environmental problems. One major problem has been the renovation/disposal of household wastewaters. Most of these people are beyond the reaches of municipal sewer systems and must depend upon on-site wastewater renovation systems. These systems are a continuing source of environmental concern.

An acceptable on-site wastewater renovation system must renovate the wastewaters and return them to the hydrologic cycle without adversely altering the environment. This objective is not always accomplished, however, due to poor construction techniques, improper system design, or utilization of soils which are not suited to present filter field designs. It is the purpose of this report to present an evaluation of two septic tank filter field designs on the Nixa soils.

The most outstanding features of Nixa soils are the high contents of chert fragments throughout their depths and the fragipan which occurs about 60 cm below the soil surface. The fragipan reduces the downward rate of water movement and is the design-limiting factor for septic tank filter fields. These soils were selected for study not only because of the large acreages of them that exist in the Ozarks, but also because of their similarity to other soils which have subsurface features (plinthite and duripans, for example) that restrict vertical movement of water. Additionally, although these soils are not prime farmland, they are well suited for housing sites except for problems of household wastewater renovation. Their use for housing sites will not seriously limit our base for agricultural production and is, in our opinion, their wisest and best use.

The specific objectives of the project that generated the information presented in this report were

1) To use measured hydraulic conductivities of the various soil horizons to design improved septic tank filter fields for the Nixa soils,

2) To install a modified and a standard septic tank filter field with built-in monitoring equipment in Nixa soils,

3) To measure water movement and effluent purification in the improved and the standard septic tank filter field in Nixa soils.

REVIEW OF LITERATURE

INTRODUCTION

Disposal of liquid domestic waste by a subsurface filter field is an economical and efficient way to reclaim water and return it to the hydrologic cycle. It has been estimated that as much as one-third of the total domestic liquid waste in the U. S. is disposed of in this manner (Kropf et al., 1977). Therefore, such installations are significant for the overall health and sanitation and, with research and development, may be relied upon even more heavily in the future.

The septic tank-filter field system is relatively simple and, when properly designed and constructed on a soil having appropriate characteristics, performs satisfactorily. Liquid wastes flow from the house into the septic tank where the liquids and associated solids are anaerobically digested by microorganisms producing a sludge that settles to the bottom of the tank and an effluent which passes into the seepage beds. The settled solids must be periodically removed in order to prevent them from "spilling out" into the seepage beds and clogging of soil pores. As a result, it has been suggested that the septic tank be sized to provide a 3-day retention time for the wastewater (Bouma, 1975). Effluent leaving the septic tank is high in biological oxygen demand (BOD), contains many fecal and other microorganisms, and is a potential health hazard (Table 1). However, the necessary final treatment of the effluent is provided by the soil of the filter field.

Table 1. Identifying Characteristics of Liquid Wastes (Thomas and Bedixen, 1969)

Characteristic	Concentration Septic Tank Effluent*
	(mg/L)
COD	220
BOD	93
Nitrogen	
Total-N	33.3
Organic-N	7.9
NH_3-N	25.4
NO_3-N	0.1
TSS	45
VSS	38
Chlorides	95
Alkalinity	390
	Range
pH	7.1 - 8.3

*One-year averages

COD - chemical oxygen demand

BOD - biological oxygen demand

TSS - total suspended solids

VSS - volatile suspended solids

UNSATURATED FLOW

Soil can be an effective filter both with respect to microorganisms and solutes where conditions are suitable (Pound and Crites, 1973). As the effluent moves through the soil, the suspended solids, microorganisms, biodegradable materials, and many chemical nutrients are removed by processes of filtration, sorption, and microbiological decomposition. The water will ultimately reach the groundwater supply but hopefully only after satisfactory purification. Previous research has shown that soil treatment of wastewater is equivalent or often superior to that of the artificial systems proposed by advanced technology (Pound and Crites, 1973). A comparison of the efficiency of waste treatment and disposal methods is given in Table 2. The ability of soil to accept and purify the effluent depends primarily upon the soil's hydraulic characteristics. Terms such as permeability and infiltrative capacity can be used to describe a soil's potential for liquid waste disposal. The use of these terms is usually restricted to saturated conditions when all pores are filled with liquid. In some seepage beds, however, mechanical barriers such as clogged or compacted layers occur on infiltrative surfaces. These barriers induce unsaturated conditions in the soil below or adjacent to these barriers causing the larger pores to be filled with air. As a result, movement of effluent from these barriers occurs by unsaturated flow.

Table 2. Comparison of efficiency of waste treatment and disposal methods (Westman, 1972)

	Percentage Removed						
	Biological and chemical oxygen demand (BOD and COD)	Suspended matter	Bacteria	Viruses	Phos- phorous	Nitro- gen	Heavy metals (Cadmium, chromium etc.)
Primary treatment							
Fine filter (screens)	5-10	5-20	10-20	0			
Settling tank	25-40	40-70	25-75	0	0-10	0	0
Secondary treatment							
Trickling tilers	65-95	65-92	90-95	0	10-70	50	0-10
Tertiary treatment							
Advanced chemical treatment	65-95(98*)	80-95(98*)	90-98(99*)	0(90)	60-98	85	99
Soil filter (land disposal)	90-95(98*)	85-95(98*)	95-98(99*)	100	98	85	99

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*Environmental Protection Agency estimates, 1971.

OCCURRENCE OF UNSATURATED FLOW

The results obtained from monitoring *in situ* several filter fields operating in sand textured soils indicated that unsaturated soil existed both below and at the sides of the trenches even though effluent was ponded to considerable depth inside the trench (Bouma et al., 1972). Similarly, laboratory studies involving artificial soil conditions in lysimeters have substantiated the results obtained from field studies (Jones and Taylor, 1965; Daniel and Bouma, 1974). The existence of unsaturated conditions was due to an impeding layer or "crust" present at the infiltrative surface. A combination of factors are believed to contribute to the formation of the crust in sand. Accumulation of suspended solids, associated biological growth, and formation of inorganic compounds under anaerobic conditions appear to be the most significant causes for crust development (Allison, 1947; Jones and Taylor, 1965; Thomas et al., 1966). Frankenberger et al., (1979) found the hydraulic conductivity to decrease as the bacterial population increased and showed that bacterial clogging under prolonged conditions was dependent upon the nutrients and energy sources supplied, the soil moisture level, biological activity and bacterial population. In sand, crust formation or soil clogging prevents saturation from occurring in the subcrust soil although the crust itself is subject to a positive hydraulic head (Hillel and Gardner, 1969; 1970a). Therefore, the crust restricts water movement. As crust resistance increases, the infiltration rate and degree of saturation decrease, thereby maintaining unsaturated conditions. However, data obtained from seepage systems operating in sand indicate that the crust resistance reaches an equilibrium with induced subcrust tensions of approximately 20 cm of water (Bouma et al., 1972). Therefore, systems constructed in sand can be designed to operate at an ultimate flow rate corresponding to 20 cm tension.

In another study Bouma et al. (1975) found that the equilibrium concept defined for sands may not apply to finer textured soils. In their study six systems operating in loamy soils were monitored for crust characteristics. However, only three of the systems were found to be ponded with effluent. The subcrust tensions for these three systems ranged from 20 to 37 cm. Excavations were made to observe the infiltrative surfaces. The observations made at that time indicated that excavating equipment had been driven over the bottom of the seepage bed of the ponded systems before the gravel was applied. Thus, the ponding effects were assumed to be due to a mechanical barrier caused by puddling or compaction of the soil when equipment was driven over the seepage bed and not due to biological crust. The remaining three systems accepted the effluent, and subsurface beds or trenches did not contain ponded effluent. The infiltrative surfaces of these systems were observed to have well-exposed soil structure with open worm and root channels and planar voids between structural elements (peds). Obstruction of the larger pores had not occurred from mechanical compaction. Perhaps more important, a biological crust had not formed in the three non-ponded systems.

Two conclusions can be drawn from this study. First, adequate absorption of effluent can be achieved in loamy soils if the larger pores in the soil can contribute to the flow. Second, ponded seepage systems have barriers to flow at the infiltrative surface formed by either mechanical compaction (finer textured soils) or biological clogging (sands) that tends to obstruct the larger pores. These barriers can be physically characterized by calculation of the hydraulic resistance, Rb (days), as follows:

$$Rb = \frac{Ho + M + Zb}{q} \qquad (1)$$

where q (cm/day) is the infiltration rate which is equal to the unsaturated K value of the soil at the measured moisture tension M (cm of water) in a one-dimensional flow system, Ho (cm) is the positive hydraulic head on top of the barrier caused by ponded liquid and Zb (cm) is the thickness of the barrier (Bouma et al., 1975).

The hydraulic effects of barriers can be predicted by equation 1 when hydraulic conductivity curves of the soil below the barriers are available and when Rb values of the barriers themselves are known. These effects are shown in Figure 1, in which representative K curves for sand, silt loam, and clay textured soils are given (Bouma, 1975). The other curves, hereafter referred to as resistance curves, were derived from equation 1 assuming different Rb and Ho values and a value of 2 cm for Zb. The latter value was chosen on the basis of visual observation (Bouma et al., 1972).

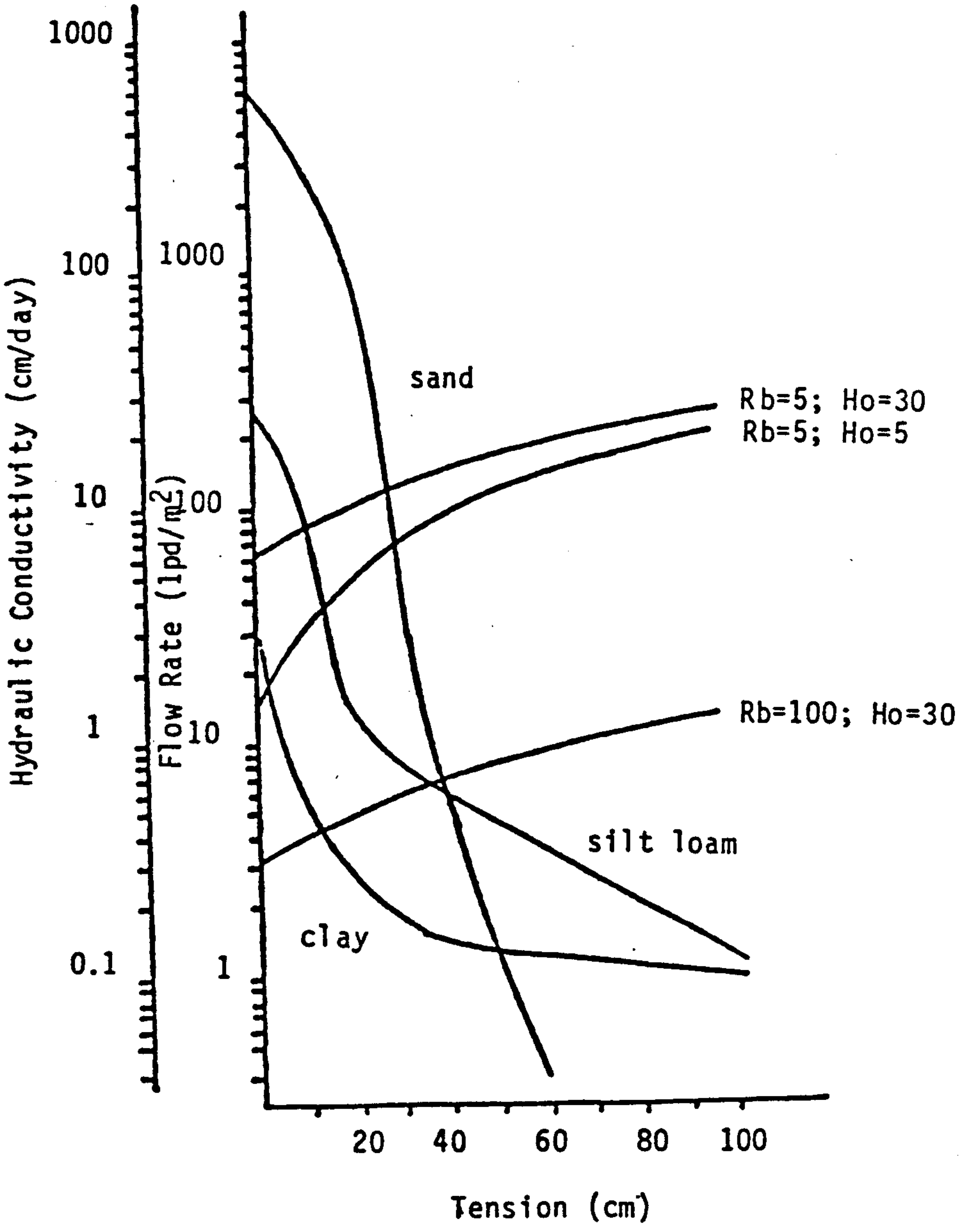


Figure 1. Hydraulic conductivity curves for three major soil textures and curves expressing the hydraulic effect of impeding barriers of different resistances (Rb) subjected to different hydraulic heads (Ho). (From Bouma et al. 1975).

The points where both curves cross represent the only hydraulic conditions, in terms of tensions below barriers and flow rates, that can be expected at the specified Ho, Zb, and Rb values. For example, the Rb value determined from in situ measurement of a mechanically puddled barrier in a silt loam soil was approximately 100 days (Bouma, 1975). This system had effluent ponded to a depth of 30 cm (Ho = 30) within the seepage bed. Therefore, this barrier would be expected to induce an equilibrium tension of 40 cm with a corresponding flow rate of 0.7 cm/day in a silt loam (Figure 1). Identical barriers induce different moisture tensions in different soils because their hydraulic effect is dependent not only upon their own resistance but also upon the capillary properties of the underlying porous medium (Bouma, 1975). Therefore, the same barrier with Rb = 100 and Ho = 30 would induce a tension of 12 cm and a flow rate of 0.43 cm/day in a clay soil (Figure 1). By observing sound construction practices that prevent compaction of the infiltrative surface, highly resistant mechanical barriers can be avoided.

Although biological crusts have not been observed to develop in finer textured soils, their hydraulic effect can be demonstrated. In sand, flow barriers of this type had a characteristic Rb of 5 (days) (Bouma et al., 1972). Assuming that biological clogging results in barriers of identical resistance, regardless of soil texture in which they formed, it follows that such a barrier would induce a tension of 14 cm at a flow rate of 3.8 cm/day in silt loam and 3 cm tension at 1.8 cm/day in clay (Figure 1). These values were determined by using Equation 1, substituting Rb = 5 days, Ho = 5 cm (arbitrary) and Zb = 2 cm (Depth of clogging in sands). Increasing the hydraulic head on top of a barrier of fixed resistance increases flow rates and reduces tensions. Thus, if Ho is increased to 30 cm on a barrier of Rb = 5 days, the tension is reduced to 12 cm and the corresponding flow becomes 8.0 cm/day (Figure 1).

The hypothesis can be made that biological clogging will not result in ponding, to cause inadequate infiltration if the loading rate does not exceed the critical flow rate induced by a hypothetical biological crust of Rb = 5 days (Bouma et al., 1975). The critical flow rate is defined by the point where the resistance curve and K curve cross. However, the critical flow rates for finer textured soils such as loams, silt loams, or silty clay loams are presently ill-defined. Perhaps as a first approximation, the critical flow rate should be defined as a certain percentage of the saturated flow rate so that flow rates can be maximized while providing an aerobic environment.

SIGNIFICANCE OF UNSATURATED FLOW

Darcy's law states that the rate of flow through a soil is proportional to the reduction of the hydraulic head per unit distance in the direction of flow. In its most basic form, stated for a one-dimensional, steady state condition of flow, Darcy's Law is:

$$q = K\frac{\Delta H}{L}$$

where q = flux (cm/day) of water [= Q/At] which is the volume Q (cm^3) of water flowing through a cross-sectional area A (cm^2) per time t (day), K is the hydraulic conductivity (cm/day) and $\Delta H/L$ is the hydraulic gradient (dimensionless). This equation applies to both saturated and unsaturated soils for steady state conditions of flow.

Soil horizons containing pores with an upper size limit of 1 to 2 mm lose little water until the tension exceeds 10 cm (Childs, 1969). The emptying of a pore at this tension leaves the solid walls coated with a thin film of water in which liquid flow takes place, but at a much slower rate. A reduction in moisture content is thus equivalent to a reduction in hydraulic conductivity. Since the moisture content is progressively reduced by an increase in tension, the larger pores empty first. These larger pores also are the most effective conductors, and it follows that a small reduction in moisture content from saturation may result in a large reduction in hydraulic conductivity. As pores fill with air, they become barriers to flow in the liquid phase. Liquid that originally passed through the pore will be deflected around the pore when it is filled with air. The flow paths thereby become longer and more tortuous, with a reduction of the hydraulic conductivity.

Several reasons can be cited for the importance of unsaturated conditions when disposing of liquid wastes. First, in unsaturated soil the average distance between effluent particles and the solid phase of the soil is decreased allowing for better attenuation by adsorption. Second, the flow paths become longer and more tortuous effecting greater contact time between the effluent and soil particles. Column studies conducted in the laboratory indicated that the adsorptive capacity of the soil and the amount of constituents removed by adsorption were directly related to contact time (Creson, 1975; Robeck et al., 1964). Finally, since flow of liquid in unsaturated soil is through the smaller pores and the hydraulic envelopes, the large pores are filled with air providing an aerobic environment. Such conditions are essential to the microorganisms responsible for the biodegradation of the wastewater constituents.

PURIFICATION

Purification of liquid waste introduces two basic types of concerns: those associated with health problems such as the occurrence of pathogenic bacteria and viruses or a high nitrate concentration in potable waters and those associated with euthrophication of ground and surface waters caused by nutrients in the effluent reaching the water supply. Some of the influences on the extent to which percolating effluent from filter fields will add to the nutrient load of water supplies are (1) the density of dwellings in the area and the loading rates of the systems, (2) the distance to a water table and the physical properties of the soil underlying the system, (3) the distance of groundwater flow before entering surface waters and associated dilution, and (4) the mobility of nitrogen and phosphorus in streams and lakes (Bouma, 1974).

NITROGEN TRANSFORMATIONS AND REMOVAL

Wastewater, as it leaves the septic tank, contains both organic and inorganic forms of nitrogen. The various forms of organic nitrogen will eventually be converted by soil microflora to the inorganic forms: ammonium (NH_4^+-N), nitrate (NO_3^--N), or nitrite (NO_2-N), depending on the aeration status of the soil below the filter field.

Pruel and Schroepfer (1968) concluded from lysimeter studies that adsorption and biological action were the main influences on the fate of nitrogen in soils. One of these processes may dominate the other depending upon the soil environment. The process of adsorption is important when nitrogen is in the ammonium (NH_4^+-N) form since this form is readily adsorbed onto the exchange complex of the soil. Although adsorption of nitrate is not normally thought to be extensive, Creson (1975) stated that at a pH of 6.0 or less, adsorption of nitrates could be significant. The pH of typical domestic wastewater is about 7.0; therefore, in the range of pH found in the filter field, nitrates are able to move freely with the soil solution and may be transported to ground or surface waters.

While studying five operating systems, Walker et al. (1973) found NH_4^+-N concentrations to be relatively high immediately under the seepage beds. However, within a few centimeters of the crust, NH_4^+-N concentration decreased greatly. The major mechanisms of NH_4^+-N removal in the systems was nitrification. This action was evidenced by the general increase in the concentration of nitrate (NO_3^-N) with depth concurrent with a decrease in NH_4^+-N concentration. For example, the NH_4^+-N concentration was 62 ppm at 1 cm below the seepage bed but only 6 ppm at 5 cm. On the other hand, nitrate was 3 ppm at 1 cm and 13 ppm at 5 cm. In all aerobic filter fields, nitrification started in the unsaturated zone within 2 cm of the crust. However, inspection of a seepage bed inundated by a seasonally high water table revealed that nitrate forms were not present adjacent to the bed indicating that nitrification had not occurred. The high concentrations of exchangeable NH_4^+-N indicated that ammonium was being retained by the exchange complex.

In his study of nitrogen transformations in soil columns, Magdoff et al. (1974b) observed a decrease in the inorganic forms of nitrogen in the soil solution. The low oxygen concentrations measured and the redox values obtained indicated that environmental conditions were favorable for denitrification. The average nitrogen loss due to denitrification was 32% of the total influent nitrogen. In the presence of anaerobic conditions, however, high denitrification rates in natural soil are probably of short duration unless copious amounts of organic matter are available as an energy source for microorganisms (Volz et al., 1975).

In response to concern about nitrate pollution, Sikora and Keeney (1976) proposed an on-site denitrification system. Nitrate removal in their system was accomplished by employing sulfur compounds and the ubiquitous obligate chemolithotroph _Thiobacillus_ denitrificans. This microorganism obtains its energy by oxidizing reduced sulfur compounds and passing electrons to NO_3^- in the absence of oxygen. Nitrate was thereby converted to elemental nitrogen (N_2) which escaped harmlessly into the atmosphere. The application of this system, however, may be limited by the buildup of high concentrations of sulfate. The permissible level of SO_4^{-2} in the drinking water is 250 μg SO_4^{-2}/ml (83 μg S/ml). Whether this concentration is reached in ground water below the T. denitrificans NO_3^- removal system depends upon the density of systems per unit area and the volume and recharge characteristics of the aquifer or watershed.

Klausner and Kardos (1975) pointed out in their research that the conditions required for denitrification also promote the reduction of iron and manganese which could, if not prevented, result in excessive amounts of these elements in the soil solution. At low pH and under reducing conditions Fe^{+2} and Mn^{+2} can be solubilized and become mobile. This increased mobility can result in the formation of rather impervious iron and manganese pans in soils as well as deposits of inorganic hydroxides which may further reduce effluent movement.

PHOSPHOROUS TRANSFORMATION AND REMOVAL

Phosphorous retention in soils is achieved primarily by adsorption on the exchange complex of the soil colloids and by chemical precipitation to form insoluble compounds. Although soils are known to sorb phosphorus (P) readily, the P sorption capacity of various soils is diverse. Laboratory experiments conducted by Sawhney and Hill (1975) showed the P sorption capacity of major Connecticut soils varied by as much as threefold. Hence, the time required to saturate different soils surrounding a filter field was considered to vary accordingly. Calculations based upon P sorption capacities of soils determined from the sorption isotherms, the total volume of soil surrounding different installations, and a loading rate of 1.8 kg/year of soluble inorganic P showed that a 30-cm thick section of a sandy loam surrounding a trench would require 2.3 years for saturation. The sorption capacity of this soil was 9 mg/100g soil. The same section of a fine sandy loam with a sorption capacity of 29 mg/100g soil would require 15 years to saturate, a sevenfold difference. The time required to saturate a soil is also dependent upon design geometry or "effective" seepage area. Therefore, the time required to saturate a 30-cm section surrounding a leaching pit would be 1 year for the sandy loam and 5 years for the fine sandy loam. Saturation times around seepage beds were essentially the same as the times for seepage trenches. Further experiments with operating filter fields indicated that most P in the effluent was sorbed within distances shorter than laboratory experiments had predicted. Furthermore, the amount of phosphorus adsorbed was greater in the field than in the laboratory because wetting and drying of the soil regenerated P sorption sites. This result was confirmed in the laboratory using alternate wetting and drying techniques.

In Virginia, phosphorous accumulations in two soils with high perched water tables were monitored as a function of distance and depth to determine the fate of P from septic effluent in natural soil systems (Reneau and Pettry, 1976). Phosphate present in ground waters adjacent to the drain fields at both locations indicated P was generally present in perched water tables above very slowly permeable horizons. Phosphate concentrations in the perched water table decreased rapidly with distance from the drain field with little P present at a 12-m distance. This system had been in operation for 4 years. A plinthite horizon at this location and a fragipan at the other site, proved to be very effective barriers to movement of P in the vertical direction. The researchers concluded that only a limited possibility existed for contamination of a permanent ground water table via vertical movement in these soils. According to Otis (1976), phosphorous leakage to the groundwater may occur where high permanent water tables exist, where very coarse sand or gravel is encountered, or where the seepage bed has been loaded heavily for a long time. He estimated that P can move 50 to 100 cm per year through clean sand but movement in loams, silt loams, and clays is only 5 to 10 cm per year.

In addition to sorption of soluble P, phosphorus is effectively removed from the soil solution by fixation. Certain cations such as aluminum, iron, and manganese are inherent to nearly all soils and are capable of fixing P in very complex and insoluble forms (Brady, 1974). Experimentally, added soluble phosphate in six soils, with pH ranging from 5.3 to 7.5, was found mainly fixed as aluminum phosphate and secondarily as iron phosphate and calcium phosphate (Chang and Chu, 1961). The clay fraction is the main site of phosphate fixation in inorganic soils. In clay, the content of aluminum is greater than that of either iron or calcium. Therefore, added soluble phosphate is most likely to be fixed as aluminum phosphate in the initial stages but, in time, iron phosphate would dominate from transformations of the other forms. In experiments conducted on the same soils flooded continuously for 100 days, it was found that iron phosphate was the dominant form fixed (Chang and Chu, 1961).

Makin (1973) conducted a study to examine the phosphorous removal characteristics of soil materials from or similar to those of Northwest Arkansas. The results indicated that cherty soils effect a high degree of phosphorous removal due to high levels of iron present. Further investigations were performed to determine whether removal of P could be enhanced by mixing additives with the soil. Of the additives used, iron enhanced removal the most; however, use of iron as an additive could lead to excessive amounts of the substance in groundwater. A concentration of 1.0 ppm Fe is considered the maximum for drinking water (Davis & DeWiest, 1966). The amount of calcium present in domestic wastewater should be sufficient to react with the phosphorus to prevent any major pollution hazard. Therefore, one could expect little danger of phosphorous pollution from a properly operating filter field.

ORGANIC REMOVAL

Although most of the solids present in household wastewaters settle out as sludge at the bottom of the septic tank, the water trickling into the filter field is not completely free from insoluble solids. Harkin et al. (1975) state that normal septic tank effluent reaching the drain field will contain 140 to 150 ppm of suspended solids. The removal of these organic materials is achieved through filtration by the soil at the infiltrative surface, adsorption by the soil and crust material, and biodegradation by a mixed population of aerobic microorganisms.

Robeck et al. (1963) found that soil lysimeters treated with sewage effluent accumulated an organic mat or "crust" at the interface between layers of gravel and sand. Several other studies have substantiated the presence of this crust (Jones and Taylor, 1965; Thomas et al., 1966; Bouma et al., 1972). Analysis of the crust material revealed that it was highly adsorbent and microbially active and, furthermore, was the determinant in the effectiveness of organic removal. Three reasons were cited for the importance of such a layer. First, the accumulated organic matter increased the adsorptive capacity for dissolved organics. Adsorption of organics is essential if microorganisms are to degrade them efficiently. Second, the crust reduced the conductivity through the underlying soil, thereby increasing contact time and subsequently increasing the overall removal of the wastewater constituents by adsorption. Finally, the crust provided a nutrient rich environment for the development and maintenance of a rich, mixed microflora to effect rapid degradation of organics under aerobic conditions. In a related study employing lysimeters, Thomas and Bendixen (1969) reported that soil microbes were able to degrade 80% of added organic carbon under a variety of conditions. Large variations in temperature, loading rate, and duration of loading had no significant effect on degradation. Organic carbon loading rates of 14 ton ha^{-1} yr^{-1} resulted in only a 1.3 ton ha/year residue in a silt loam. Decreasing the loading rate to 1.65 ton ha/year resulted in a net loss in the same soil.

Soil columns containing 60 cm of gravel, sandy loam, and silt loam were used in an experiment to simulate removal of organic carbon in a soil disposal system (Magdoff et al., 1974a). Treatment of the columns with 2 cm of influent every 6 hours (8 cm/day) resulted in the sandy fill being predominantly aerobic while the silt loam was anaerobic. Five-day BOD determinations of the influent averaged 170 mg/liter. Percolation of the effluent through these columns resulted in the removal of essentially all of the soluble organic carbon. Septic tank effluent is the product of a relatively short (3- to 5-day residence time) anaerobic digestion. Apparently the organic compounds stabilized in this manner are readily degraded upon introduction to the aerobic environment of the filter field.

REMOVAL OF BACTERIA AND VIRUS

From the standpoint of public health, the removal of pathogenic bacteria and viruses is the most essential function of the filter field. Most important in the removal of pathogens by soil are soil texture, temperature, pH, bacterial adsorption to soil and crust materials, soil moisture, nutrient content, and bacterial antagonisms (Otis, 1976). Laboratory experiments produced evidence that 60-cm sand columns failed to transmit appreciable numbers of viruses when the columns were loaded at a rate to maintain unsaturated conditions (Robeck et al., 1964). A 5 to 10% per day die-off rate of the organisms was recorded. The frequency of virus recovery, *in situ*, was found to decrease with increasing distance from its source (Vaughn et al., 1981). However, it was concluded that lateral movement of viruses in sandy soils may be extensive and eventually lead to contamination of drinking water.

Certain species of bacteria, particularly *Escherichia coli* and related organisms designated as coliforms such as fecal streptococci and *Clostridium perfringens*, inhabit the large intestine of man and are consequently present in the feces. Therefore, the presence of such organisms in water supplies has been used as an indicator of possible pollution by human wastes. The movement of coliform in the lateral direction is limited and vertical movement below 120 cm of the soils tested by Brown et al. (1979) was minimal. Coliform densities in ground water decrease as a logarithmic function of distance from the disposal area (Reneau, 1978). However, the overwhelming numbers of soil bacteria, as well as their known potential for antagonism, have made it very difficult to detect either the pollution indicators or actual human pathogens in nature. The indicator organisms in monitored operating systems were found to be reduced to background counts of the soil within 60 cm below the filter field (Bouma et al., 1972). The abrupt decrease in bacterial population occurred in the crust zone. It was not possible from the data to determine whether the high bacterial count in the crust was from entrapment by adsorption or from growth. Probably both processes occur since nutrient levels, pH, temperature, and moisture are generally favorable for growth. High populations of actiniomycetes, as well as Pseudomonas and Bacillus species, were also found in the nutrient rich, moist, aerated zone immediately under the filter fields. All three of these groups of bacteria are active producers of antibiotics and thus may play an important role in the die-off of the fecal coliforms and streptococci.

The significance of the trapping of bacteria in the crust should be noted. Although the crust is only a few centimeters thick and has a high bacterial population, it is extremely efficient in adsorbing and holding both general and pollution bacteria. If the crust is poorly or unevenly developed, evidence shows that the bacteria can possibly penetrate more deeply below the filter field (Bouma et al., 1972).

The movement of total and fecal coliforms from septic effluent through three Virginia soils was monitored over a two-year period (Reneau and Pettry, 1975). These soils were considered marginally suited for sanitary disposal of wastes because of fluctuating seasonal water tables and/or restricting layers. Since movement of water in the soils occurred mainly in the horizontal direction as a result of slowly permeable horizons, piezometers were installed for sample collection at selected depths and distances. The results indicated that, although purification is thought to occur in the vertical direction, percolation of the effluent horizontally through the soil reduced coliform indicators significantly at distances no greater than 13 m for the three soils. One of the systems studied had been in operation for 15 years. The slowly permeable horizons in each soil proved to be very effective barriers to coliform movement in the vertical direction with few detectable organisms present below the restricting layers. It was concluded that pollution of the permanent ground water table was not likely to occur in the vertical direction.

In addition to filtration and adsorption, the processes of competition and antagonism also control the fate of pathogenic and pollution organisms in the septic tank effluent. Organisms which have established themselves in the same ecological niche have a profound influence upon each other because of competition for the same nutrients and environmental conditions. In such situations the best adapted microorganisms will predominate or completely eliminate the other organisms. Such is the situation in the filter field where organisms introduced in the effluent must compete with established soil populations. Many of these soil microorganisms are antagonistic in that they produce and secrete lytic enzymes which destroy the cell wall of other organisms.

METHODS AND MATERIALS

DESCRIPTION OF THE STUDY AREA

The Ozark Highlands of southern Missouri, northern Arkansas, and northeastern Oklahoma are characterized by three step-like geomorphic surfaces. These surfaces successively increase in altitude southwestward across the 300-m Salem Plateau, the 400-m Springfield Plateau, and the 600-m Boston Mountain Plateau. All rocks exposed in this area are of sedimentary origin and range in age from Oridivician to Carboniferous (Croneis, 1930). In general, the oldest beds are exposed in the northern and the youngest along the southern extremities.

LOCATION, GEOLOGY, GEOMORPHOLOGY

A suitable area for this study was found in the western portion of northern Washington County, Arkansas, approximately 3 km northeast and 6 km northwest of the communities of Savoy and Wheeler, Arkansas, respectively. The study area lies within the Springfield Plateau.

The Springfield Plateau is underlain mainly by rocks of Mississippian age (Thornbury, 1965). In Arkansas, the northeast facing Eureka Springs Escarpment serves to form the boundary between the Salem and Springfield Plateaus. The scarp reaches a thickness of 120 m near Eureka Springs but becomes progressively less well-defined toward the east. Most of the plateau stands between 300 and 450 m above sea level, but at several places, including the

Fayetteville quadrangle, prominent erosional remnants of the Boston Mountains may rise 70 to 200 m higher above the general surface (Croneis, 1930; MacDonald et al., 1975).

The surface topography of the Springfield Plateau is rather rough, particularly near its northern border, where streams cut to the Eureka Springs Escarpment and to the south where erosional remnants are most prominent. In many areas, however, the surface is only gently undulating. This surface feature is most conspicuous in the area surrounding Fayetteville and is referred to in the literature as "prairie" (Croneis, 1930; Thornbury, 1965).

Most of the surface rocks of the region belong to the Boone formation, which is approximately 90 m thick in central Washington County (Frezon and Glick, 1959). All the limestones of the Boone formation above its lower member are nearly pure calcium carbonate and, therefore, very soluble in water. In addition, chert is found in nearly all horizons of the Boone formation above the St. Joe limestone member (Croneis, 1930). Therefore, as the limestone weathers, the insoluble chert is left behind as surface and subsurface deposits. Such deposits are widespread over the Springfield Plateau. Much of the unweathered chert is dense, hard, compact, and brittle and has concoidal fracture (Croneis, 1930).

Associated also with the relatively high solubility of the Boone formation, is the occurrence of solution valleys that dissect much of the area leaving long, narrow, nearly level ridges that are truncated by the steep slopes of the solution valleys. These valleys are strikingly uniform in width and are nearly straight. According to Croneis (1930), these valleys are so characteristic of the Springfield Plateau that they may be used as criterion of that physiographic province.

SOILS

Three soil associations are recognized on the Springfield Plateau of Washington County (Harper et al., 1969). These soils developed predominantly under hardwood vegetation and are underlain by silty or clayey materials, cherty limestone, or alluvium derived from these sources.

The soils in the immediate study area are within the Clarksville-Nixa-Baxter association. They occur on the highly dissected Springfield Plateau, with long, narrow, gently sloping ridges separated by steep solution valleys (Harper et al., 1969). The Clarksville soils occur on the steep slopes of the solution valleys and account for approximately 45% of the association. They are 50 to 90% chert with a grayish-brown or brown cherty silt loam surface texture that is 15 to 30 cm thick and strong-brown to pale-brown cherty silt loam subsoil. The Baxter soils also occur on the hillsides and account for 15% of the association. Their surface layer is grayish-brown or brown cherty silt loam 15 to 30 cm thick and the subsoil is dark-red to yellowish-red cherty clay or cherty silty clay. Approximately 20% of the association is composed of the Nixa series. These soils developed on long narrow ridge-tops from residuum derived from cherty limestone. They are deeply developed and occur on slopes that range from nearly level to moderately steep. The surface layer is very dark grayish-brown and the subsurface layer is brown, very cherty silt loam about 26 cm thick. The upper part of the subsoil is light yellowish-brown, very cherty silt loam about 26 cm thick underlain by a compact, brittle fragipan of yellowish-brown, mottled, very cherty silt loam. Because of the fragipan horizon, the Nixa soil is considered very slowly permeable to water. As a consequence, these soils have a severe limitation to accommodate septic tank filter fields.

EXPERIMENTAL SITE CHARACTERISTICS

Table 3 contains the official series description of the Nixa soils which are the subject of this study. The experimental site is situated near the crest of a ridge (Figure 2). The steepest slope is northeast to southwest across the site. The standard and modified standard filter fields, which are positioned on the contour, are each on 3.3% slopes.

The background wells are located upslope from the two filter fields. This position might suggest a somewhat better soil drainage than that for the location of the experimental filter fields. The similarity in soil morphologies at the two locations, however, would not support significant differences in the soils.

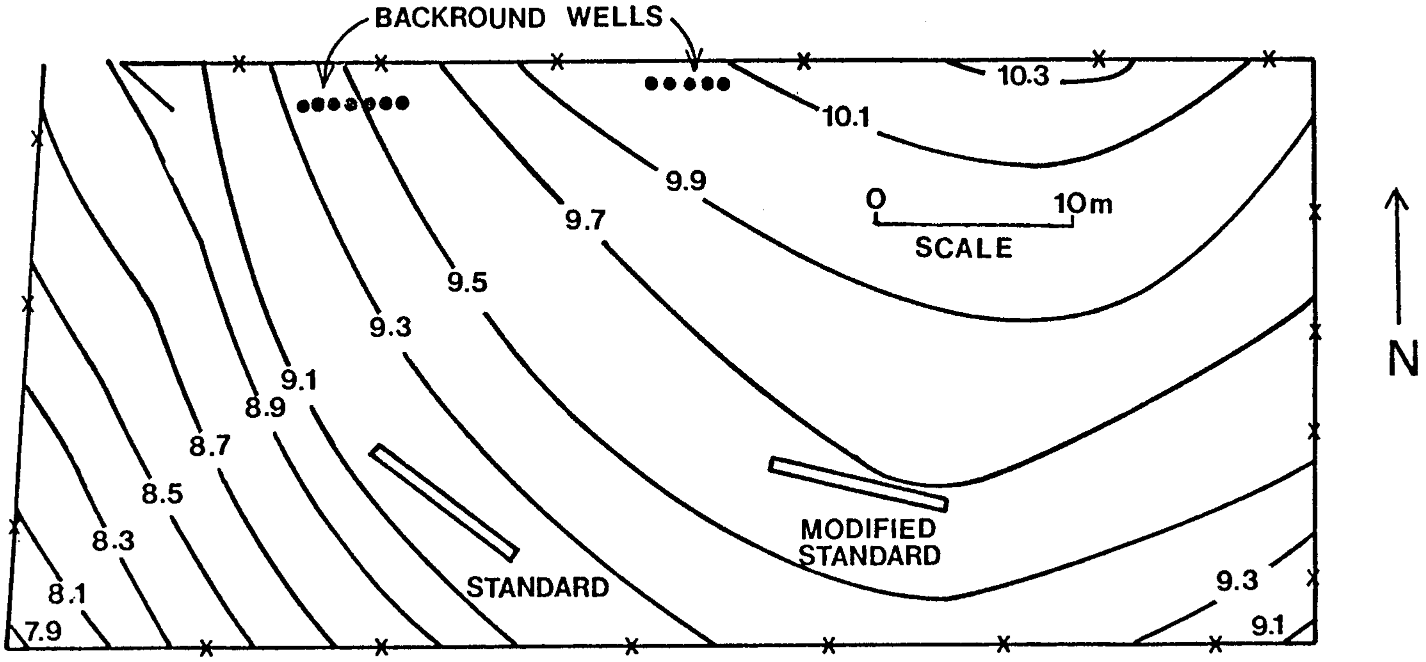


Figure 2. Topographic map of the experimental site with location of two experimental filter fields and background wells.

Table 3. Official series description of the Nixa soils (National Cooperative Soil Survey, 1977).

The Nixa series consists of moderately well drained, very slowly permeable soils on upland ridgetops and sideslopes of the Ozark Highlands. They formed in loamy residuum weathered from cherty limestone. Slopes range from 1 to 20 percent.

Taxonomic Class: Loamy-skeletal, siliceous, mesic Glossic Fragiudults.

Typical Pedon: Nixa very cherty silt loam on a 4 percent slope in forest.
(Colors are for moist soil unless otherwise stated.)

A1--0 to 5 cm; very dark grayish brown (10YR 4/2) very cherty silt loam; weak fine granular structure; friable; common fine roots; few fine pores; 40 percent by volume chert fragments 1 to 10 cm in diameter; strongly acid; clear smooth boundary. (0 to 8 cm thick)

A2--5 to 28 cm; brown (10YR 5/3) very cherty silt loam; weak fine subangular blocky structure; friable; common fine and medium roots; common fine pores; 40 percent by volume chert fragments 1 to 10 cm in diameter; strongly acid; gradual smooth boundary. (13 to 25 cm thick)

B1--28 to 56; light yellowish brown (10YR 6/4) very cherty silt loam; weak and moderate medium subangular blocky structure; friable; common fine and medium roots; few fine pores; 60 percent chert fragments 2 to 10 cm diameter; very strongly acid; gradual wavy boundary. (13 to 36 cm thick)

Bx--56 to 112 cm; yellowish brown (10YR 5/4) very cherty silt loam; common medium distinct strong brown (7.5YR 5/6), light brownish gray (10YR 6/2), and few fine yellowish red (5YR 5/6) mottles; weak fine subangular structure; firm and brittle; 70 percent by volume chert fragments 2 to 15 cm in diameter; common fine pores; thin patchy clay films on faces of peds and on chert fragments; few fine roots in gray streaks; few dark concretions; black stains on chert faces; very strongly acid; gradual wavy boundary. (25 to 76 cm thick)

B2t--112 to 183 cm; mottled 50 percent yellowish red (5YR 4/6), 30 percent strong brown (7.5YR 5/6), and 20 percent light brownish gray (10YR 6/2) very cherty silty clay loam; weak medium angular blocky structure to massive; firm; slightly brittle; 80

Table 3. Official series description of the Nixa soils (National Cooperative Soil Survey, 1977). (continued)

percent by volume weathered chert fragments up to 15 cm in diameter; few fine pores; thin continuous clay films on faces of peds and chert fragments; very strongly acid.

Type Location: Marion County, Arkansas; 6.6 kms north on Arkansas-14 from junction of U.S. 62 on right side of highway, NW1/4SE1/4SW1/4 sec. 21, T. 19 N., R. 16 W.

Range in Characteristics: Depth to the fragipan is 36 to 61 cm. Depth to unconsolidated chert beds is 61 to 122 cm and depth to consolidated bedrock is over 152 cm. The soil is strongly acid or very strongly acid throughout except where surface layers are limed.

The A1 horizon has hue of 10YR, value of 3 or 4, and chroma of 2. The A2 horizon has hue of 10YR, value of 5 or 6, and chroma of 3 or 4; value of 5, and chroma of 2. The Ap horizon of cultivated areas has hue of 10YR, value of 4 or 5, and chroma of 3; value of 5, and chroma of 4. Texture of the A horizon is very cherty silt loam, cherty silt loam, or cherty loam.

The B1 horizon has hue of 10YR, value of 5 or 6, and chroma of 4 or 6; value of 5, and chroma of 3. The fine-earth fraction is silt loam, silty clay loam, clay loam, or loam with a very cherty modifier. Chert content ranges from 35 to 75 percent.

An A'2 horizon, if present, has hue of 10YR, value of 5 and 6, and chroma of 2 or 3, and in some pedons, has mottles of lower chroma. Texture is very cherty silt loam or very cherty loam. Clay content is less than that of the B1 horizon.

The Bx horizon has hue of 10YR, value of 5, and chroma of 4 or 6; value of 6, and chroma of 6; hue of 7.5YR, value of 5, and chroma of 4 or 6, and mottled in shades of brown, gray, or red. The fine-earth fraction is silt loam, silty clay loam, loam, or clay loam with a very cherty textural modifier. The Bx horizon has 40 to 75 percent chert.

The B2t horizon has hue 2.5YR or 5YR, value of 3, 4, or 5, and chroma of 4, 6, or 8, or mottled in shades of red, brown, or gray. The fine-earth fraction is clay, silty clay, or silty clay loam with very cherty textural modifier. This horizon contains 50 to 85 weathered chert fragments or is discontinuous bedded chert with closely spaced vertical fractures and cracks and horizontal seams 1 to 10 cm in thickness.

Table 3. Official series description of the Nixa soils (National Cooperative Soil Survey, 1977). (continued)

Drainage and Permeability: Moderately well drained. Runoff is medium to rapid. Permeability is very slow.

Use and Vegetation: Used mainly for forest and pasture but a small amount is used for cropland. Native forests were mainly of post oak, blackjack oak, and hickory.

Distribution and Extent: Arkansas, Kentucky, Missouri, Oklahoma, and possibly Tennessee. The series is of large extent, probably of 150,000 acres.

National Cooperative Soil Survey
U.S.A.

FILTER FIELD DESIGN

EFFLUENT DELIVERY

Figure 3 shows the location of the experimental filter fields and the experimental effluent collection and distribution system with respect to the existing septic system. The system used to deliver septic tank effluent to the experimental filter fields is illustrated in Figure 4. A 1900-liter concrete tank which served as a septic tank effluent reservoir (sump) was installed in the line between the existing septic tank and the gravity filter field serving a single family residence. A standard, shallow-well, centrifugal domestic-water-supply pump and pressure tank was used to pump the effluent from the sump, through the control valves and meters, and to the experimental filter fields. A pressure tank maintained the pressure on the delivery system between 103.4 and 206.9 kPa. A strainer with a 50-mesh screen served to remove particles from the effluent before it reached the flow meter. PVC-body needle valves (1.3 cm) were used to throttle the flow rate through the line to each experimental filter field. Kent Polymer PSM water meters, rated for flow rates of 0.95 to 76 liters per minute, were used to measure the flow of effluent.

The application of the effluent to the experimental filter fields was controlled by a time switch which caused a solenoid valve in each pressure line to open for approximately 30 seconds per hour. The rate of flow during the time the solenoid valve was open was regulated by manual adjustment of the PVC-body needle valves.

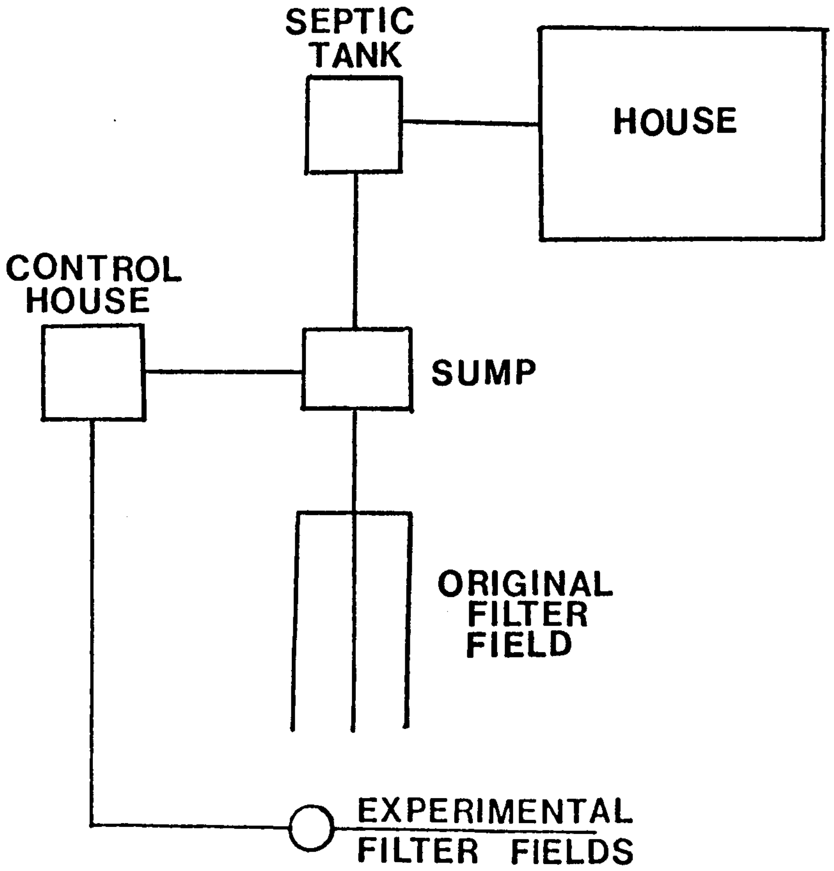


Figure 3. Location of experimental filter fields and equipment with respect to the existing septic system.

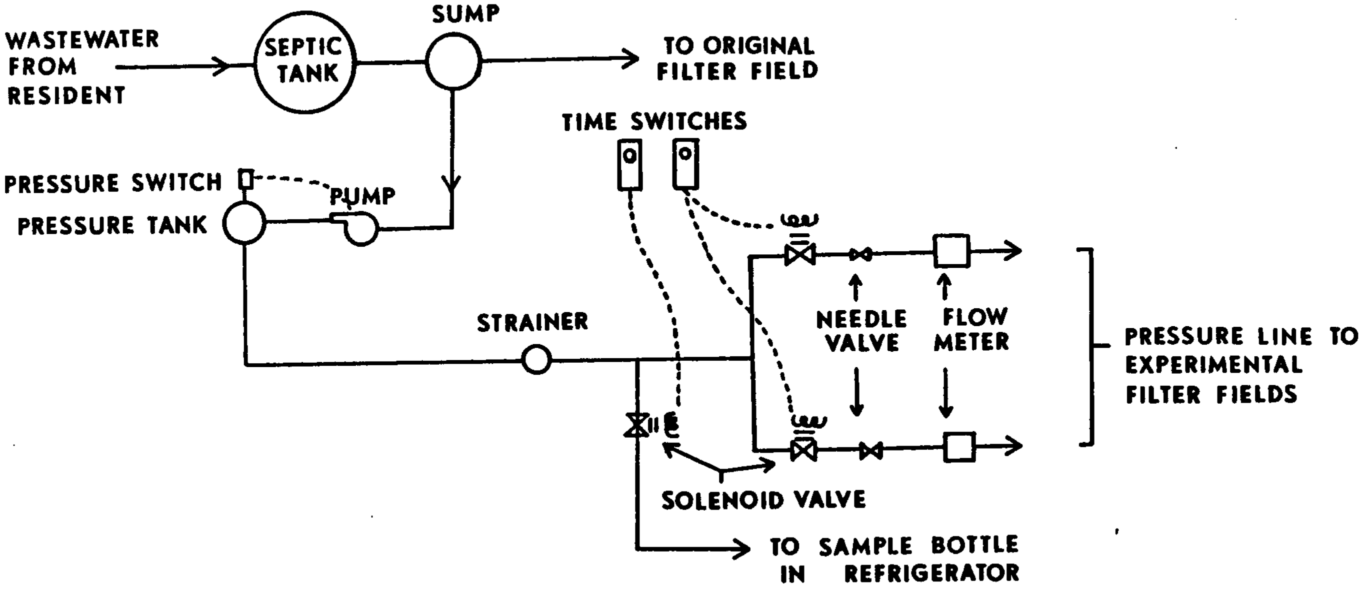


Figure 4. Effluent delivery system.

SEEPAGE BEDS

Seepage beds for the two experimental filter fields were constructed in 60-cm wide trenches positioned in the soil profile as shown in Figure 5. Each of the seepage beds consisted of a perforated, 10-cm diameter, plastic sewer and drain distribution pipe (with holes at 4 and 8 o'clock) surrounded by crushed limestone aggregate. The thickness of the aggregate was 30 cm in the standard seepage bed and 25 cm in the modified standard. Each seepage bed was 9 m long.

A pressure dissipation chamber, as shown in Figure 6, was installed on the inlet end of each of the seepage-bed-effluent-distribution lines. This chamber insured gravity distribution of the effluent in the seepage bed. The 10-cm, perforated plastic distribution pipe in each seepage bed had a fall of approximately 1.5 cm per 9 m. The downstream end of the distribution line was not capped.

ENVIRONMENTAL MONITORING

Precipitation and temperature were recorded weekly using a simple rain gauge and mercury thermometer, respectively. A small amount of lubricant was left in the rain gauge to insure minimal evaporation losses. The thermometer was placed in a ventilated shelter to protect it from direct sunlight.

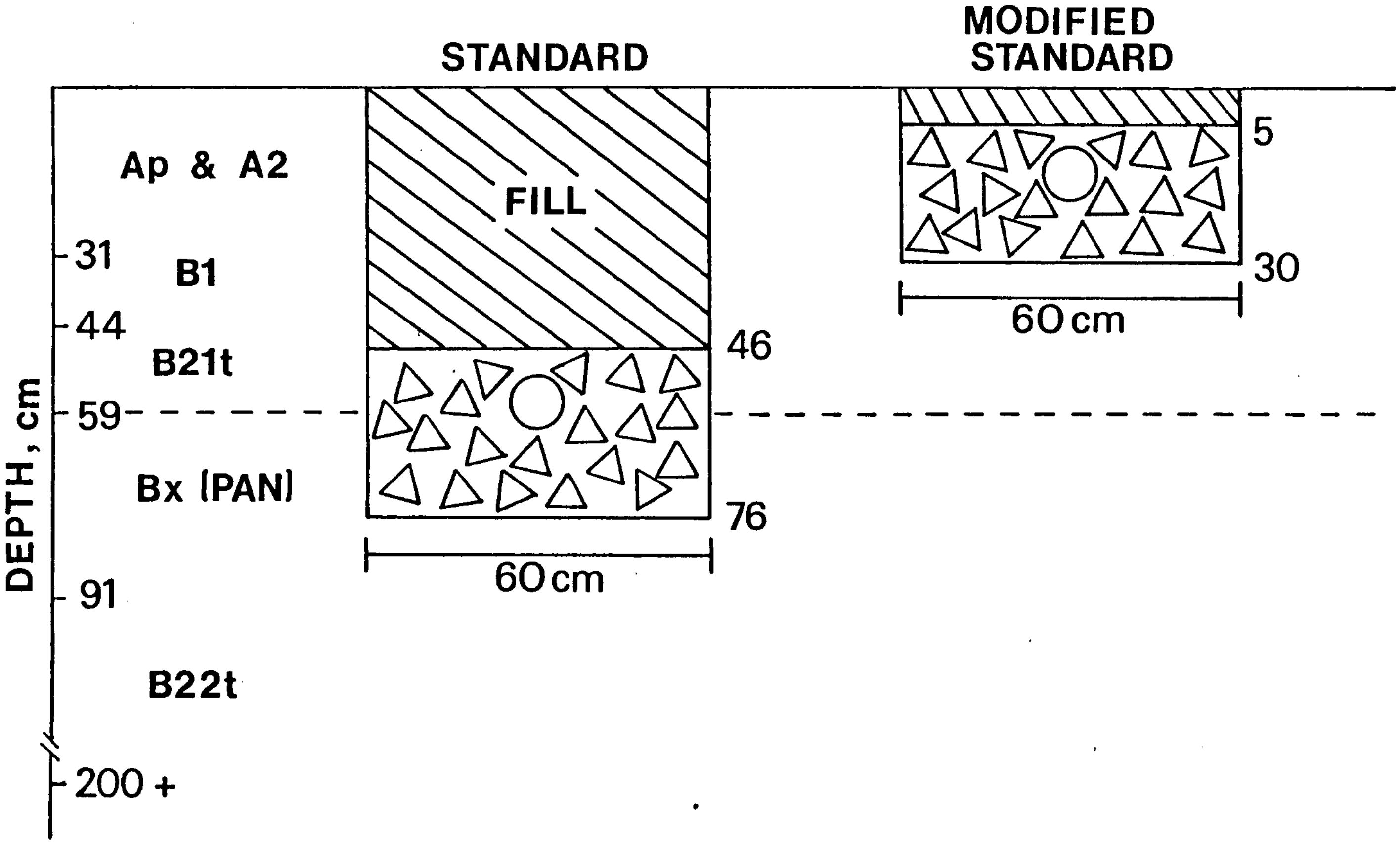


Figure 5. Position of seepage beds in the soil.

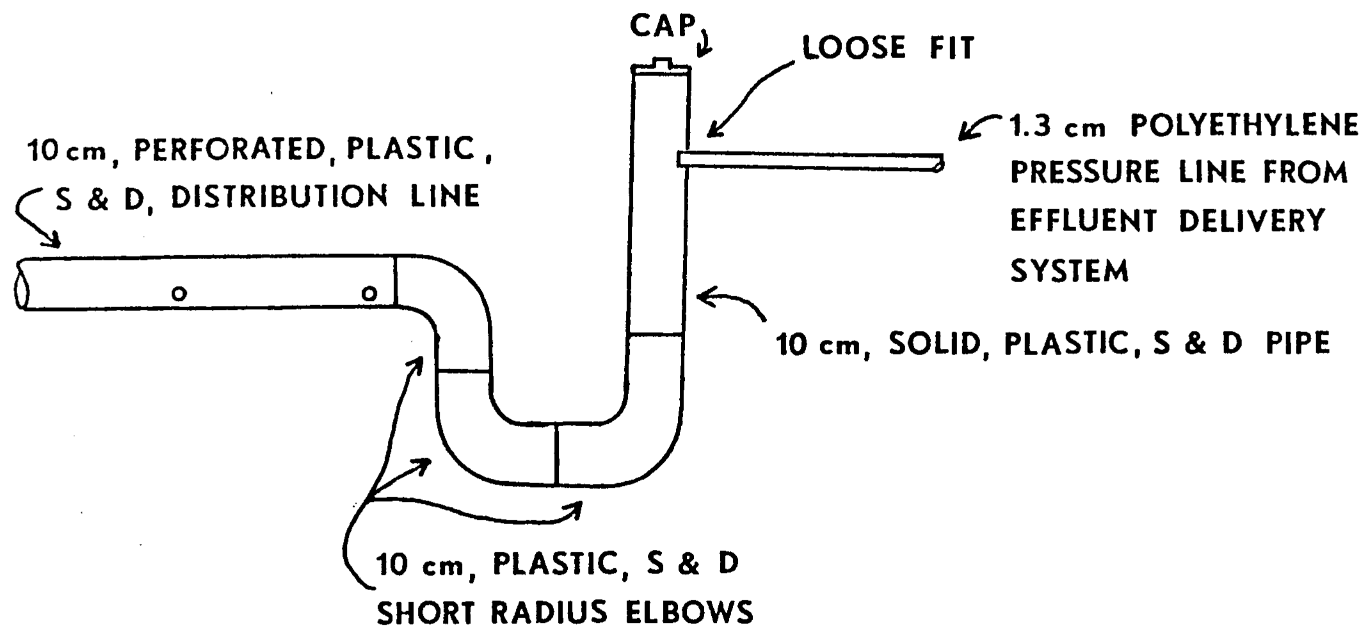


Figure 6. Effluent pressure dissipation chamber.

LABORATORY TECHNIQUES

SOIL PROPERTIES

A Nixa soil, located about midway between the standard and the modified standard filter field (Figure 7), was described (Appendix Table A-1) and sampled by horizons or subhorizons. The bulk samples of soil were allowed to air dry and then were ground to pass a 2-mm sieve. Material greater than 2 mm was discarded. The ground sample was retained for analysis.

Particle Size: The ground soil material was dispersed with a malt mixer using reagent grade sodium hexametaphosphate buffered to a pH 8.2 as the dispersing agent. No pretreatment was used on any of the samples. The hydrometer method described by Day (1956) was used to determine the amount of clay, fine silt, and medium silt. The sand was dry sieved, fractionated, and weighed. The coarse silt was determined by difference.

pH: The pH of the soil samples was determined from a 1:1 soil-water suspension (method 8Cla; Soil Survey Staff, 1972).

Organic Carbon: Organic carbon was determined by dry combustion according to method 6A2b in Soil Survey Investigations Report No. 1 (Soil Survey Staff, 1972).

Extractable Bases: The extractable bases were determined by leaching a 10-g soil sample with 100 ml N pH 7.0 ammonium acetate (method 5A6; Soil Survey Staff, 1972) and determining the concentration of K, Ca, Mg, and Na in the leachate by atomic absorption (methods 6Q2b, 6N2e, 6O2d, and 6P2b; Soil Survey Staff, 1972).

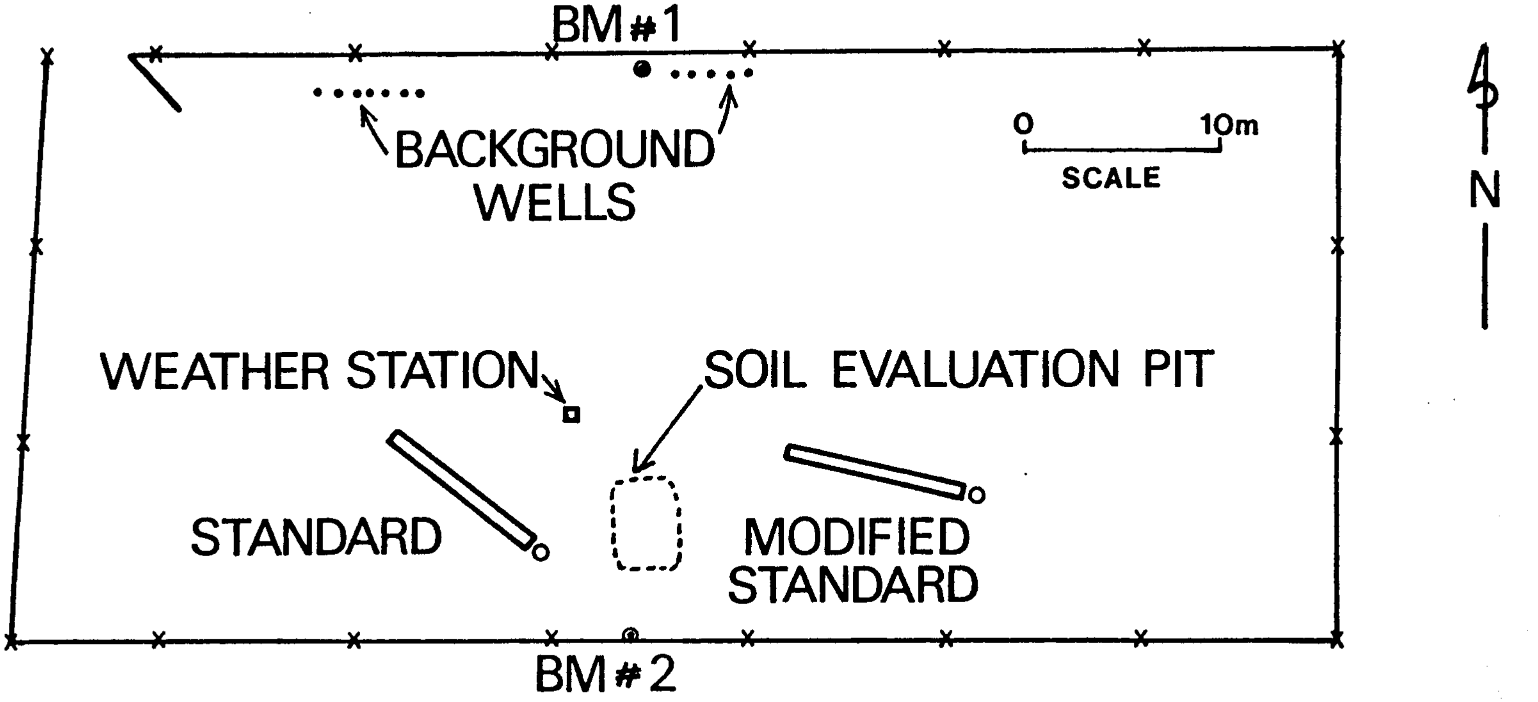


Figure 7. Plane view of experimental filter fields and related installations.

Extractable Acidity: The extractable acidity was determined by a triethanolamine-barium chloride method (method 6Hla; Soil Survey Staff, 1972).

Note: All laboratory analyses performed on the soil samples were run in duplicate or until duplication tolerances were met. All data are reported on an oven dry basis.

WATER MEASUREMENTS

WELLS

Observation wells were used to monitor ground water levels. Wells were installed at two background locations (Figure 7 & Table 4) and in and around the modified and standard seepage beds (Figure 8 & Table 4).

Water depths in the wells were measured with an ohmmeter attached to the top of a scaled 2.5-cm PVC tube (Figure 9). Electrical leads that extended from the ohmmeter to the end of the tube had a low resistance between them, thus causing a deflection of the ohmmeter upon contact with water. The wells which were backfilled in a manner that essentially eliminated flow between the well and the undisturbed soil acted as piezometers (indicators of water pressure at the intake). We have interpreted the depth to water in the wells as depth to free-water in the soil. Such interpretation for piezometers can include error, the magnitude of which increases as the downward rate of water movement increases in a given soil. Since water moves slowly downward in Nixa soils, we assume the error in depth to free-water interpretations is minimal.

Table 4. Specifications and location of wells of the standard and modified standard filter fields and background wells.

Well I.D.	Distance from Inlet End (cm)	Distance from Soil Surface (cm)(intake)	Distance from Edge of bed (cm)	Height of Well above Soil Surface (cm)	Type of Well Construction[1]
			STANDARD		
1A1	396	76.0	61N	13.3	1
1A2	457	91.0	46N	15.2	1
1A3	1067	106.0	76N	14.0	1
1B1	305	76.0	61S	18.4	1
1B2	350	91.0	61S	17.8	1
1B3	396	106.0	46S	14.0	1
1C1	670	76.0	-15N	3.8	2
1C2	594	91.0	76N	25.4	1
1C3	625	106.0	107N	5.1	1
1D1	670	76.0	-61S	3.2	2
1D2	533	91.0	91S	24.8	1
1D3	579	106.0	122S	16.5	1
1E1	670	60.0	53S	16.5	3
1E2	579	75.0	25S	18.0	3
1E3	428	90.0	36S	17.1	3
1G1	670	60.0	231S	30.0	3
1G2	670	60.0	426S	30.0	3
1G3	670	60.0	731S	30.0	3
			MODIFIED STANDARD		
2A1	396	30.0	-15N	11.4	2
2A2	410	45.0	30N	10.0	1
2A3	442	60.0	137N	12.1	1
2B1	396	30.0	-15S	12.0	2
2B2	381	45.0	46S	10.2	1
2B3	366	60.0	91S	12.7	1

Table 4. Specifications and location of wells of the standard and modified standard filter fields and background wells.(continued)

Well I.D.	Distance from Inlet End (cm)	Distance from Soil Surface (cm)(intake)	Distance from Edge of bed (cm)	Height of Well above Soil Surface (cm)	Type of Well Construction[1/]
		MODIFIED STANDARD			
2C1	686	30.0	61N	10.0	1
2C2	716	45.0	61N	10.0	1
2C3	702	60.0	61N	10.0	1
2D1	690	30.0	61S	10.1	1
2D2	701	45.0	46S	16.5	1
2D3	731	60.0	61S	8.2	1
2E1	807	76.0	5S	17.1	3
2E2	852	91.0	14S	14.6	3
2E3	897	106.0	15S	18.3	3
2E4	552	76.0	30S	13.3	3
2E5	507	91.0	30S	13.5	3
2E6	446	106.0	38S	14.1	3
2E7	291	52.0	18S	10.0	3
		BACKGROUND			
F1		15.0		11.1	4
F2		15.0		13.4	4
F3		30.0		13.8	4
F4		30.0		15.1	4
F5		46.0		10.7	4
F6		46.0		15.8	4
F7		61.0		16.0	4
F8		61.0		15.4	4
F9		76.0		12.1	4
F10		76.0		15.2	4
F12		91.0		11.2	4
F14		120.0		16.6	5

Table 4. Specifications and location of wells of the standard and modified standard filter fields and background wells.(continued)

Well I.D.	Distance from Inlet End (cm)	Distance from Soil Surface (cm)(intake)	Distance from Edge of bed (cm)	Height of Well above Soil Surface (cm)	Type of Well Construction[1/]
		BACKGROUND			
F16		200.0		15.1	5

[1/] Types of well construction

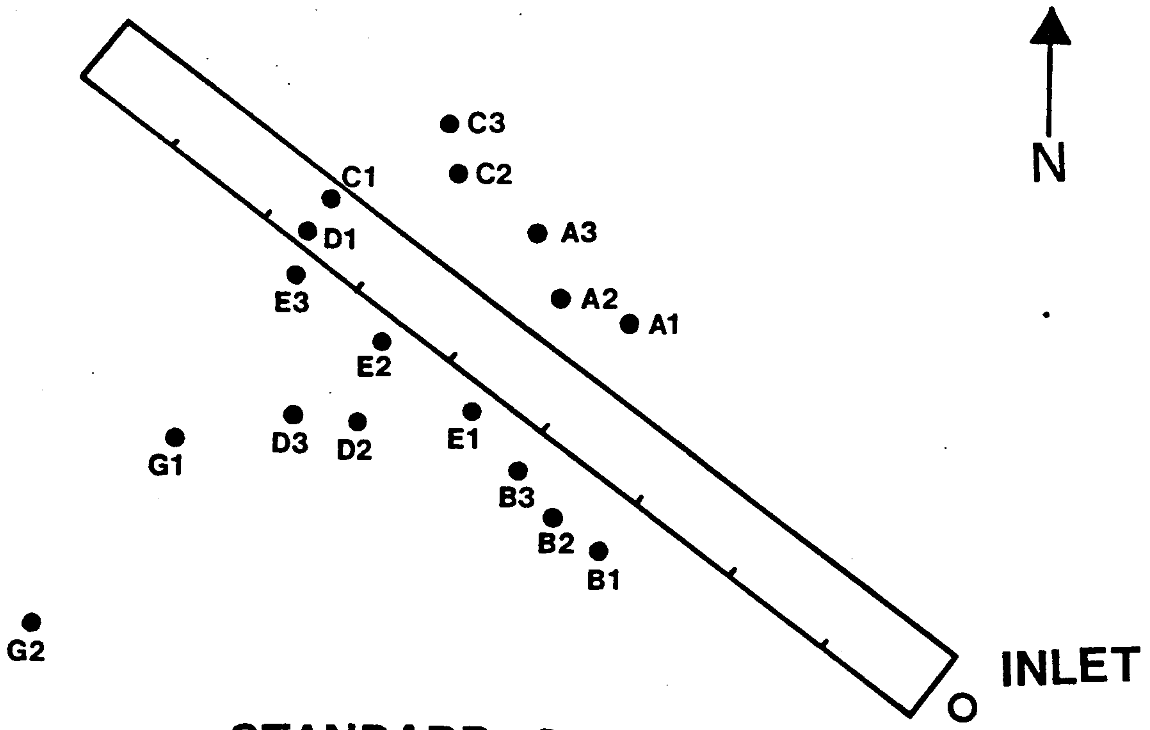
1. Electrical conduit (2.5 cm) pipe with three 0.6-cm intake holes 30 cm above the bottom of the pipe which was improperly sealed. Holes backfilled with tamped Nixa soil.

2. Electrical conduit (2.5 cm) pipe with three 0.6-cm intake holes 30 cm above the bottom of the pipe which was properly sealed. Holes backfilled with tamped Nixa soil.

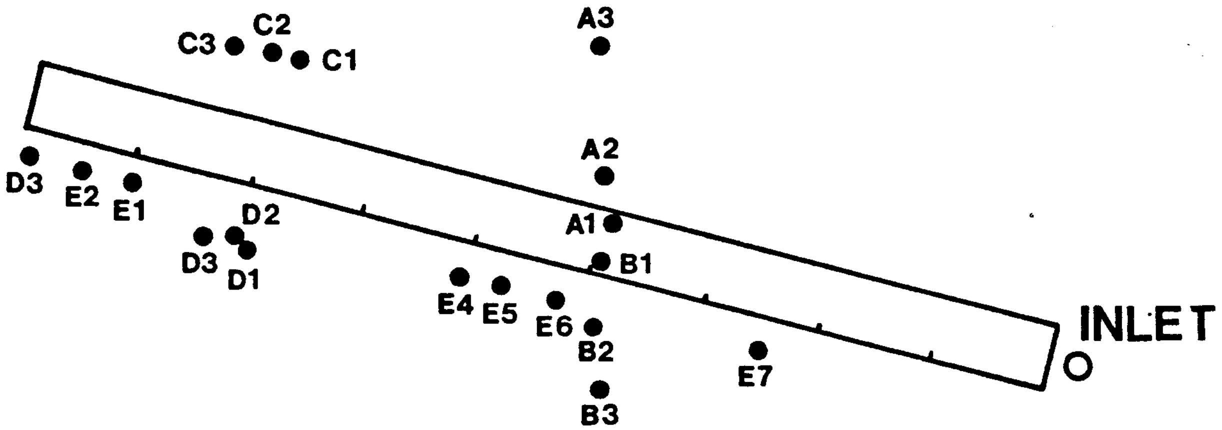
3. Electrical conduit (2.5 cm) pipe with open ends. Holes backfilled with tamped Nixa soil.

4. Electrical conduit (2.5 cm) pipe with open ends and three 0.6-cm holes 2, 4, and 6 cm from the bottom. Holes backfilled (bottom to top) with 10 cm of sand, 5 cm of bentonite clay and then to the surface with "off-the-shelf" redi mix concrete.

5. PVC (3.2 cm) pipe with open ends. Holes backfilled as in No. 4 above.



STANDARD SYSTEM



MODIFIED STANDARD

Figure 8. Location of wells with respect to the standard and modified standard filter fields.

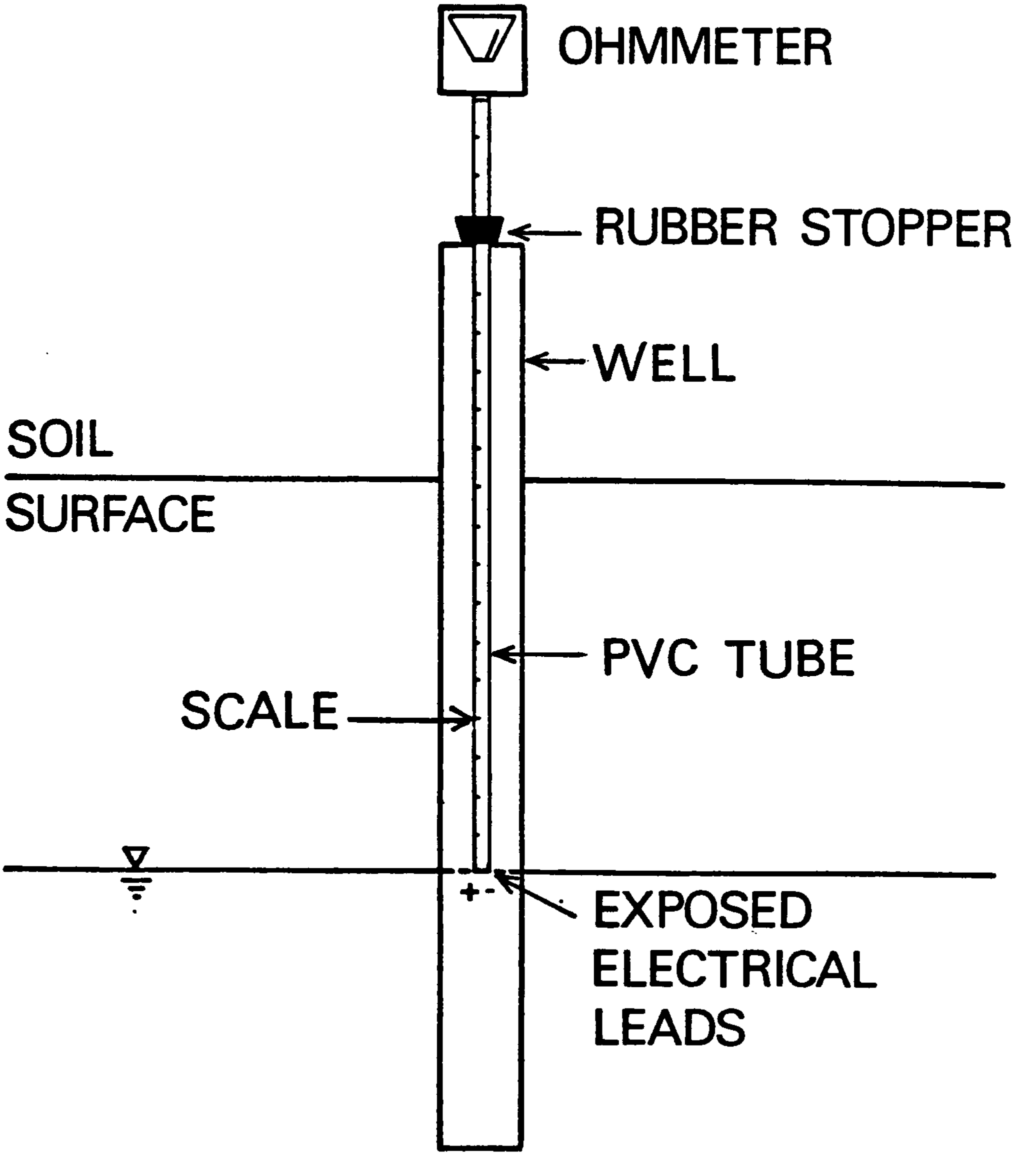


Figure 9. Water depth reading device.

TENSIOMETERS

Tensiometers were installed at the time the seepage beds were constructed. They were placed about 2 cm into the natural soil (Figures 10 and 11). The greatest number of tensiometers was placed into the bottom of the seepage bed at the gravel-soil interface.

A three-way tensiometer as described by Richards (1965), was used. It was made of 0.3-cm plastic tubing and brass fittings. Within the 0.3-cm tubing was a 0.16-cm surgical tubing that extended from the open end of the larger tube to the ceramic cup (Figure 12). Tensiometers were purged by using a syringe to force water into the small surgical tubing until all air had escaped. Then, the other free end of the larger tubing was placed into a mercury manometer (see Figure 13). All tensiometers were disconnected and drained of water when temperatures were low enough that freezing of the water might occur.

DATA ACQUISITION, STORAGE, AND PROCESSING

Data, including quantities of effluent pumped to each filter field, precipitation, temperature, barometric pressure, and depth to water in the various wells (Figure 9) were normally recorded at least weekly. Oil was placed in the rain gauge to reduce evaporation. Data were stored and processed in a computer using the Statistical Analysis System (SAS).

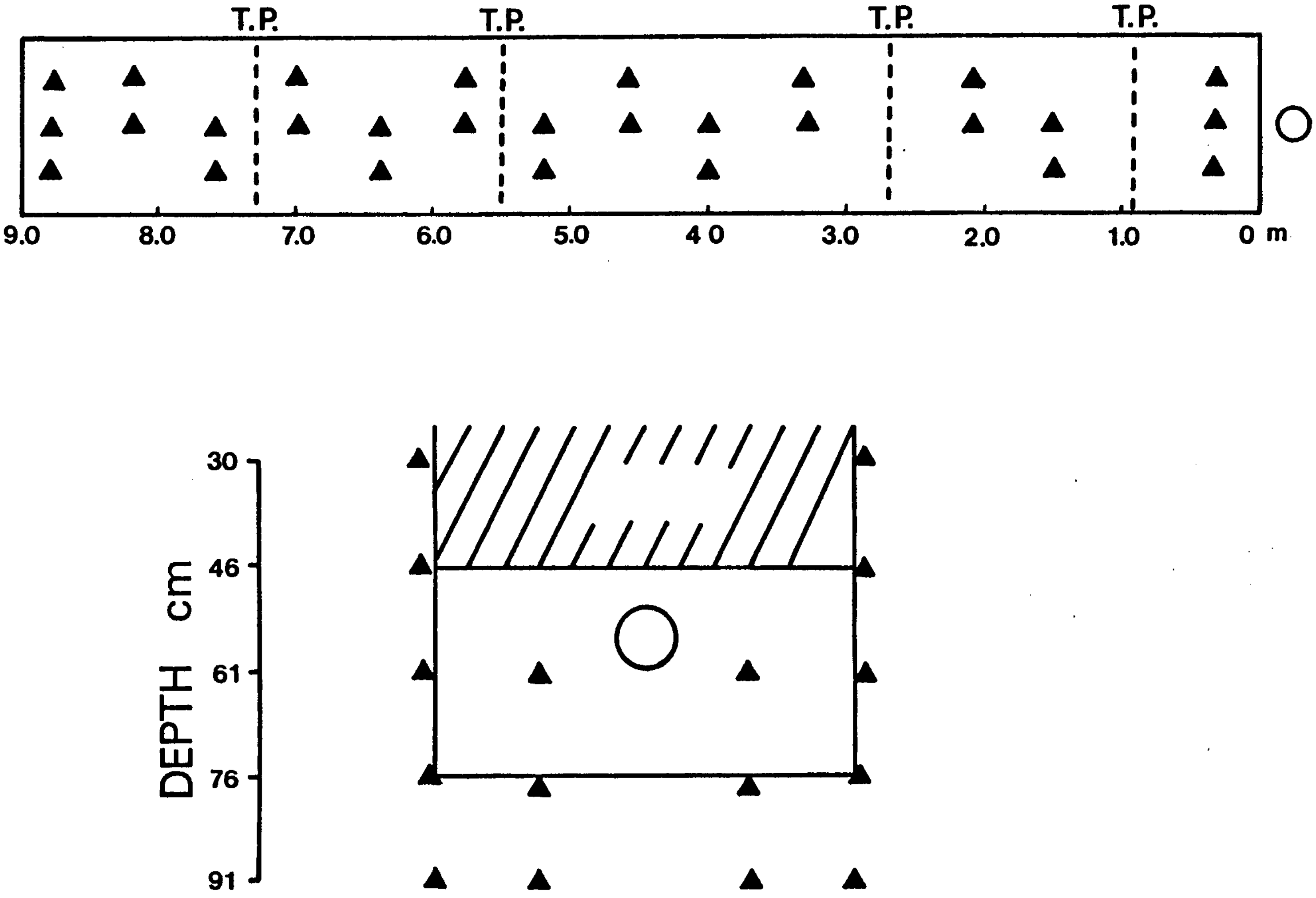


Figure 10. Tensiometer placement within the standard filter field.

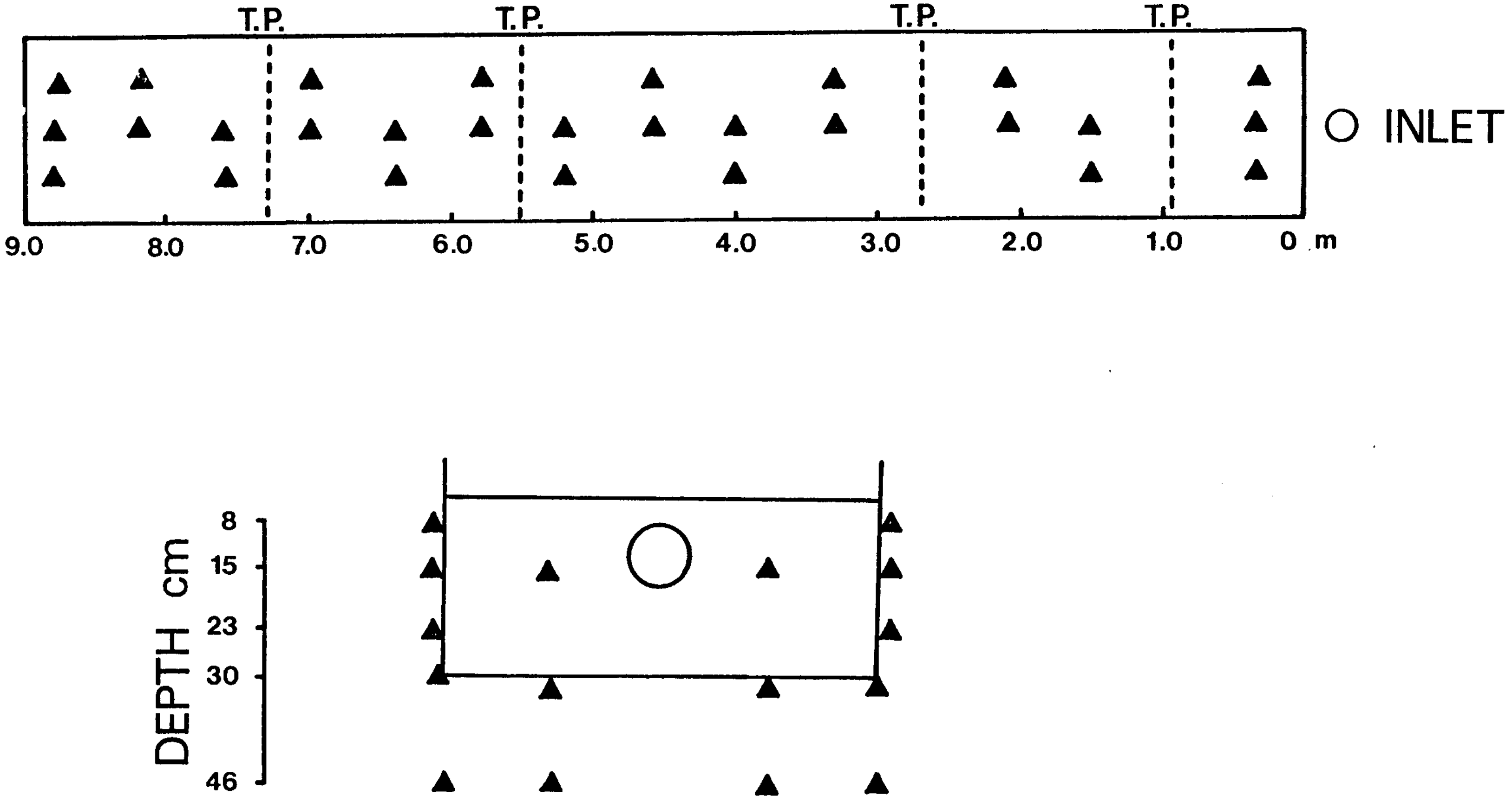


Figure 11. Tensiometer placement within the modified standard filter field.

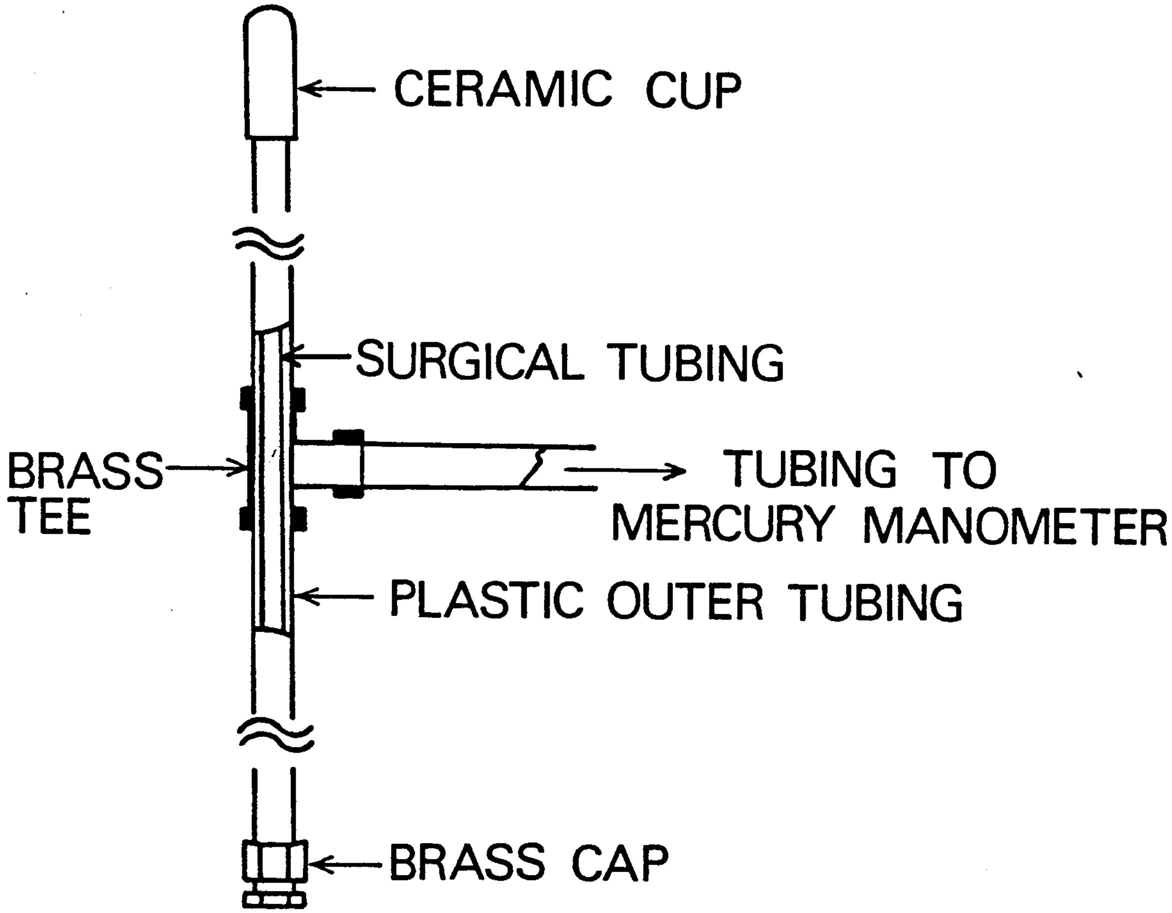
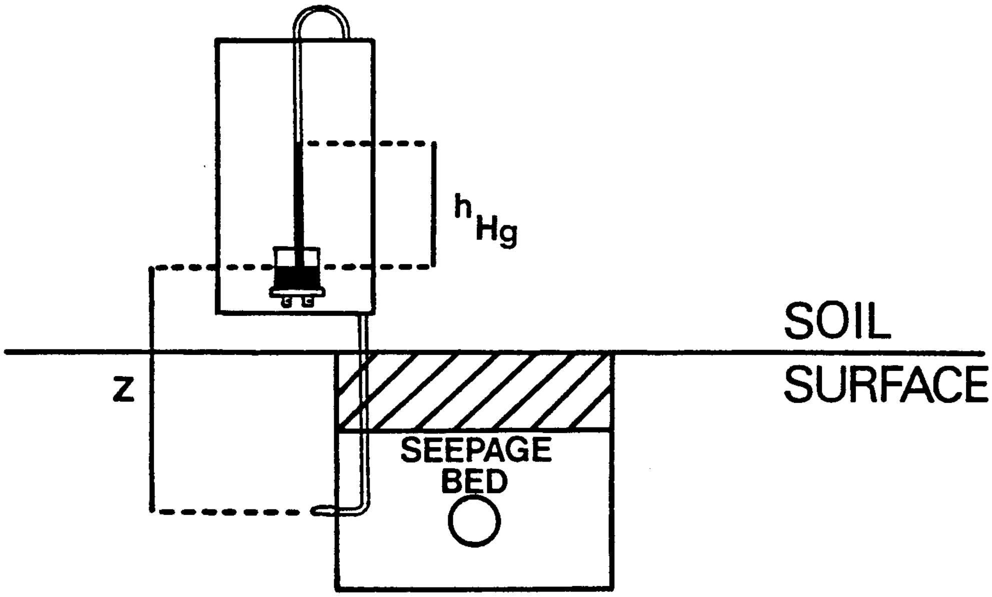


Figure 12. Schematic diagram of tensiometer.



$$\Psi_{Hg} = -12.54\ Hg + Z$$

$$\Psi_{M} = -(h_{Hg} \times 12.54) + Z$$

Figure 13. Diagram of typical tensiometer positioning with potentials shown.

RESULTS AND DISCUSSION

SOIL EVALUATION

The representative pedon of Nixa soils within the experimental area (Figure 7), which was excavated to 2 m, was described (Appendix Table A-1) and analyzed (Appendix Table A-2). The pedon had a chert content ranging between 30 and 50% by volume (Table 5). The fragipan was well developed and occurred between 59 and 91 cm below the surface. Morphological features indicated the presence of a perched seasonal water table in the B21t horizon (44-59 cm) and below. The pedon differed from pedons of the Nixa series as noted in Appendix Table A-1; mainly in having clay films above the fragipan. These differences are not expected to significantly influence performance of septic tank filter fields and are minor enough that the pedon is a similar soil to Nixa soils and thus is considered a Nixa soil.

Stafford (1979) measured rates of water movement in the Nixa soils within the experimental area. He used these measurements to evaluate Nixa soils for various filter field designs. Percolation rates (Table 6) were variable in four test holes. These data indicate that two of the test holes passed the Arkansas Department of Health (1977) criterion, which is a rate equal to or greater than 18 min/cm or less after 4 hours of presoaking, and two holes failed this requirement. The rate of fall decreased after 24 hours of presoaking in two of the test holes and remained the same in two others. Ransom (1976) showed that percolation rates in Nixa soils

Table 5. Abbreviated pedon description for the Nixa soil in the experimental site.[1]

Ap	0 - 13 cm	Yellowish brown (10YR 5/4) cherty silt loam; common coarse and medium dark brown (10YR 4/3) mottles; weak medium and fine subangular blocky structure; 30 to 40% by Vol. chert fragments.
A2	13 - 31 cm	Yellowish brown (10YR 5/4) cherty silt loam; weak medium subangular blocky structure; 30 to 40% by Vol. chert fragments.
B1t	31 - 44 cm	Strong brown (7.5YR 5/6) cherty silt loam; common medium brownish yellow (10YR 6/6) mottles; weak to moderate medium subangular blocky structure; 35 to 40% by Vol. chert fragments.
B21t	44 - 59 cm	Strong brown (7.5YR 5/6) cherty silty clay loam; common medium yellowish red (5YR 4/6) few medium brownish yellow (10YR 6/6) few fine light gray (10YR 7/2) mottles; moderate medium and fine angular blocky structure; 30 to 35% by Vol. chert fragments.
Bx1	59 - 76 cm	Yellowish red (5YR 4/6) cherty silty clay loam; common medium yellowish brown (10YR 5/4) mottles; moderate fine angular blocky structure; 40 to 50% by Vol. chert fragments.
Bx2	76 - 91 cm	Red (2.5YR 4/6) cherty silty clay loam; few fine light brownish gray (10YR 6/2) mottles; moderate fine angular blocky structure; 40 to 50% by Vol. chert fragments.
B22t	91 - 218 cm	Dark red (2.5YR 3/6) clay; common coarse red (2.5YR 4/6) and a few medium strong brown (7.5YR 5/8) mottles; moderate fine and medium angular blocky structure; 30 to 40% by Vol. chert fragments.

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[1] A detailed description presented in Appendix Table A-1.

were dependent upon the presence or absence of the seasonal water table and that when the water table was present, water did not drain from percolation test holes. Stafford's measurements were made in the absence of a seasonal water table.

Table 6. Percolation rates of the Nixa soils in the experimental area.[1/]

Location	Percolation rate min/cm	
	4 hr presoak	24 hr presoak
1	16	32
2	NM[2/]	NM
3	24	24
4	9	24

[1/] Data from Stafford (1979)

[2/] NM - Water movement not measureable

Quantitative evaluation of the soil's saturated and unsaturated vertical hydraulic conductivities were determined _in situ_ by Stafford (1979). The saturated hydraulic conductivities (Table 7) were so variable between the first two replications that a third determination was made. Dye was used in the water of the third determination in order to qualitatively evaluate the major pathways of water movement. These dye studies indicated that boundary flow sometimes occurred between the infiltrometer and the soil. This may account for some of the higher measured rates of water movement. The dye studies also indicated that water moved mainly through the gray seams along prism faces within the fragipan (Appendix Table A-1). Since the range in spacing of gray seams within the fragipan exceeded the diameter (25 cm) of the infiltrometer, the instrument was not large enough to obtain a representative measurement of saturated hydraulic conductivity in the fragipan.

Table 7. Saturated hydraulic conductivities for selected horizons of the Nixa soil in the experimental area.[1]

	Ksat (cm/day)			
Horizon	Rep 1	Rep 2	Rep 3	Mean
Ap	349	117		233
A2	242	11	196[2]	150
B21t	130	2	163[2]	98
Bx1	56	0.5	24[2]	27
Bx2	32	3		18
B22t	19	0.5		10

[1] Data from Stafford (1979)

[2] Dyed for identification of flow pathways

Stafford (1979) evaluated the Nixa soils for various filter field designs using the most limiting saturated hydraulic conductivity values. He utilized the approximation method of Bybordi (1968) to calculate moisture profiles during steady state infiltration. This approach is limited because infiltrated rainfall is not mathematically evaluated. However, Stafford qualitatively considered rainfall in the various designs and loading rates. His approach showed that a standard filter field, with the seepage bed 60 to 90 cm below the soil surface, would not be appropriate for the Nixa soils. Comparable analysis indicated that raising the seepage bed into the upper soil horizons which have higher saturated hydraulic conductivities would enhance the performance of the filter field. Stafford's analysis showed that a seepage bed placed 30 cm into the soil (referred to as a modified standard filter field) and loaded at 1.5 cm per day could be expected to function properly. Therefore, the standard filter field was constructed with its seepage bed interface 76 cm deep and the modified standard filter field seepage bed interface was located 30 cm below the soil surface. For comparative purposes, both filter fields were loaded at the same rate, 1.5 cm per day.

CLIMATIC CONDITIONS

The weather during the study period was quite variable and can be characterized as drier with slightly lower temperatures than normal. Thirty-year monthly mean rainfalls for 1978 through 1980 are tabulated in Table 8. These rainfall data were obtained from the Arkansas Agricultural Experiment Station at Fayetteville which is located approximately 14.5 km from the study site and on the experimental site at Savoy. More detailed rainfall data for Fayetteville and the experimental site are presented in Appendix Table A-4. Rainfall from the beginning of the study until December 1978 was near normal. After December 1978 the cumulative rainfall was lower than normal and the deficit became larger as time passed. By the end of the study on September 30, 1980, the rainfall deficit

Table 8. Monthly rainfall at Fayetteville and at the experimental site (Harper et al., 1969, and NOAA, 1978-1980).

Month	30-Year Mean (Fayetteville) Ave. Total	One year in 10 will have Less than	More than	Fayetteville 1978	1979	1980	Experimental site Savoy, AR 1978	1979	1980
January	6.5	1.7	13.9	4.1	7.6	2.3		6.6	2.9
February	7.7	2.2	12.1	6.6	4.7	1.3		4.7	3.4
March	8.5	3.9	15.1	14.1	5.1	10.0		5.2	13.0
April	12.1	5.8	18.1	6.7	11.4	3.5		11.1	2.8
May	15.2	5.9	26.0	16.5	14.6	8.7		11.9	8.1
June	12.9	1.9	21.0	17.7	7.2	14.4		7.8	13.0
July	9.2	2.1	16.8	6.1	16.2	3.2		18.3	0.7
August	8.6	2.3	16.2	4.9	5.4	1.3	8.1	4.9	1.8
September	10.4	2.2	23.3	12.0	1.3	10.0	11.9	1.5	6.5
October	9.0	2.6	16.1	2.4	7.4		2.9	2.9	
November	8.2	1.7	14.1	14.0	7.0		13.1	13.3	
December	6.5	1.5	12.3	2.8	2.8		4.0	0.3	
Year	114.8			107.9	90.7				

was approximately 50 cm. Therefore, it can be concluded that rainfall was less than normal during most of the study period.

A summary of the mean monthly temperatures at Fayetteville is presented in Table 9. These data show the expected annual temperature variations. Mean monthly temperatures during the study period ranged from a low of -5°C during January 1979 to a high of 29°C during July 1980. Comparison of the actual monthly temperatures with the long term mean temperature at this location shows that most actual temperatures were lower than the mean. The exceptions occurred during the summer of 1980 when the monthly mean temperatures were above normal at approximately 30°C.

THE STANDARD FILTER FIELD

INBED AND EXBED WATER DEPTHS

The standard filter field was responsive to soil conditions, mainly permeability to water, and to climatic conditions, rainfall and evapotranspiration (Tables 8, 9, and Appendix Table A-4). Figure 14 provides an approach to obtaining an overall view of the performance of the standard filter field during the study period. In Figure 14, the inbed effluent depths (measured from the soil surface) are an average of determinations from the two inbed wells (Appendix Table A-6), except during the earlier part of the experiment (April 28 to September 20, 1978) when tensiometer values were averaged to obtain inbed effluent levels (Appendix Table A-5). The exbed (perched) ground water depths are an average of depths of

Table 9. Monthly temperatures at Fayetteville. (Harper et al., 1969 and NOAA, 1978-1980).

Month	Temperature (°C)							
	30-Year mean		Daily averages					
	Daily Max.	Daily Min.	1978 Max.	1978 Min.	1979 Max.	1979 Min.	1980 Max.	1980 Min.
January	9	-2	2	-8	0	-10	9	-2
February	11	-1	3	-6	6	-6	8	-7
March	16	3	12	1	14	3	14	-1
April	21	8	22	9	20	8	20	6
May	25	13	24	13	23	12	24	13
June	30	18	28	17	27	17	29	30
July	33	19	33	22	30	20	36	22
August	33	19	32	20	30	19	34	21
September	29	14	29	18	28	13	30	17
October	23	9	22	6	24	7		
November	15	2	17	5	13	1		
December	10	-1	8	-3	11	-2		
Year	21	8	19	8	19	7		

ground water in three arbitrarily chosen wells which are placed in the natural soil, 61 cm outside the seepage bed. (All discussions of inbed and exbed levels will refer to these mean values which have been calculated as indicated in Appendix Tables A-6 and A-7). The rainfall data shown in Figure 14 are cumulative since the last observation. An "X" in Figure 14 denotes no rainfall occurred since the last observation.

Data in Figure 14 suggest that both inbed and exbed water depths are farther from the soil surface during periods of low rainfall and that both rise during periods of higher rainfall. These data also suggest that the maximum rise of inbed and exbed depths frequently occurs during winter and early spring months when rainfall is relatively high and evapotranspiration (ET) is relatively low. The inbed and exbed depths varied in relation to each other, and inbed depths were consistently higher than exbed depths (Figure 14 and Appendix Table A-6). Following a rainfall event the inbed and exbed depths rose together, but the continuous addition of effluent caused the inbed depths to rise above the exbed depths until a sufficient hydraulic gradient and interface area was obtained to permit the needed flow from the seepage bed.

Figure 15 shows the relation between inbed effluent depths and exbed ground water depths within the standard filter field. All paired mean inbed and exbed values (Appendix Table A-6), except two sets influenced by effluent delivery failures, were analyzed further to explore this relation (Appendix Table A-8). Regression

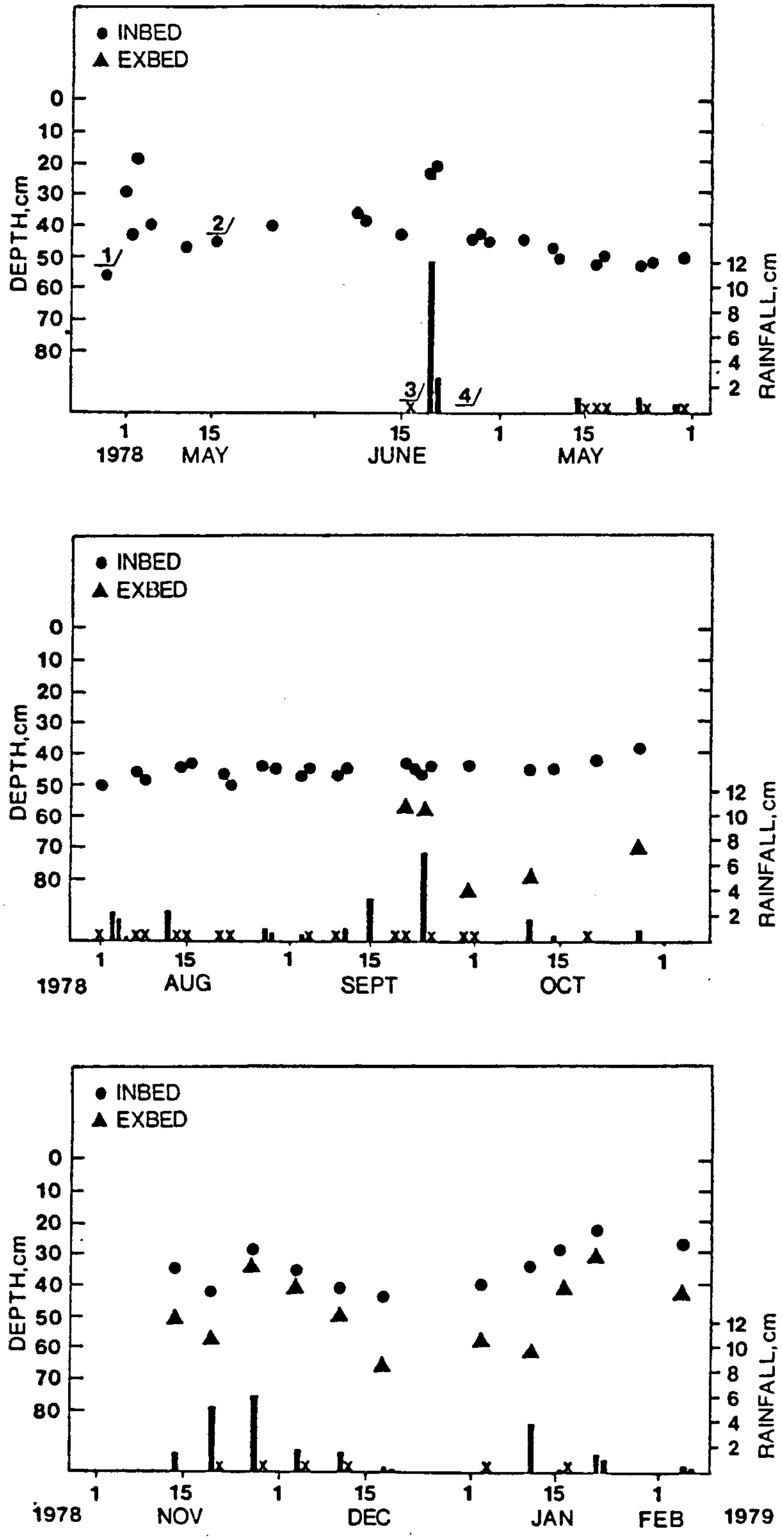
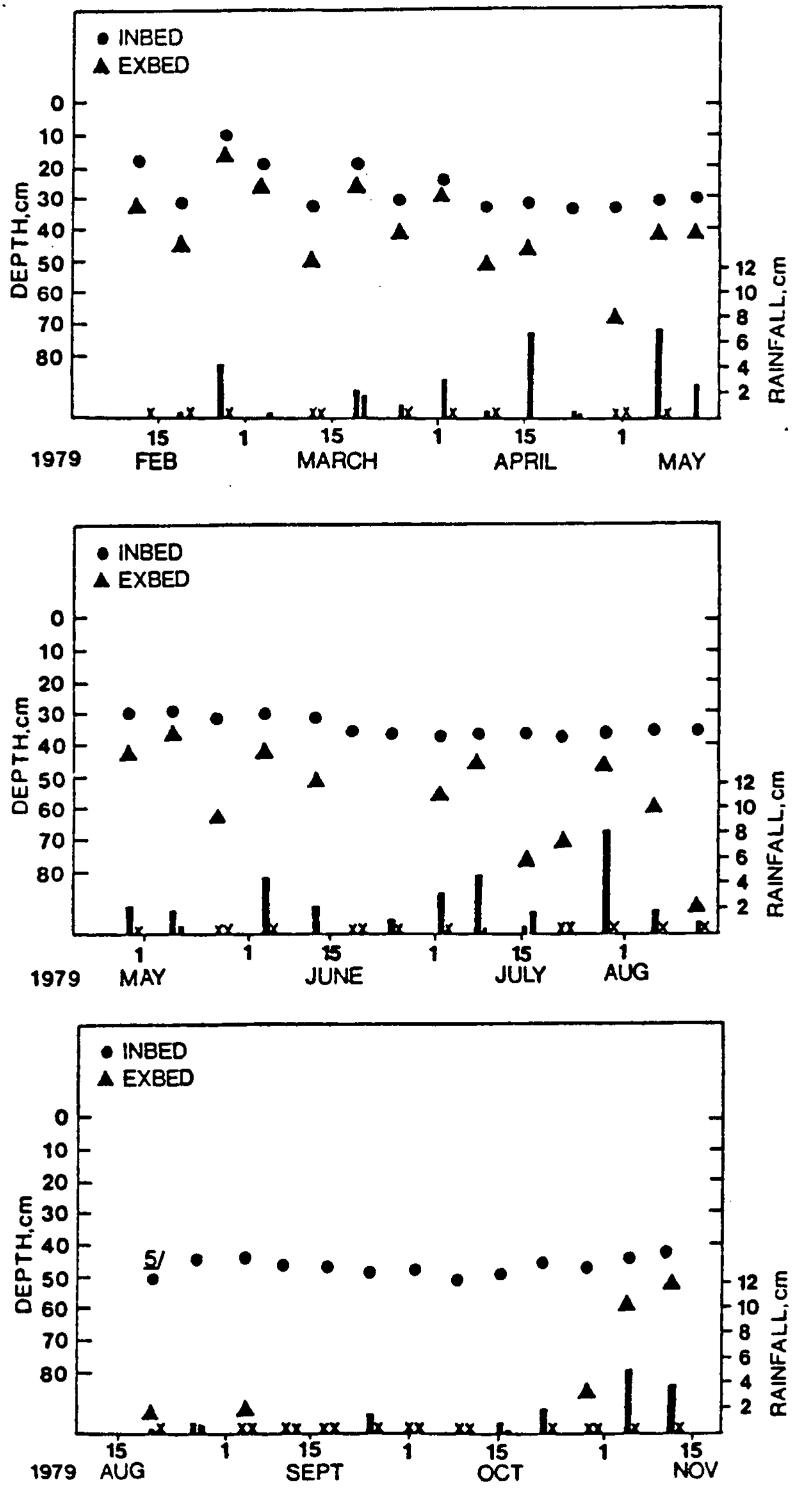


Figure 14a. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the standard filter field.



4b. Relations among inbed effluent depths, exbed ground wate
fall within the standard filter field, continued.

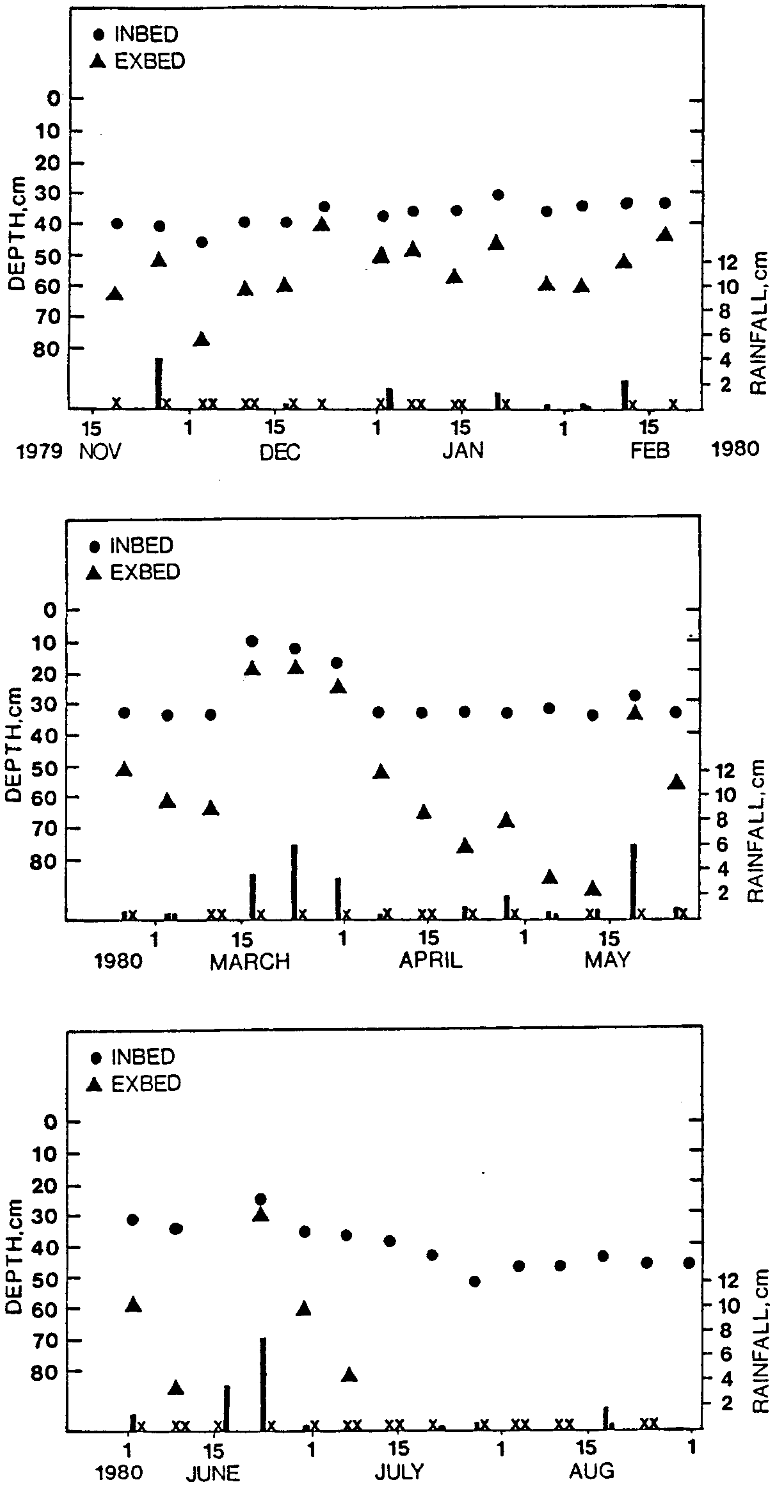


Figure 14c. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the standard filter field, continued.

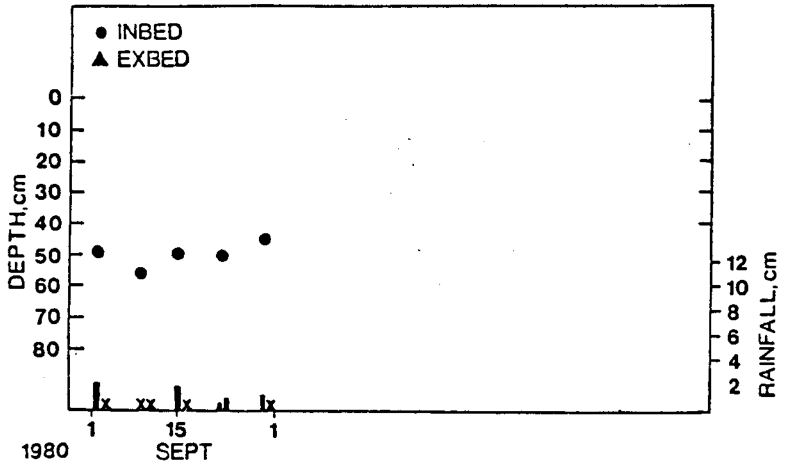


Figure 14d. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the standard filter field continued.

Footnotes for figure showing inbed and exbed depths and rainfall by dates for the standard system at Savoy.

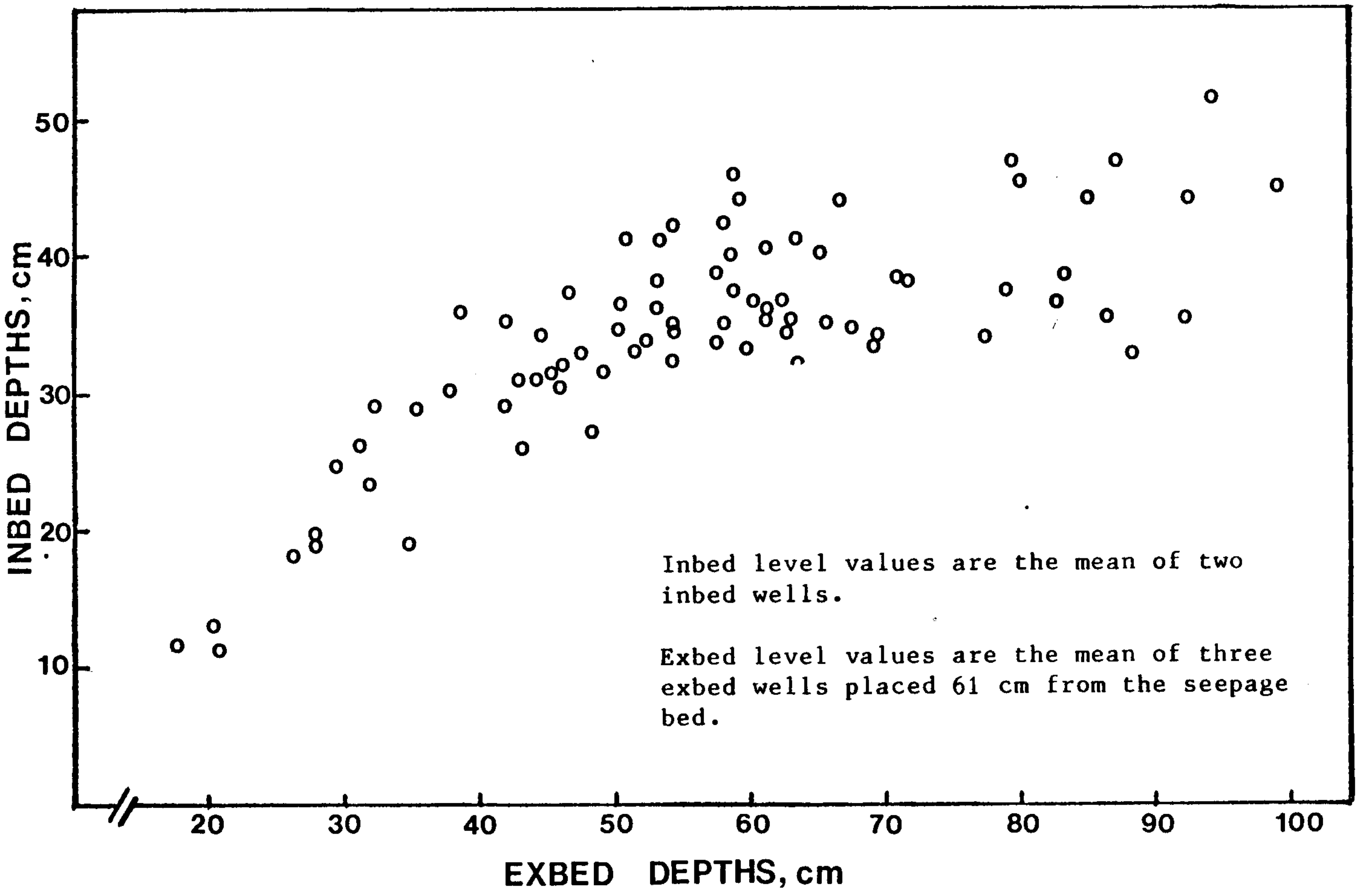
[1] Inbed depths were obtained from tensiometer observations (Appendix Table A-5) for the period April 23, 1978, to September 20, 1978. Other inbed data and all exbed data were obtained from well observations (Appendix Table A-6).

[2] Effluent first delivered to the seepage bed May 15, 1978.

[3] Rainfall measurements are cumulative since the previous observation. "X" denotes no rainfall had occurred since previous observation. Measurements initiated on June 17, 1978.

[4] The rain gauge was inoperative June 27 through July 10, 1978.

[5] Data influenced by disruption of effluent delivery system. Details on disruptions of effluent delivery are given in Appendix Table A-3.



Inbed level values are the mean of two inbed wells.

Exbed level values are the mean of three exbed wells placed 61 cm from the seepage bed.

Figure 15. Relations between inbed effluent levels and exbed groundwater levels within the standard filter fields.

with several models yielded the following equations:

$$Y = \underset{(\pm 1.9)}{16.9} + \underset{(\pm .031)}{0.309}X \qquad R^2 = .56 \qquad (1)$$

$$Y = \underset{(\pm 3.44)}{-4.96} + \underset{(\pm 0.12)}{1.16}X - \underset{(\pm 0.00106)}{0.00744}X^2 \qquad R^2 = .73 \qquad (2)$$

$$Y = \underset{(\pm 2.3)}{66.9} - \underset{(\pm 16)}{232}\left(\frac{1}{\sqrt{X}}\right) \qquad R^2 = .73 \qquad (3)$$

(±) = Standard error of estimate

In these equations Y is the inbed depth in centimeters and X is the exbed depth in centimeters (both of which are measured from the soil surface). Equations (2) and (3) are essentially equal in their ability to account for the variability in inbed depths and both are superior to equation 1.

Visual evaluation of Figure 15 suggests inbed and exbed depths were closely related when the exbed depths were near the soil surface but were not closely related when exbed depths were lower in the soil. The top of the fragipan in this soil occurs at 59 cm below the soil surface; this appears to be near the point of change in the relationship between inbed and exbed depths. Regression (with X and Y as previously used) on paired inbed-exbed means with exbed depths less than 59 cm yields the following relations:

$$Y = \underset{(\pm 2.22)}{3.42} + \underset{(\pm 0.050)}{0.635}X \qquad R^2 = .80 \qquad (4)$$

$$Y = \underset{(\pm 6.2)}{-15.6} + \underset{(\pm 0.33)}{1.69}X - \underset{(\pm 0.0041)}{0.0133}X^2 \qquad R^2 = .84 \qquad (5)$$

$$Y = \underset{(\pm 3.9)}{77.2} - \underset{(\pm 24)}{291}\left(\frac{1}{\sqrt{X}}\right) \qquad R^2 = .89 \qquad (6)$$

(±) = Standard error of estimate

Regression was attempted on equations comparable to (4), (5), and (6) above for paired inbed-exbed means with exbed values equal to or greater than 59 cm. These equations did not yield meaningful relationships at the 0.1 level of significance.

Thus, separate consideration of inbed-exbed depth relations when exbed depths were both above and below the top of the fragipan indicated that inbed and exbed depths were closely related when exbed depths were above the fragipan, but that exbed depths did not significantly influence inbed depths when the exbed depths dropped below the top of the fragipan. These data suggest that, when exbed depths dropped below the top of the fragipan, the hydraulic gradient for flow from the seepage bed (inbed) to the adjoining soil (exbed) had maximized and subsequent lowering of the exbed depths did not result in additional lowering of inbed effluent depths. This hypothesis is supported by the data in Figure 14 which show that in the transition periods from shallow to deep ground water (exbed depths), the exbed depths continually decreased until at least some exbed water depths dropped below the well intake. However, during this same transition period, the inbed well depths continued to drop until some maximum depth was reached and then the inbed depths tended to remain nearly constant.

Figures 16, 17, and 18 show cross sections of inbed and exbed free-water surfaces during "dry," "moist," and "wet" conditions, respectively. Dry conditions are represented by free-water surfaces occurring on dates of the maximum yearly inbed depths.

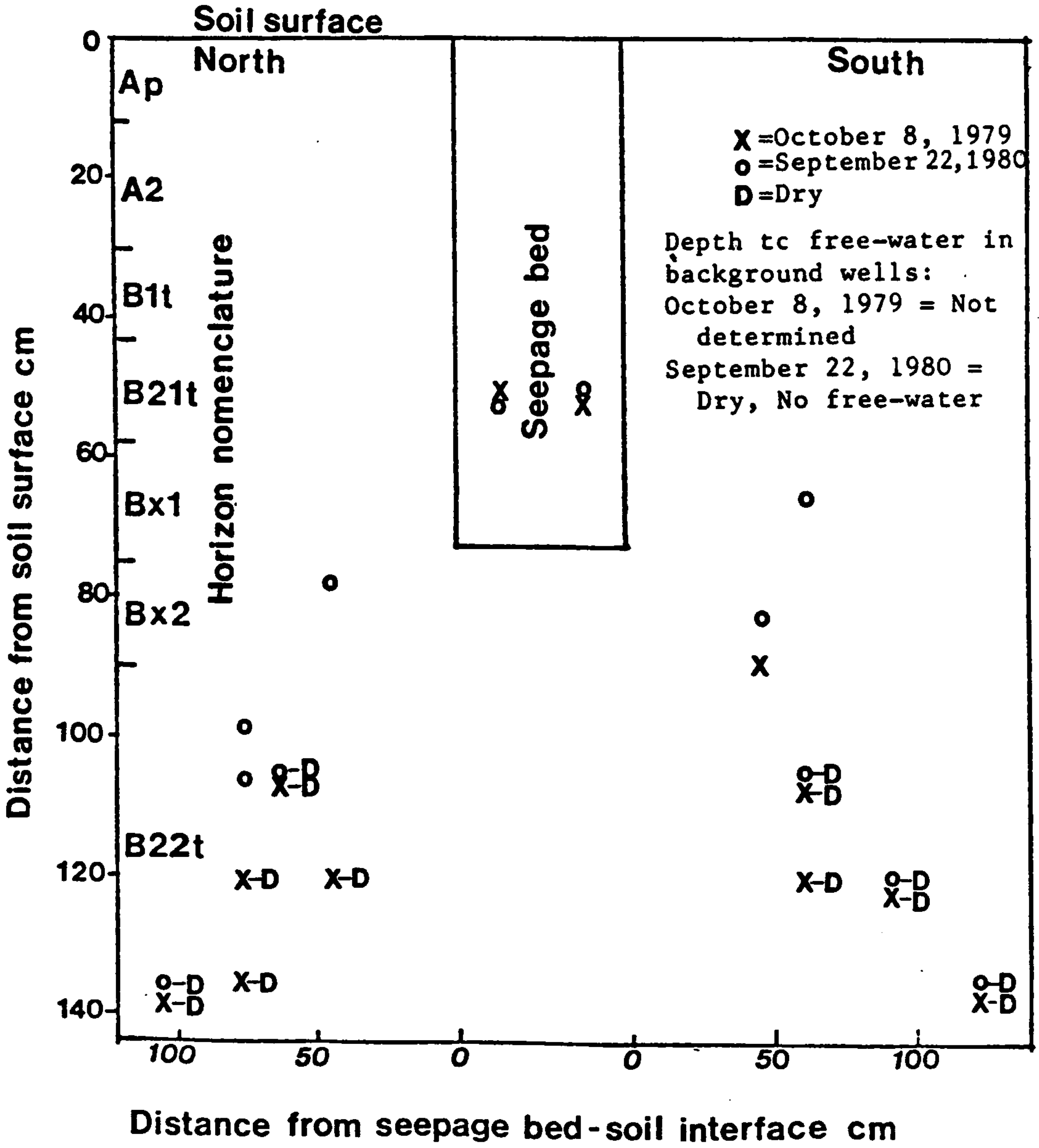


Figure 16. Depth to inbed effluent and exbed ground water in the standard filter field during dry conditions.

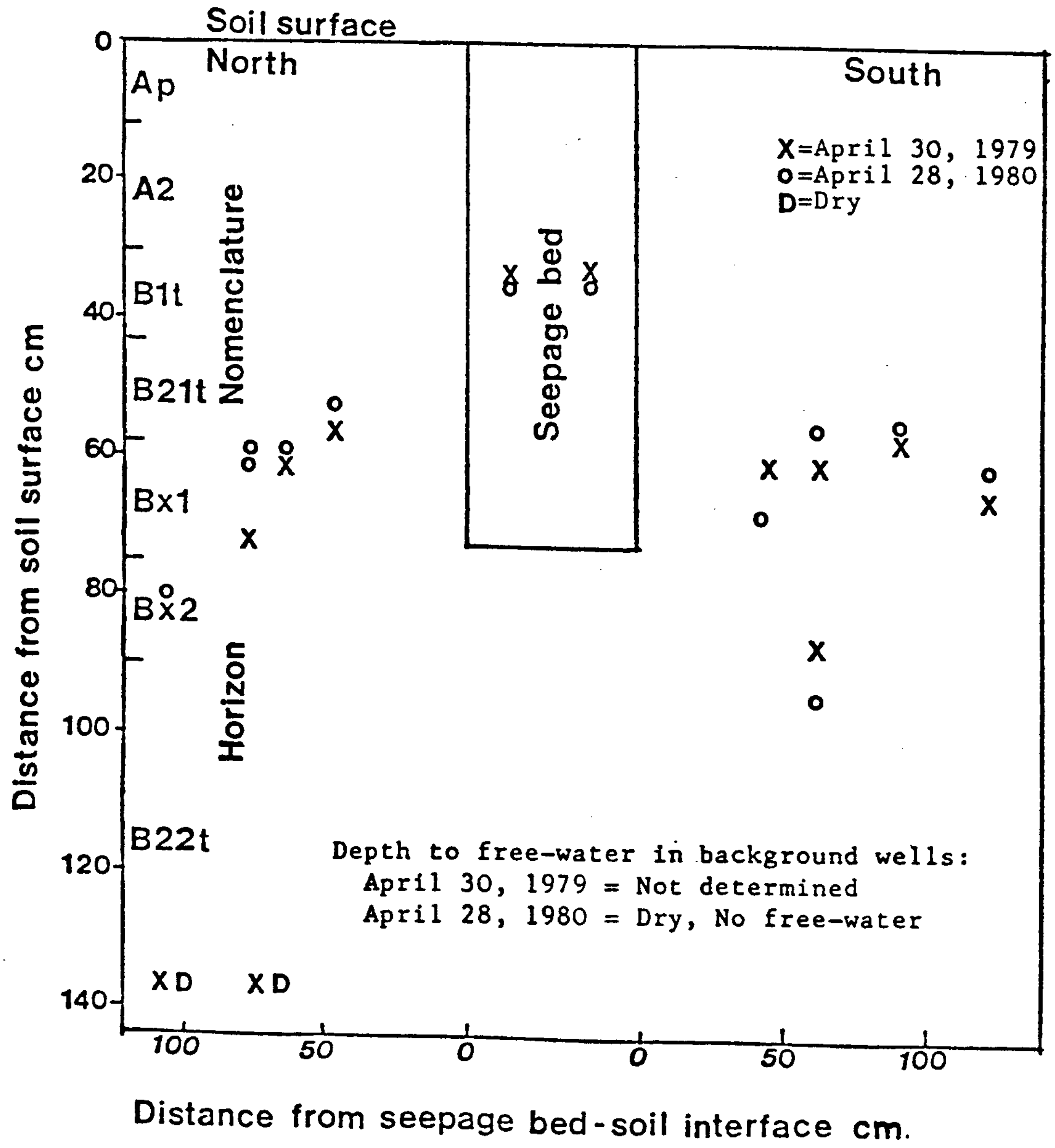


Figure 17. Depth to inbed effluent and exbed ground water in the standard filter field during moist conditions.

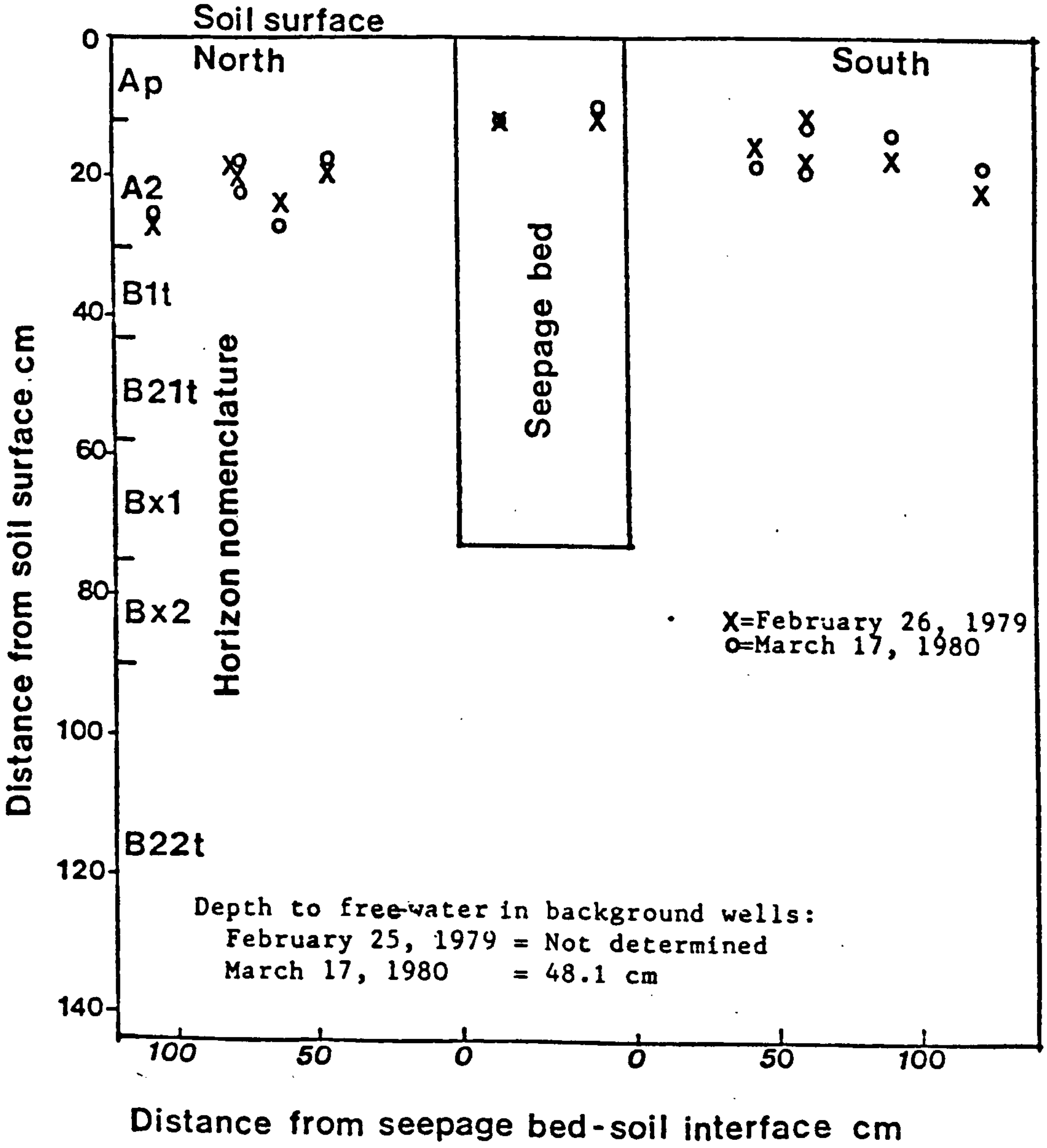


Figure 18. Depth to inbed effluent and exbed ground water in the standard filter field during moist conditions.

Comparably, wet conditions are represented by free-water surfaces which occurred on the dates of the two minimum yearly inbed free-water depths. Moist conditions are represented by intermediate free-water depths on two arbitrarily chosen dates.

Figure 16 depicts dry conditions during which inbed depths could not be satisfactorily predicted from exbed depths because exbed depths were below the top of the fragipan (Bx1). Inbed depths could be predicted from exbed depths under conditions represented in Figures 17 and 18 because mean exbed depths were above the top of the fragipan. The wet conditions presented in Figure 18 represent the filter field when it was in stress periods, which are the design-limiting periods. During these periods, the inbed effluent is much higher (at shallow depths) than usual in the seepage bed. If crusting occurred in this seepage bed, it would be expected to have occurred in the lower portion of the seepage bed, which normally contains effluent, and not along the side walls of the upper portion which are infrequently saturated. Thus, it is assumed that during stress periods with high inbed effluent, much of the effluent is moving through an uncrusted portion of the interface. This assumption is supported by the low lateral flow gradients, 0.11 cm/cm to the north and 0.05 cm/cm to the south (Figure 18), which indicate a low resistance to flow during wet periods. Although crusting may be important to the operation of filter fields during moist and dry periods, our data cause us to question its universal importance during the design-limiting stress periods.

CLIMATIC STRESS PERIODS

The sensitivity of inbed effluent depths to exbed depths and thus to climatic conditions clearly indicates the need to design filter fields based on some period of maximum climatic stress. Basic design principles dictate that any system should be designed to withstand some maximum and stated stress. The climatic stress for filter fields occurs when the ground water is at shallow depths, and thus the hydraulic gradient for flow from the seepage bed is low. Shallow ground water normally occurs during or at the end of an extended period of rainfall concurrent with low ET. Since the degree of stress is variable from year to year, the design of filter fields should be based on a stress of some specified frequency. This would be analogous to dams designed to retain floods of 50 years, 100 years, or some other specified frequency. The 10-year frequency stress period is suggested as both a modest and arbitrary goal to utilize in designing and evaluating filter fields.

The climatic stress period for filter fields in Arkansas often occurs during February, March, and April. Filter field failures are most frequently reported during this period. During this period ET is relatively low, but ET begins to increase during late March and early April. The February-March-April stress period will be emphasized in this report even though additional stress periods occur with less frequency during other portions of the year. The February-March-April stress period will be characterized by comparing the cumulative rainfall during these months each year of the experiment with the average rainfall and the 10-year frequency wet year rainfall during each month. Additional work needs to be done to identify and compare stress periods more quantitatively. They should be identified using both precipitation and ET in a balance approach.

Long term rainfall data are available for Fayetteville which is located about 14.5 km east, southeast of the experimental site (Savoy, AR). Table 10 shows the average and 10-year high rainfalls for the February-March-April period and rainfalls for these months during the experiment. These data indicate the experiment was started (May, 1978) following a February-March-April stress period when the site had received essentially average rainfall. The Fayetteville rainfall data also indicate that May rainfall was slightly above average for that year (Table 8). Ground water depths within the system were monitored for 18 days before effluent was introduced. During this period, ground water was within the seepage bed and fluctuated markedly (Figure 5) in response to rainfall events which, regretably, were not recorded at the site. The standard filter field contained ground water when effluent was introduced on May 15, 1978, and has contained standing effluent for the duration of the experiment.

During the February-March-April period of 1979, Savoy received 74% of the average rainfall for those dates (Table 10). The same period for 1980 was even drier, with only 68% of the average rainfall. Thus, comparison of long term average rainfall during the February-March-April stress periods indicates that the experimental systems have not been taxed. Inbed effluent depths (Figure 14) reached their maximum during the February-March-April period in both 1979 and 1980. In 1979, inbed depths rose to within 12 cm of the soil surface on February 26. In 1980, the effluent depths rose to within 11 cm of the soil surface on March 17. Since these minima were reached during stress periods with less than normal rainfall (74% and 68% of the average in 1979 and 1980, respectively), it seems appropriate to assume that the standard system would fail by discharging effluent to the soil surface during a stress period with rainfall of a 10-year frequency wet period.

Table 10. February-March-April rainfall at Fayetteville and at the experimental site (Harper et al., 1969 and NOAA, 1978).

Location and year(s)	February	March	April	Total
Fayetteville, 30-year mean, cm	7.7	8.5	12.1	28.3
Fayetteville, one year in 10 will have >, cm	12.1	15.1	18.1	
Fayetteville, 1978,[1/] cm	6.6	14.1	6.7	24.4
Savoy,[2/] 1979, cm	4.7	5.2	11.1	21.0
Savoy, 1980, cm	3.4	13.0	2.8	19.2

[1/] Fayetteville data substituted for Savoy data which are not available.

[2/] Savoy is the experimental site.

CRUSTING

Previous studies have shown that septic tank filter fields normally form a crust at the seepage bed-soil interface. This crust reduces the permeability to water at the seepage bed interface and, thus, reduces the rate of effluent flow from the seepage bed into the adjoining soil. The reduced flow rate usually causes ponding of the effluent within the seepage bed. If ponding has previously occurred, the crust causes the effluent to rise additionally within the seepage bed. Since the hydraulic conductivity data for the Nixa soil were quite variable and reliable values were not obtained, the initial permeability of the experimental systems is not known with enough precision to compare permeabilities and, thereby, to detect changes in permeabilities which may have been caused by crusting.

Since effluent loading rates were essentially constant, inbed effluent depths were a function of rainfall additions, ET losses, interface permeabilities, and the hydraulic gradient between the seepage bed and the adjoining soil. When periods of negligible rainfall and of relatively comparable ET rates, such as summer and early fall months are considered, the variables can be reduced to the interface permeability and the hydraulic gradient. During relatively dry periods, the exbed waters are deep; the gradient is maximum. Since hydraulic gradients during these periods can be treated as constants, comparison of inbed effluent depths during periods of negligible rainfall, of comparable ET, and deep exbed waters should give a relative indication of crusting effects.

When effluent was introduced into the experimental systems in May of 1978, ground water was standing in the seepage bed (Figure 14), and we assume it also was present in the adjoining soil at comparable depths. Thus, this period had a low hydraulic gradient from the seepage bed to the adjoining soil and can not be utilized for comparison of inbed effluent depths. Also, exbed depths were not recorded until September 20, 1978. Therefore, more meaningful comparisons of inbed depths as related to exbed depths must be made after that date.

Although exbed depths were not recorded until September, rainfall during late June and early July of 1978 was relatively low, and it is assumed that exbed depths were near a maximum. The maximum inbed depth during this period was 51 cm below the soil surface on July 17. Inbed maximum of 46 and 45 cm also occurred on October 10 and 14, 1978, respectively. The exbed depth was 80 cm October 10, but no exbed depth is available for October 14, because one of the wells was dry. The 1979 maximum inbed depths were 52 cm on August 20 and 51 cm on October 8. The August 20 low followed a period of about 6 days when the household occupants were on vacation and no effluent was added to the system (Appendix Table A-3). Therefore, the low on August 20, 1979, is not valid for comparison to other lows. The October 8 low of 51 cm was preceded by 3 weeks of 48-cm values and followed by 1 week with a 49-cm value. All exbed wells were dry on October 8.

The most appropriate 1980 inbed maximum low appears to be 51 cm on September 22. The maximum inbed low of 54 cm on July 28, 1980 is not valid for comparison because it was influenced by a failure to deliver effluent to the filter field (Appendix Table A-3). The inbed low of 56 cm on September 8, 1980, is considered to be erroneous since it differs markedly from values for preceding and following weeks.

Thus, the maximum yearly inbed lows were 51 cm in July 1978, 51 cm in October 1979, and 51 cm in September 1980. Assuming the exbed depths in July 1978 were comparable to those accompanying the inbed lows of 1979 and 1980, these data indicate that crusting did not significantly affect the interface permeability between July of 1978 and September of 1980. Thus, if interface crusting occurred, it occurred between the initiation of the experiment on May of 1978 and July of 1978. The data do not permit detection of changes in interface permeability which may have occurred during this period due to the assumed shallow exbed ground water depths.

The preceding discussion assumes that inbed minima during July, 1978, October, 1979, and September, 1980, are comparable because during these periods effluent input was essentially constant; rainfall was negligible; ET was high; and hydraulic gradients from the seepage bed, as evaluated by exbed depths, were maximum. Although these assumptions are apparently valid, another problem could exist. The September, 1979, and October, 1980, periods followed extended periods of low rainfall and high ET, whereas, the July, 1978, period followed a shorter period of high ET and much shorter period of low rainfall. Consequently, the September, 1979, and October, 1980, inbed lows may reflect the effects of extended dry periods of high ET, but the July, 1978, period was not preceded by comparable climatic conditions. If the September, 1979, and the October, 1980, inbed maxima were the result of the cumulative effects of the preceding periods of high ET and low rainfall, then inbed effluent depths should consistently become lower and lower until the yearly inbed maximum is reached. The inbed maximum (51 cm) of October 8, 1979, was preceded by 3 weeks of 48-cm readings (Appendix Table A-6). The September 22, 1980, inbed maximum was preceded by 4 weeks of inbed readings of 48 to 51 cm except for the assumed erroneous reading of 56 cm on September 8, 1980. Thus, the two fall inbed maxima are preceded by values of up to 3 cm nearer the soil surface. These data indicate that there may be some cumulative environmental effect, but that it is minor and can be ignored with minimum error.

THE MODIFIED STANDARD FILTER FIELD

The modified standard filter field was constructed adjacent to the standard filter field (Figure 3) and, therefore, was subjected to the same environmental conditions. Both filter fields had gravity effluent distribution and were loaded at essentially the same rate of 1.5 cm per day (Appendix Table A-3). The modified filter field differed from the standard filter field in placement of the seepage bed within the natural soil. The bottom of the seepage bed of the standard filter field was 76 cm below the soil surface, whereas the bottom of the seepage bed of the modified standard filter field was only 30 cm below the soil surface. Thus, the bottom or horizontal interface of the seepage bed of the standard filter field was within the fragipan of the Nixa soil, but the horizontal interface of the modified standard filter field was 29 cm above the top of the fragipan and in a much more permeable portion of the soil.

INBED AND EXBED WATER DEPTHS

The modified standard filter field and the standard filter field performed quite differently with respect to water depth within the seepage bed. The seepage bed of the standard filter field was saturated throughout the experiment (Figure 14), but the seepage bed of the modified filter field was completely saturated only for brief periods which were associated with specific rainfall events or periods of rain. Tensiometer data (presented later in Table 11) and inbed well data (Appendix Table A-7) indicate the modified standard filter field was observed to be completely saturated on only a few occasions throughout the experiment. Thus, due to the infrequency of interface saturation, only eight pairs of inbed-exbed values were available for use in developing the relation between inbed and exbed water depths (from the soil surface). Regression analysis with several models yielded the following equations:

$$Y = \underset{(\pm 3.1)}{14.4} + \underset{(\pm 0.091)}{0.326X} \qquad R^2 = .68 \qquad (7)$$

$$Y = \underset{(\pm 12.00)}{-8.36} + \underset{(\pm 0.77)}{1.82X} - \underset{(\pm 0.0120)}{0.0234X^2} \qquad R^2 = .82 \qquad (8)$$

$$Y = \underset{(\pm 4.7)}{46.0} - \underset{(\pm 26.3)}{117.1} \left(\frac{1}{\sqrt{X}}\right) \qquad R^2 = .77 \qquad (9)$$

(±) = Standard error of estimate

In these equations Y is the inbed depth in cm and X is the exbed depth in cm. Although only eight pairs of inbed-exbed values were available for the regression model, the above equations indicate inbed depths are related to exbed depths for the modified standard filter field as was the case for the standard filter field. These data suggest that, as the exbed depths approach the soil surface, the gradient for flow from the seepage bed was reduced enough to cause the inbed effluent depth to rise. Inbed effluent depths rise until a sufficient hydraulic gradient and interface area exist to permit the needed flow from the bed. In the standard filter field the inbed-exbed depths were related only when the exbed depth were above the fragipan. Such analyses are not appropriate for the modified filter field since inbed wells contain water only when the exbed depths are above the fragipan. Thus, the relations shown in the previous equation are for periods when exbed depths were above the top of the fragipan and no data are available for developing inbed-exbed water depth relations when the exbed depths were below the top of the fragipan.

The most obvious conclusion regarding the relation of inbed-exbed water depth is that inbed water depths were seldom related to exbed water depths since inbed saturation seldom occurred. The infrequent saturation of the seepage bed in the modified standard filter field indicates that construction of the seepage bed above the fragipan, rather than within the fragipan as in the standard filter field, reduced the effects of the exbed water which build above the fragipan on the inbed water depths.

Figures 19, 20, and 21 show cross sections of inbed and exbed free-water surfaces during "dry," "moist," and "wet" conditions in the modified standard filter fields. The dates were chosen to correspond with the dates used to present comparable data on the standard filter field (Figures 16, 17, and 18). Dry conditions are on the dates of the maximum inbed depth for the standard filter fields. The wet conditions (Figure 21) represent free-water surfaces on the dates when inbed depths were the most shallow of the year within the standard filter field. In the winter of 1978-79, inbeds depths within the modified standard system ranged between 26 cm and 29 cm below the soil surface (Appendix Table A-7) on eight occasions. In the winter of 1979-80, inbed wells were dry except on two occasions, March 17 and 24, 1980, when the depths were 19 and 23 cm, respectively. Moist conditions represent intermediate free-water depths on two arbitrarily chosen dates.

Figure 19, which depicts dry conditions, shows that no free-water was detected in the soil during the driest portion of the year. During moist conditions (Figure 20), free-water accumulated below the seepage bed but did not accumulate within the seepage bed. Only during wet conditions (Figure 21) was free-water present within the seepage bed of the modified filter field. During the depicted wet conditions, visual evaluation indicates the lateral flow gradient to be less than during the moist conditions as was the case in the standard filter field. No crusting is expected to have occurred along the vertical interfaces (side walls) of the modified filter field since this interface has seldom been saturated.

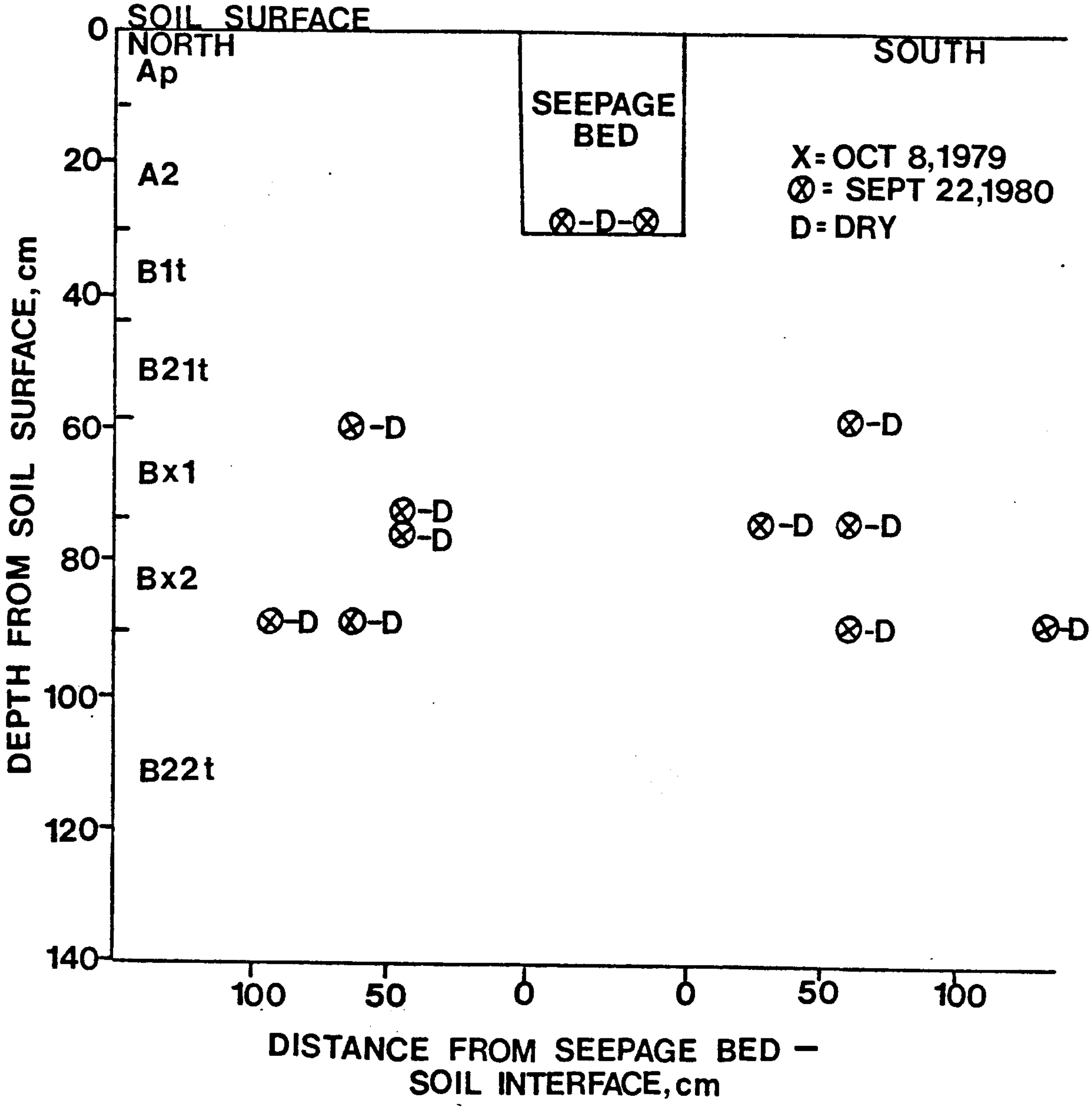


Figure 19. Depth to inbed effluent and exbed ground water in the modified standard filter field during dry conditions.

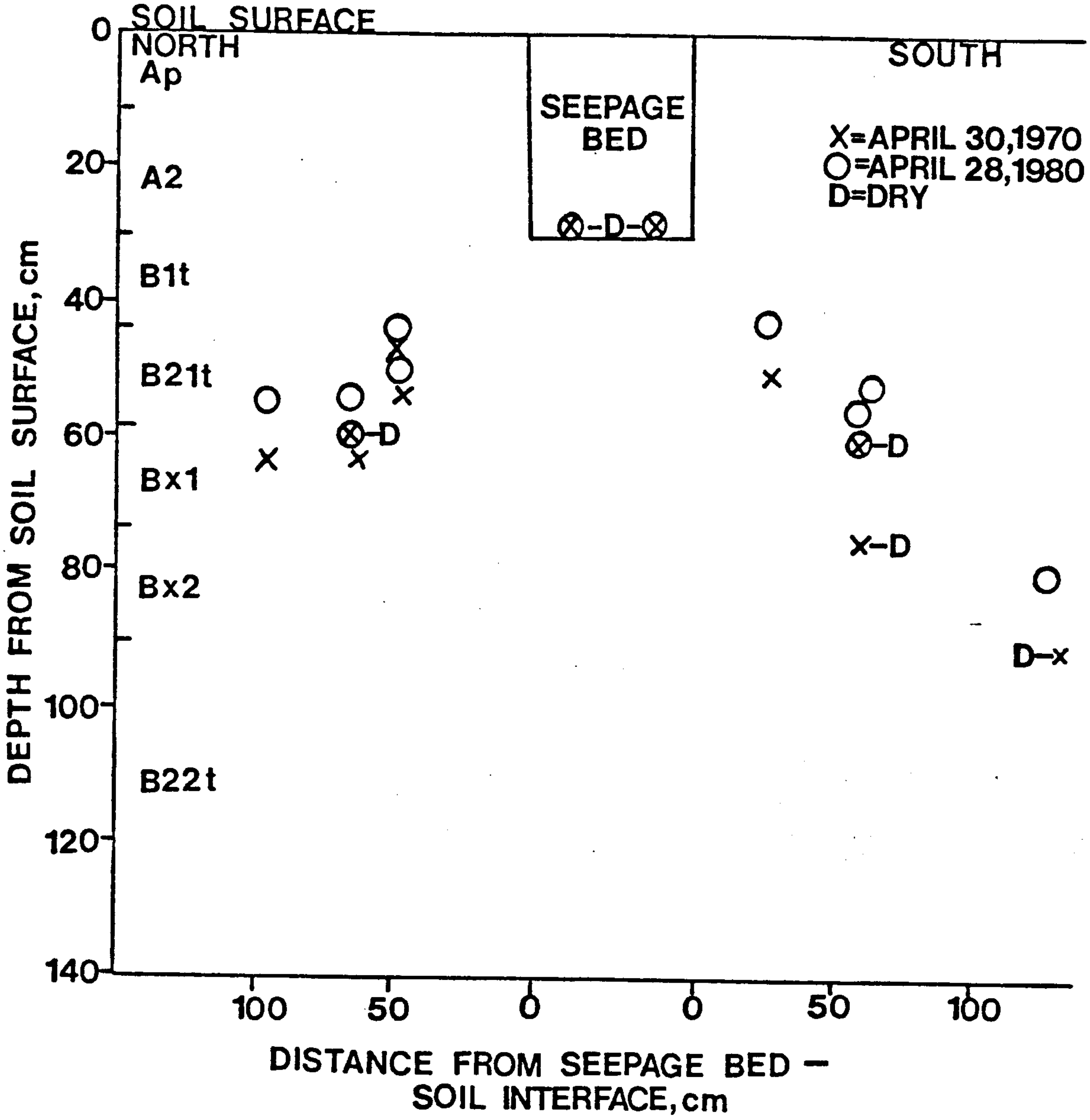


Figure 20. Depth to inbed effluent and exbed ground water in the modified standard filter field during moist conditions.

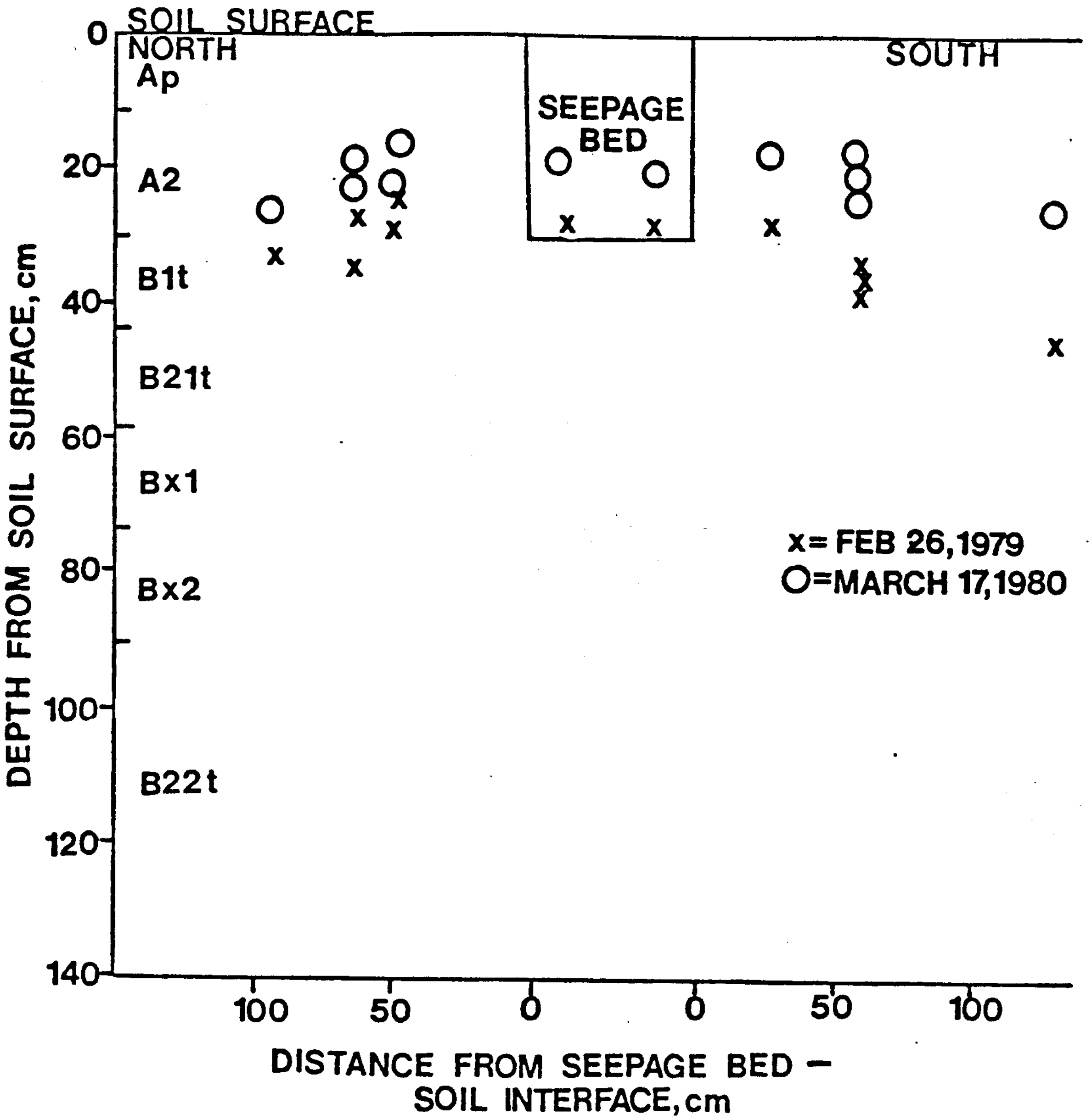


Figure 21. Depth to inbed effluent and exbed ground water in the modified standard filter field during wet conditions.

The cross section of the free-water surfaces associated with the standard filter field during dry conditions (Figure 16) indicates inbed effluent at about 51 cm below the soil surface and the presence of water in the exbed wells within the fragipan. Comparable data (Figure 19) indicate no free-water in the seepage bed of the modified standard filter field and none within the exbed wells in the fragipan. These data suggest that water is draining more freely from the modified standard seepage bed than from the standard seepage. This condition may be explained in two ways: (1) The soil is more permeable under the modified standard filter field. (2) Crusting or mechanical damage that may have occurred in the modified standard filter field occurred in the upper, more permeable horizon, but such flow rate reductions which may have occurred in the standard filter field occurred in the fragipan horizon where the seepage bed is located and further reduced the permeability of the fragipan horizon. Combinations of these two possibilities may also occur. No basis is available for choosing among these possibilities or combinations of them.

CLIMATIC STRESS PERIODS

Earlier discussions regarding the standard filter field advanced the concept that septic tank filter fields should be designed to withstand stress periods of a specified frequency. The February-March-April period was proposed as the most common yearly stress periods for filter fields in Arkansas. It was suggested that filter fields should be able to withstand the maximum stress period which occurs once in 10 years, although this goal is both modest and arbitrary. As a starting point, the intensity of the February-March-April stress periods should be evaluated by comparing the cumulative rainfall occurring during that portion of a given year to that occurring during the average year and to what occurs monthly during the wet year of once in 10 years.

In the modified standard filter field, the 1979 minimum inbed effluent depth, which occurred on both March 4 and April 2, was 26 cm below the soil surface. However, inbed depths of 27 to 28 cm occurred on February 12 and 26 and on March 19. The minimum inbed effluent depth during 1980 was 19 cm below the soil surface on March 17. The next shallowest inbed depth during 1980 was 23 cm on March 24. Thus, for the two complete years over which the modified standard filter field has operated, the yearly inbed minimums have both occurred during the February-March-April stress period. These depths came to within 26 cm and 19 cm of the soil surface in 1979 and 1980, respectively. However, as pointed out in discussing the standard filter field, the stress periods in both 1979 and 1980 received near or below normal rainfalls (Table 10). The 1979 February-March-April period received 74% of the average rainfall and the 1980 February-March-April period received 68% of the average rainfall. The failure of this filter field to be stressed severely limits prediction of its long term success or failure.

The 1979 and 1980 minimum inbed effluent depths for the standard filter field were 12 and 11 cm below the soil surface, respectively. The 1979 and 1980 inbed minimum effluent depths were 26 and 19 cm, respectively, for the modified standard filter field. Thus, in both years the minimum inbed effluent depths were considerably lower in the modified standard filter field than in the standard filter field. Although the failure to have these filter fields subjected to the desired climatic stress has reduced our ability to predict their long term performance, the inbed yearly minimum depth and the infrequent occurrence of inbed effluent in the modified filter field indicates its long range performance will be superior to that of the standard filter field.

CRUSTING

Other researchers have proposed that when gravity effluent distribution is utilized, the horizontal interface of the seepage bed will progressively crust until the interface is completely crusted. They envisioned that the effluent would be primarily loaded into one area of the seepage bed. This continual effluent loading into one area would keep that area moist enough to form a crust. The crust which formed would reduce the hydraulic conductivity of the interface and cause additional crust formation. This process was envisioned to continue until the entire horizontal interface would become completely crusted. Crusting would then develop up the seepage bed side walls until the flow rate out of the crusted seepage bed would be equal to the incoming rate of effluent addition.

Crust formation can not be directly measured as it forms on the seepage bed interface. However, since the degree of crust formation and the degree of interface saturation are assumed to be directly related, the extent of crusting can be inferred from the amount of interface saturation. The degree of interface saturation is also assumed to be related to the effluent loading rate, to ET losses, and to the exbed ground water levels. Since the effluent loading rate was approximately constant during the experiment, the degree of crusting and the degree of interface saturation are assumed to be most closely related when exbed ground water depths were great and ET losses were near maximum, i.e., during periods of low rainfall in the summer and early fall months.

Degree of saturation of the seepage bed was determined by tensiometers placed on the horizontal interface of the seepage bed (Table 11). These data indicate that the interface was completely saturated only on May 1, May 3, June 20, and June 21 during the summer of 1978. The saturations on May 1 and 3 occurred before effluent was added to the seepage bed (May 15, 1978). They are

Table 11. Saturation of the horizontal seepage bed interface of the modified standard filter field.[1]

Date	Saturation %[2]	Date	Saturation %[2]	Date	Saturation %
1978		1978		1979	
4/28	0	7/18	30	6/1	90[2]
5/1	100	7/25	20	6/12	84[2]
5/2	0	7/26	20	6/14	70[2]
5/3	100	7/31	20	6/19	42[2]
5/5	0	8/1	20	6/24	64[2]
5/11	0	8/7	20	7/2	40[2]
5/16	20	8/4	20	7/8	100
5/28	23	8/14	23	7/16	90[2]
6/8	56	8/15	23	7/23	90[2]
6/9	30	8/21	20	7/29	100
6/15	43	8/22	0	8/13	65[3]
6/20	100	8/28	23	8/20	15[3]
6/21	100	8/29	23	8/27	15[3]
6/23	70	9/3	16	9/4	15[3]
6/27	23	9/4	36	9/10	44[3]
6/28	30	9/9	23	9/11	55[3]
6/29	30	9/20	30	9/17	73[3]
7/5	49	9/21	23	9/24	45[3]
7/10	30	9/23	20	10/8	55[3]
7/11	30	9/24	30	10/15	35[3]
7/17	20	9/30	30	10/22	38[4]
				10/29	38[4]

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[1] Interpreted from tensiometer data.

[2] Saturation occurs in a contiguous area starting from the western end of the seepage bed.

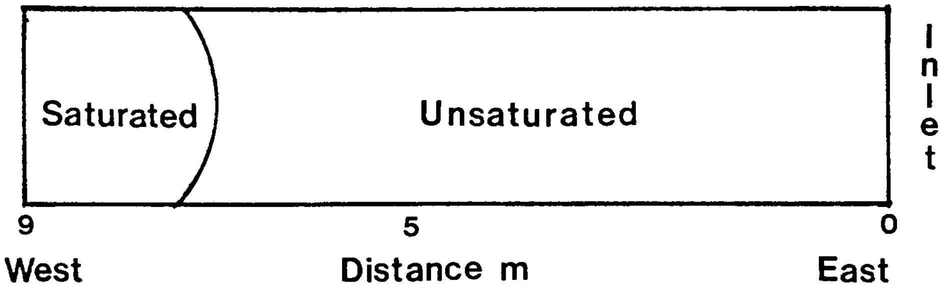
[3] Saturation occurs in noncontiguous areas.

[4] Saturation occurs in contiguous areas starting from the eastern end of the seepage bed.

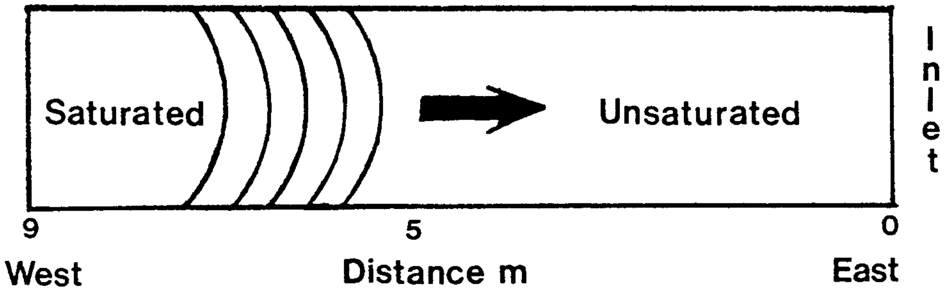
assumed to be due to rainfalls which, regrettably, were not measured at the experimental site during that period. The interface saturations (100%) on June 20 and June 21 are evidently in response to rainfalls reported on those dates (Appendix Table A-4). During the remainder of the summer and early fall of 1978, interface saturations were in the 20 to 30% range (Table 11) and did not show a tendency to increase. Thus, the degree of interface saturation during the summer and early fall of 1978 indicated no progressive increase in crust formation during that period.

Rainfall distribution (Appendix Table A-4) during the summer of 1979 indicates that the interface saturations of 40 to 64% on June 19, June 24, and July 2 occurred under conditions similar to the 20 to 30% interface saturations of 1978. These data denote an increase in crusting between the summers of 1978 and 1979. Interface saturations during August, September, and October of 1979 are not comparable to earlier interface saturations because the effluent distribution within the seepage bed changed in early August of 1979.

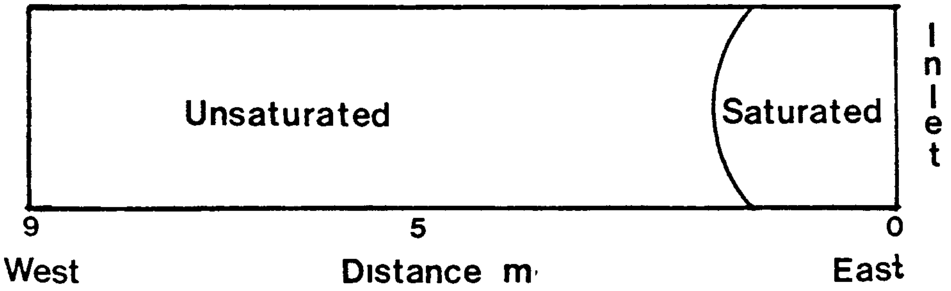
Shortly after the introduction of effluent into the modified standard filter field (May 15, 1978) tensiometer data indicated the effluent was wetting the horizontal interface at the western end of the seepage bed (Figure 22a). Although the effluent inlet was on the eastern end of the seepage bed, the effluent was traveling the length of the 10-cm diameter plastic pipe and entering the western end of the seepage bed. The effluent was able to travel the length



a) Initial interface saturation



b) Expected progression of saturation



c) Interface saturation after 16 months of operation

Figure 22. Saturation of the horizontal interface of the modified standard filter field.

of the pipe because the outlet holes were at 4 and 8 o'clock and none were located on the bottom. Also, the end of the pipe was uncapped.

Effluent distribution within the modified standard filter field evidently remained comparable from the initiation of the experiment on May 15, 1978, until August 13, 1979. During this period one of three conditions existed: (1) the interface was 100% saturated, or (2) none of the interface was saturated, or (3) some continuous portion (less than 100%) of the interface was saturated. When less than 100% of the interface was saturated, the saturation always occurred at the western end of the filter field and extended for varying distances toward the eastern or inlet end. It was assumed, as outlined earlier, that the crust would grow progressively from the western end of the interface until it extended completely to the eastern end (Figure 22b). However, on August 13, 1979, the tensiometer data indicated both the eastern and western ends of the interface were saturated and the center portion of the interface was unsaturated. The tensiometer data on August 20 and 27 and on September 4 and 10 indicate that the interface was saturated in various spots, ie several noncontiguous zones. Interface saturation on September 11 through October 15 was mainly in the eastern and western ends. The data on October 22 and 29, 1979, indicated the interface was saturated only on the eastern (inlet) end as shown in Figure 22c.

Hence, during periods of less than 100% interface saturation, the saturated area had changed ends within the modified standard seepage bed. During 1978, the prime area of interface saturation was at the western end, but by October, 1979, the prime area was at the eastern end. Observation of grass growth patterns during 1980 (when the tensiometers no longer gave reliable data) indicated the inlet end was strikingly more moist.

During the summer of 1980, the inlet end of the modified standard system was opened and examined. No physical damage or change was noted in the distribution system. It was noted that the 10-cm distribution pipe was filled to the bottom of the distribution holes (occurring at approximately 4 and 8 o'clock) with a gelatin-like substance. It was obvious that, due to the presence of the gelatin-like substance, the effluent was being discharged from the first distribution holes, those on the eastern end which is nearest the inlet. Thus, it appears that the effluent was first discharged into the seepage bed at the end most distant from the inlet because it could flow to that end without rising to the level of the outlet holes. At some time, the distribution pipe began to be filled with the gelatin-like substance which eventually filled the pipe below the discharge holes and caused the effluent to be discharged at the inlet end. The time between termination of complete discharge at the western end and continuous discharge at the eastern end, apparently July 29, 1979 to October 22, 1979, was the period of most uniform discharge of effluent within the system. During this period effluent was discharged into one end of the seepage bed and into at least some other portion of the bed. Since this period lasted only about two and one-half months and was followed again by discharge into only one end of the bed, the case for uniform effluent distribution from gravity fed systems is most discouraging. If we assume that this gelatin-like substance forms in all gravity fed distribution pipes which are not continuously filled with effluent, then we may also assume that with time all distribution lines will result in nonuniform distribution regardless of the placement techniques utilized in constructing the seepage bed.

CONCLUSIONS

Observation and evaluation of the performance of the standard and modified standard filter field over a period of 30 months have led to some general conclusions which seem applicable, in varying degrees, to all filter fields.

1) The long-term performance of filter fields, with respect to failure by emitting untreated effluent to the soil surface, will be determined by the climatic stress placed upon them as well as by soil properties, crusting, method of effluent loading, effluent loading rate, construction techniques, etc.
2) Stress periods for filter fields occur when ground waters accumulate adjacent to the seepage bed(s). These exbed waters reduce the gradient for flow from the seepage bed and cause the inbed effluent to rise until a sufficient gradient and interface surface area are achieved to provide the required flow from the seepage bed.
3) High ground waters normally occur during and following periods of extended rainfall and low ET. In Arkansas, February-March-April, is defined as the normal stress period for filter fields. It is recognized that filter fields may be stressed during other periods of the year.
4) Septic tank filter fields should be designed to withstand a specific stress as essentially all other structures are. We suggest that filter fields be designed to withstand the stress period of 1-in-10-year frequency. We consider this both an

arbitrary and modest goal.

5) Although crusting may be important to the operation of filter fields during moist and dry periods, crusting during the design-limiting stress periods seems of diminished or little importance for seepage beds that receive an essentially constant effluent loading rate. For such seepage beds the lower portions may contain ponded effluent which is considered to lead to formation of crusts. However, during stress periods the effluent rises and contacts sidewall areas in the upper part of the seepage bed. These sidewall areas should be essentially uncrusted (because they are in contact with effluent for only a few weeks per year) and, thus, remain more permeable than the lower part of the seepage bed.

6) Our observations indicate that filter field performance is more closely related to rates of water movement than to stone content. The major considerations in filter field performance are rates and directions of water movement, stress period intensity, designs utilized, and construction techniques.

Evaluation of the performance of the two experimental filter fields are summarized as follows:

1) The performance of the modified standard filter field indicates it is superior to the standard filter field with respect to failure by emitting untreated effluent to the soil surface. The 1979 and 1980 minimum inbed effluent depths for the standard filter field were 12 and 11 cm, respectively. The 1979

and 1980 minimum inbed effluent depths were considerably lower in the modified standard filter field.

2) Since the inbed effluent depths of the standard filter field have come very near the soil surface in both 1979 and 1980, it is assumed that this filter field will emit effluent to the soil surface during the stress period of the 1-in-10 year frequency. The ability of the modified standard filter field to withstand the 1-in-10 year stress is unclear.

3) The standard and modified standard filter fields performed quite differently with respect to water within their seepage beds. The seepage bed of the standard filter field was saturated for the duration of the experiment, whereas the seepage bed of the modified filter field was completely saturated for only brief periods which were associated with specific rainfall events or specific periods of rainfall.

4) Inbed water depths were related to exbed water depths in the standard filter field when the exbed water depths were above the top of the fragipan (50 cm), but the two depths showed no significant relation when the exbed depths were below the top of the fragipan.

5) The infrequency of complete inbed saturation in the modified standard filter field indicated that construction of the seepage bed above the fragipan, rather than partially within the fragipan as in the case of the standard filter field, reduces the effects of the exbed waters which build above the fragipan

on the inbed water depths in the seepage bed of the modified standard filter field.

6) Crusting, as evaluated by inbed effluent depths during comparable environmental periods, is not indicated to have occurred on the seepage bed-soil interface of the standard filter field between July 17, 1978 and September 22, 1980. Crusting which may have occurred during the first 2 months of the experiment could not be evaluated due to the presence of exbed ground water at shallow depths during this period.

7) Crusting in the modified standard filter field, as evaluated by the degree of interface saturation during comparable environmental periods, did not appear to have changed during the summer and early fall of 1978 when about 20 to 30% of the interface was saturated. Interface saturation during comparable environmental periods of 1979 was 40 to 64%, thus indicating crusting had occurred between the summers of 1978 and 1979. Interface saturations, as related to crust formation, are not comparable between the summers of 1979 and 1980 since the pattern of effluent distribution changed in August of 1979.

8) A gelatin-like substance accumulated within the distribution pipe of the modified standard filter field and caused the point of effluent discharge to change from the western to eastern (inlet) end of the seepage bed. If it is assumed that this gelatin-like substance grows in all gravity fed distribution pipes which are not continuously filled with effluent, then it

must also be assumed that with time all such distribution lines will experience a cross-sectional area change which will result in changes in distribution uniformity regardless of the placement techniques utilized in construction of the seepage bed.

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APPENDIX TABLES

Table A-1. Description of the Nixa soil at the experimental site.

Location: University of Arkansas Agricultural Experiment Station: Beef Farm near Savoy. SE ¼, SW ¼, SW ¼, Section 20, T17N, R31W; 81 meters south of Sligar house, on the crest of a Nixa ridge about 80 meters wide (Washington County, Arkansas).

Physiography and elevation: Springfield plateau; 0.5 - 1.0 meters below maximum elevation of the area.

Parent material: Cherty limestone residuum

Slope: 1 to 3 percent

Soil drainage: Moderately well drained

Vegetation: Native grasses; sometimes used for garden.

Described and sampled by: P.S. Stafford and E.M. Rutledge, June 2, 1977.

Classification: Typic Fragiudult; loamy-skeletal, siliceous, mesic.

Pedon description:

Ap	0-13 cm	Yellowish brown (10YR 5/4) cherty silt loam; common coarse and medium dark brown (10YR 4/3) mottles; weak medium and fine subangular blocky structure; friable; many very fine, many fine and many medium imped pores; many very fine, many fine and many medium roots; 30 - 40% by volume coarse fragments ranging from 2 mm-12 cm in diameter but dominantly 2 mm-3 cm; abrupt smooth boundary. Sample No. 8555
A2	13-31 cm	Yellowish brown (10YR 5/4) cherty silt loam; weak medium subangular blocky structure; friable; few root channels filled with dark brown (10YR 4/3) material from Ap; many very fine, many fine and many medium imped pores with many medium vesicular pores; many very fine and common fine roots; 35-40% by volume coarse fragments ranging from 2 mm-4 cm in diameter but dominantly 2 mm-2 cm; clear smooth boundary. Sample No. 8556
B1t	31-44 cm	Strong brown (7.5YR 5/6) cherty heavy silt loam; common medium brownish yellow (10YR 6/6) mottles; weak to moderate medium subangular blocky structure; firm; occasional thin strong brown (7.5YR 5/6) clay film; few thin (.5 mm) white (10YR 8/2) dry silty skeletans that disappear upon wetting; many very

Table A-1. Description of the Nixa soil at the experimental site. (Continued)

		fine, many fine and many medium imped pores; common very fine and few fine roots; 35-40% by volume coarse fragments ranging from 2 mm-6 cm in diameter but dominantly 2 mm-3 cm; clear smooth boundary. Sample No. 8557
B21t	44-59 cm	Strong brown (7.5yR 5/6) light cherty silty clay loam; common medium yellowish red (5YR 4/6), few medium brownish yellow (10YR 6/6), few fine light gray (10YR 7/2) mottles; moderate medium and fine common very fine, common fine and few medium imped pores; common very fine roots; common fine and few 30-35% by volume coarse fragments 2 mm-6 cm in diameter but dominantly 2 mm-2 cm; abrupt smooth boundary. Sample No. 8558
Bx1	59-76 cm	Yellowish red (5YR 4/6) cherty light silty clay loam; common medium yellowish brown (10YR 5/4) mottles; moderate fine angular blocky structure; firm and brittle in 85% of matrix; non-brittle portion consists of seams of light brownish gray (10YR 6/2) silty clay loam forming a polygonal pattern; horizontal seams are about 5 mm wide and 2-10 cm apart, vertical seams are about 1 cm wide and spaced on an average of 20 cm apart but range from 5-50 cm apart; roots are excluded from red matrix and occur exclusively in gray seams; upper boundary of fragipan defined by gray seam throughout the pedon; thin patchy red (2.5YR 4/6) and light brownish gray (10YR 6/2) clay films; no skeletans observed; common very fine pores; few very fine roots in gray seams only; 40-50% by volume coarse fragments ranging from 2 mm-6 cm in diameter with occasional 20 cm fragment; clear smooth boundary. Sample No. 8559
Bx2	76-91 cm	Red (2.5YR 4/6) cherty silt clay loam; few fine light brownish gray (10YR 6/2) mottles; moderate fine angular blocky structure; very firm and brittle; thin discontinuous yellowish red (5YR 4/6) and thin patchy dark red (2.5YR 3/6) clay films with occasional light brownish gray (10YR 6/2) clay film lining very fine pores and medium vesicular pores; light brownish gray (10YR 6/2) silty clay loam seams forming polygonal pattern; horizontal seams average 5 mm wide and are spaced on the average about 8 cm apart, vertical seams average 1 cm side and are spaced cm apart; strong brown coating 2 mm-1 cm thick on interface between red matrix and 20-40% of gray vertical seams; common very fine pores with occasional medium vesicular pore; few very fine roots limited

Table A-1. Description of the Nixa soil at the experimental site. (Continued)

		to gray seams; 40-50% by volume coarse fragments that are 2 mm-6 cm in diameter; clear smooth boundary that is abrupt where terminated by gray horizontal seam. Sample No. 8560
B22t	91-93 cm	Dark red (2.5YR 3/6) silty clay; common coarse red (2.5YR 4/6) and few medium strong brown (7.5YR 5/8) mottles; moderate fine and medium angular blocky structure; firm; medium discontinuous dark red (10R 3/6) clay films on ped faces and medium patchy gray (10YR 5/1) clay films in gray seams; gray seams of light brownish gray (10YR 6/2) light clay averaging 1 cm in width and form a polygonal pattern but pattern is less defined on horizontal and vertical planes than upper horizons; gray material occupies 25-30% by volume of horizon; common very fine pores; one root observed; 30-40% coarse fragments by volume ranging from 2 mm-10 cm in diameter; gradual, smooth boundary. 91-116 cm Sample No. 8561 116-142 cm Sample No. 8562 142-168 cm Sample No. 8563 168-193 cm Sample No. 8564
B23t	193-218+ cm	Dark red (2.5YR 3/6) light silty clay loam; other morphological features are as described for the B22t above; boundary not observed. Sample No. 8565

Notes: This field was apparently plowed for the first time this year. Therefore, the color differences observed in Ap were due to mixing of the A1 and A2 horizons. In addition, larger coarse fragments had been removed from the surface. Some areas of the B1t horizon lacked clay films and the roots in the B21t appeared to terminate at the upper boundary of the pan with some evidence of root matting at this interface. Roots did penetrate gray areas, however, in the fragipan.

Textures have been changed, as needed, to agree with laboratory determinations. The B22t horizon contains textures of silty clay, and clay loam.

Table A-1. Description of the Nixa soil at the experimental site. (Continued)

This soil is a taxadunct to the Nixa series. It is outside the range on the following properties: (1) the presence of an argillic horizon above the fragipan (2) the depth to unconsolidated bedded chert is greater than 218 cm (less than 48 inches is required). (3) the B22t chert content (estimated) is lower than allowed. Chert contents (estimated) of other horizons are in the lower part of the range (4) the Bx horizons have redder hues than allowed.

Pedon No. 77WS02

Table A-2. Particle size and chemical data for the Nixa soil at the experimental site.

		Fine Earth Particle Size Distribution (%)											
		Sand (mm)						Silt (μm)				Clay	
Horizon	Depth cm	VCS 2-1	CS 1-0.5	MS 0.5-0.25	FS 0.25 -0.1	VFS 0.1 0.05	TS 2-0.05	CSI 50-20	MSI 20 -5	FSI 5-2	TSI 50 -2	TC 2 UM	Textural Class
Ap	0- 13	5.8	3.4	1.3	2.4	1.9	14.8	36.6	30.1	11.0	77.7	7.5	Sil
A2	13- 31	5.2	2.5	1.2	2.2	1.8	12.9	29.0	34.1	11.9	75.0	12.1	Sil
B1t	31- 44	3.9	2.1	0.7	1.6	1.5	9.8	26.7	28.0	12.1	66.8	23.4	Sil
B21t	44- 59	3.2	2.2	0.7	1.7	1.5	9.3	27.5	25.1	10.1	62.7	28.0	Sicl
Bx1	59- 76	4.7	3.1	1.1	1.9	2.0	12.8	30.3	25.6	7.4	63.3	23.9	Sil
Bx2	76- 91	4.8	2.9	1.2	2.9	2.6	14.4	29.3	21.4	8.3	59.0	26.6	Sil
B22t	91-116	2.9	1.7	0.7	2.0	2.2	9.5	25.5	15.9	7.0	48.4	42.1	Sic
B22t	116-142	1.6	1.5	0.8	2.7	3.1	9.7	20.6	16.2	6.5	43.3	47.0	Sic
B22t	142-168	2.1	2.0	1.5	3.8	4.0	13.4	18.7	14.7	6.3	39.7	46.9	C
B22t	168-193	2.1	3.1	2.5	6.5	6.5	20.7	18.3	23.8	5.9	41.3	38.0	Cl
B23t	193-218	4.3	3.2	1.9	4.9	5.4	19.7	26.8	18.1	7.7	52.6	27.7	Sicl

				Extractable Bases								
Horizon	Depth cm	pH	Tot. Carbon %	K	Ca	Mg	Na	Ext. Acidity	Sum Base	Sum Cations	Base Sat %	Na Sat %
				---------------- meq/100g Soil						----------------		
Ap	0- 13	5.1	1.97	0.4	3.5	0.8	0.1	11.7	4.8	16.5	29	1
A2	13- 31	5.1	0.59	0.3	2.0	0.6	0.0	7.7	2.9	10.6	27	0
B1t	31- 44	4.6	0.33	0.4	2.0	1.2	0.1	12.8	3.7	16.5	22	1
B21t	44- 59	4.4	0.32	0.5	1.9	1.2	0.0	15.1	3.6	18.7	19	0
Bx1	59- 76	4.4	0.16	0.4	0.8	0.6	0.0	12.3	1.8	14.1	13	0
Bx2	76- 91	4.4	0.11	0.3	0.4	0.5	0.1	14.0	1.3	15.3	9	1
B22t	91-116	4.1	0.12	0.3	0.3	0.6	0.0	18.3	1.2	19.5	6	0
B22t	116-142	4.1	0.16	0.2	0.3	0.7	0.0	21.1	1.2	22.3	5	0
B22t	142-168	3.8	0.17	0.2	0.3	0.7	0.0	22.3	1.2	23.5	5	0
B22t	168-193	3.7	0.13	0.1	0.3	1.1	0.1	21.5	1.6	23.1	7	0
B23t	193-218	3.9	0.12	0.1	0.5	0.7	0.2	15.6	1.5	17.1	9	1

Appendix Table A-3. Effluent loading rates for the standard and modified standard filter field.[1]

Time period	Standard cm/day	Modified cm/day
1978		
15MAY-23JUN	2.34	2.16
No effluent delivered 3:00 p.m. 23 MAY to 9:37 a.m. 24MAY. Equipment adjustment.[1]		
24MAY-30MAY	1.48	1.33
30MAY-07JUN	1.49	1.50
07JUN-19JUN	1.02	1.56
An electrical storm caused a malfunction starting between 15JUN and 20JUN. Data calculated assuming 19 JUN. The stanard system was not overloaded but the modified standard was overloaded with 42.3 cm of effluent. Restarted 26JUN.		
26JUN-30JUN	1.44	1.00
No effluent delivered for 2 hours 29JUN. New meter installed on modified system.		
30JUN-04JUL	1.53	1.64
06JUL-14JUL	0.77	1.45
14JUL-25JUL	1.31	1.49
25JUL-31JUL	1.40	1.40
No effluent delivered for 2 hours on 27JUL due to equipment repair.		
31JUL-15AUG	1.50	1.47
15AUG-24AUG	1.20	1.18
No effluent delivered for 6 hours 22AUG. Equipment repair.		
No effluent delivered for 24 hours 24AUG-25AUG due to operator error.		
25AUG-03SEP	1.62	1.44
03SEP-09SEP	1.60	1.41
09SEP-18SEP	1.84	1.62
18SEP-23SEP	1.39	1.24
23SEP-30SEP	1.18	1.43
30SEP-10OCT	1.91	1.43
10OCT-14OCT	1.72	1.53
14OCT-21OCT	1.83	1.63
21OCT-28OCT	2.33	1.80
28OCT-04NOV	2.21	1.81
04NOV-08NOV	2.01	1.94
No effluent was delivered 1:30 p.m. 08NOV to 10:30 a.m. 09NOV. Check valve repair.		
09NOV-20NOV	1.90	1.73
20NOV-27NOV	1.67	1.56
27NOV-04DEC	1.62	1.49
04DEC-11DEC	1.89	1.78
11DEC-18DEC	1.84	1.64
1979		
18DEC-04JAN	1.73	1.53
04JAN-11JAN	1.54	1.36
11JAN-16JAN	1.15	1.08
16JAN-22JAN	2.07	2.03
22JAN-05FEB	2.26	2.21
05FEB-12FEB	2.07	2.00
12FEB-19FEB	2.07	1.99
No effluent was delivered for 2 hours on 14FEB. Main line valve replacement.		
19FEB-26FEB	1.93	1.80
26FEB-04MAR	2.22	2.09
04MAR-12MAR	1.44	1.37
12MAR-19MAR	1.53	1.42
19MAR-26MAR	1.51	1.40
26MAR-02APR	1.51	1.38
02APR-09APR	1.61	1.49
09APR-16APR	1.75	1.67
16APR-23APR	1.70	1.63
23APR-30APR	1.70	1.62
30APR-07MAY	1.62	1.53
No effluent delivered for 6 hours on 02MAY. Power failure, electrical storm.		
07MAY-13MAY	1.68	1.62
13MAY-20MAY	1.60	1.53
20MAY-01JUN	1.54	1.46
No effluent delivered for 2 hours 01JUN to standard system only. New meter installed.		
01JUN-12JUN	1.37	1.07
12JUN-14JUN	1.35	1.13
24JUN-02JUL	1.34	1.24
02JUL-08JUL	1.26	1.26
08JUL-16JUL	1.36	1.35

Appendix Table A-3. Effluent loading rates for the standard and modified standard filter field. (continued)

Time period	Standard cm/day	Modified cm/day
16JUL-22JUL	1.38	1.33
22JUL-29JUL	1.37	1.35
29JUL-06AUG	1.32	1.29
06AUG-14AUG	1.51	1.44
No effluent was delivered 14AUG-19 AUG. Household occupants were absent.		
20AUG-27AUG	1.26	1.28
27AUG-04SEP	1.25	1.27
04SEP-10SEP	1.28	1.25
10SEP-17SEP	1.27	1.24
17SEP-24SEP	1.25	1.25
24SEP-01OCT	1.18	1.20
01OCT-08OCT	1.09	1.19
08OCT-15OCT	1.09	1.20
15OCT-22OCT	1.14	1.23
22OCT-29OCT	1.21	1.24
29OCT-05NOV	1.20	1.17
05NOV-12NOV	1.16	1.12
12NOV-19NOV	1.13	1.10
19NOV-29NOV	1.22	1.16
No effluent was delivered 29NOV-01 Dec. Frozen pipe.		
01DEC-10DEC	1.18	0.74
10DEC-17DEC	1.36	0.95
17DEC-24DEC	1.46	1.04
1980		
24DEC-02JAN	1.50	1.13
02JAN-07JAN	1.56	1.24
07JAN-14JAN	1.63	1.32
14JAN-21JAN	1.62	1.27
21JAN-29JAN	1.60	1.32
29JAN-04FEB	1.54	1.25
04FEB-11FEB	1.49	1.22

Time period	Standard cm/day	Modified cm/day
11FEB-18FEB	1.54	1.24
18FEB-25FEB	1.51	1.23
25FEB-03MAR	1.53	1.25
03MAR-10MAR	1.52	1.25
10MAR-24MAR	1.54	1.25
24MAR-31MAR	1.53	1.24
31MAR-07APR	1.48	1.21
07APR-14APR	1.42	1.20
14APR-21APR	1.45	1.25
21APR-28APR	1.43	1.22
28APR-05MAY	1.42	1.21
05MAY-12MAY	1.38	1.24
12MAY-19MAY	1.39	1.31
19MAY-26MAY	1.38	1.17
26MAY-02JUN	1.36	1.16
02JUN-09JUN	1.33	1.23
09JUN-16JUN	1.33	1.04
16JUN-23JUN	1.36	1.16
23JUN-30JUN	1.32	1.13
30JUN-07JUL	1.39	1.18
07JUL-14JUL	1.34	1.14
14JUL-22JUL	1.36	1.17
No effluent delivered 22JUL-29JUL. Pump accidently unplugged.		
30JUL-11AUG	1.30	1.18
11AUG-18AUG	1.45	1.32
No effluent delivered to modidfied standard (only) for 3 hours 12AUG Equipment repair.		
18AUG-25AUG	1.31	1.45
25AUG-02SEP	1.39	1.43
02SEP-08SEP	1.34	1.41
08SEP-15SEP	1.38	1.44
15SEP-22SEP	1.34	1.42
22SEP-29SEP	1.41	1.40

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[1] No effluent was delivered to the filter fields on several occasions due to equipment malfunctions or the need to adjust equipment. When the time interval was eight hours or less, the time was included in calculating loading rates. When the time interval was greater than eight hours, the time was not included in calculating loading rates.

Appendix Table A-4. Detailed rainfall at the experimental site and at Fayetteville, Arkansas.

Date	Savoy cm[1]	Fay cm[2]	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1978			1978			1978		
01APR			11MAY			20JUN	12.2[3]	
02APR			12MAY		0.8	21JUN	2.7	4.3
03APR			13MAY		0.7	22JUN		0.1
04APR			14MAY			23JUN		
05APR			15MAY			24JUN		
06APR		0.7	16MAY			25JUN		
07APR			17MAY			26JUN		
08APR			18MAY			27JUN[4]		
09APR			19MAY		1.7	28JUN		
10APR		3.0	20MAY			29JUN		
11APR		1.3	21MAY			30JUN		
12APR			22MAY		1.4	JUN T		17.7
13APR			23MAY		0.1			
14APR			24MAY			01JUL		
15APR			25MAY			02JUL		0.1
16APR			26MAY			03JUL		
17APR			27MAY			04JUL		
18APR		0.5	28MAY			05JUL		
19APR			29MAY			06JUL		
20APR			30MAY			07JUL		
21APR			31MAY			08JUL		
22APR			MAY T		16.5	09JUL		
23APR		0.1				10JUL[4]	0.0	
24APR			01JUN			11JUL	0.7	0.4
25APR			02JUN		0.6	12JUL		
26APR			03JUN			13JUL		
27APR			04JUN			14JUL	1.3	0.1
28APR			05JUN		0.3	15JUL	0.0	3.2
29APR		1.1	06JUN		2.5	16JUL		
30APR			07JUN		1.0	17JUL	0.0	
APR T		6.7	08JUN		0.6	18JUL	0.0	
			09JUN			19JUL		
01MAY		2.0	10JUN			20JUL		
02MAY			11JUN			21JUL		
03MAY		2.3	12JUN			22JUL		
04MAY		1.0	13JUN			23JUL		
05MAY			14JUN			24JUL	1.3	0.9
06MAY			15JUN			25JUL	0.0	
07MAY		4.6	16JUN			26JUL		
08MAY		1.9	17JUN	0.0		27JUL		0.8
09MAY			18JUN		8.1	28JUL		
10MAY			19JUN		0.2	29JUL		

Appendix Table A-4. Detailed rainfall at the experimental site and at Fayetteville, Arkansas. (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1978			1978			1978		
30JUL	0.9		07SEP			18OCT		
31JUL	0.0	0.6	08SEP			19OCT		
JUL T		6.1	09SEP	0.0		20OCT		
			10SEP	1.0	1.2	21OCT	0.0	
01AUG	0.0		11SEP			22OCT		
02AUG			12SEP			23OCT		0.5
03AUG	2.3	0.1	13SEP			24OCT		
04AUG	1.8	0.8	14SEP	3.4	2.9	25OCT		
05AUG	0.2	0.4	15SEP			26OCT		
06AUG			16SEP			27OCT		
07AUG	0.0		17SEP			28OCT	0.8	
08AUG	0.0		18SEP	0.0		29OCT		
09AUG			19SEP	0.0		30OCT		
10AUG			20SEP			31OCT		
11AUG			21SEP		7.7	OCT T	2.9	2.4
12AUG	2.3	2.0	22SEP		0.2			
13AUG			23SEP	7.0		01NOV		
14AUG	0.0		24SEP	0.0		02NOV		
15AUG	0.0		25SEP			03NOV		
16AUG			26SEP			04NOV		
17AUG			27SEP			05NOV		
18AUG			28SEP			06NOV		0.9
19AUG			29SEP			07NOV		
20AUG		0.1	30SEP	0.0		08NOV		
21AUG	0.0		SEP T	11.9	12.0	09NOV		
22AUG	0.0					10NOV		
23AUG			01OCT	0.0		11NOV		
24AUG			02OCT			12NOV		
25AUG		0.5	03OCT			13NOV		
26AUG		0.5	04OCT			14NOV	1.6	0.2
27AUG			05OCT		0.4	15NOV		2.1
28AUG	0.9	0.2	06OCT			16NOV		1.2
29AUG	0.6	0.8	07OCT			17NOV		2.7
30AUG			08OCT			18NOV		
31AUG			09OCT		0.1	19NOV		
AUG T	8.1	4.9	10OCT	1.6	0.4	20NOV	5.3	
			11OCT			21NOV	0.0	0.2
01SEP			12OCT			22NOV		0.1
02SEP			13OCT		0.9	23NOV		0.9
03SEP	0.5		14OCT	0.5	0.1	24NOV		
04SEP	0.0		15OCT			25NOV		1.4
05SEP			16OCT			26NOV		4.3
06SEP			17OCT			27NOV	6.2	

Appendix Table A-4. Detailed rainfall at the experimental site and at Fayetteville, Arkansas. (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1978			1979			1979		
28NOV	0.0		02JAN			11FEB		
29NOV			03JAN			12FEB	0.0	
30NOV			04JAN	0.0		13FEB		
NOV T	13.1	14.0	05JAN		0.3	14FEB		
			06JAN			15FEB		
01DEC			07JAN			16FEB		
02DEC			08JAN			17FEB		
03DEC		0.8	09JAN		0.1	18FEB		
04DEC	1.9		10JAN			19FEB	0.1	
05DEC	0.0		11JAN	3.8	0.2	20FEB	0.0	
06DEC			12JAN		0.2	21FEB		
07DEC		1.2	13JAN			22FEB		
08DEC		0.1	14JAN			23FEB		1.0
09DEC			15JAN		0.2	24FEB		
10DEC			16JAN	0.3		25FEB	4.2	1.8
11DEC	1.7		17JAN	0.0	0.2	26FEB	0.0	
12DEC	0.0		18JAN			27FEB		
13DEC			19JAN		1.4	28FEB		1.1
14DEC			20JAN			FEB T	4.7	4.7
15DEC			21JAN					
16DEC			22JAN	1.5		01MAR		0.1
17DEC			23JAN	1.0		02MAR		
18DEC	0.3		24JAN		0.5	03MAR		1.3
19DEC	0.1		25JAN			04MAR		
20DEC		0.3	26JAN		1.1	05MAR	0.3[5]	
21DEC			27JAN			06MAR		
22DEC			28JAN			07MAR		
23DEC			29JAN			08MAR		
24DEC		0.4	30JAN		0.3	09MAR		
25DEC			31JAN			10MAR		
26DEC			JAN T	6.6	7.6	11MAR		
27DEC						12MAR	0.0	
28DEC			01FEB			13MAR	0.0	
29DEC			02FEB			14MAR		
30DEC			03FEB			15MAR		
31DEC			04FEB			16MAR		
DEC T	4.0	2.8	05FEB	0.3[5]		17MAR		
			06FEB	0.1[5]		18MAR		0.4
			07FEB		0.8	19MAR	2.3	0.3
1979			08FEB			20MAR	1.6	1.2
			09FEB			21MAR		
01JAN		3.1	10FEB			22MAR		

Appendix Table A-4: Detailed rainfall at the experimental site and at Fayetteville, Arkansas. (Continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1979			1979			1979		
23MAR		1.1	01MAY	0.0		10JUN		1.1
24MAR			02MAY		0.1	11JUN		
25MAR			03MAY		2.7	12JUN	2.2	
26MAR	1.0	0.2	04MAY		3.0	13JUN		
27MAR	0.0		05MAY		0.4	14JUN		
28MAR			06MAY			15JUN		
29MAR		0.3	07MAY	7.0		16JUN		
30MAR		0.2	08MAY	0.0		17JUN		
31MAR			09MAY			18JUN	0.0	
MAR T	5.2	5.1	10MAY			19JUN	0.0	
			11MAY		3.8	20JUN		
01APR		2.4	12MAY		0.2	21JUN		0.9
02APR	3.0		13MAY	2.4		22JUN		
03APR	0.0		14MAY	0.0		23JUN		0.2
04APR		0.2	15MAY			24JUN	1.2	0.6
05APR			16MAY			25JUN	0.0	
06APR			17MAY			26JUN		
07APR			18MAY			27JUN		
08APR		0.1	19MAY			28JUN		
09APR	0.5	0.2	20MAY	1.9	2.3	29JUN		
10APR	0.0		21MAY	0.6	0.4	30JUN		
11APR		2.8	22MAY		1.3	JUN T	7.8	7.2
12APR		3.8	23MAY					
13APR		0.1	24MAY			01JUL		5.1
14APR			25MAY			02JUL	3.3	0.1
15APR			26MAY			03JUL	0.0	
16APR	6.7		27MAY			04JUL		
17APR			28MAY	0.0		05JUL		
18APR			29MAY	0.0		06JUL		0.7
19APR		0.1	30MAY			07JUL		0.5
20APR			31MAY		0.4	08JUL	4.6	0.2
21APR		1.0	MAY T	11.9	14.6	09JUL	0.5	0.2
22APR						10JUL		
23APR	0.5	0.4	01JUN			11JUL		
24APR	0.4	0.3	02JUN		0.5	12JUL		
25APR			03JUN		2.1	13JUL		
26APR			04JUN	4.4		14JUL		
27APR			05JUN	0.0		15JUL		
28APR			06JUN		0.4	16JUL	0.1	
29APR			07JUN		1.4	17JUL	1.6	0.2
30APR	0.0		08JUN			18JUL		2.7
APR T	11.1	11.4	09JUN			19JUL		

Appendix Table A-4. Detailed rainfall at the experimental site and at Fayetteville, Arkansas. (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1979			1979			1979		
20JUL			28AUG	0.9	0.1	03OCT		
21JUL			29AUG		1.2	04OCT		
22JUL	0.0		30AUG			05OCT		
23JUL	0.0		31AUG			06OCT		
24JUL			AUG T	4.9	5.4	07OCT		
25JUL						08OCT	0.0	
26JUL			01SEP			09OCT	0.0	
27JUL		1.4	02SEP			10OCT		
28JUL		5.1	03SEP			11OCT		
29JUL	8.2		04SEP	0.0		12OCT		
30JUL	0.0		05SEP	0.0		13OCT		
31JUL			06SEP			14OCT		
JUL T	18.3	16.2	07SEP			15OCT	0.8	
			08SEP			16OCT	0.1	
01AUG		0.5	09SEP			17OCT		
02AUG			10SEP	0.0		18OCT		
03AUG			11SEP	0.0		19OCT		
04AUG		0.9	12SEP			20OCT		
05AUG			13SEP			21OCT		
06AUG	1.8		14SEP			22OCT	2.0	2.2
07AUG	0.0		15SEP			23OCT	0.0	
08AUG			16SEP			24OCT		
09AUG			17SEP	0.0		25OCT		
10AUG			18SEP	0.0		26OCT		
11AUG		1.3	19SEP			27OCT		
12AUG			20SEP			28OCT		
13AUG	0.9		21SEP		1.3	29OCT	0.0	
14AUG	0.0		22SEP			30OCT	0.0	
15AUG		0.3	23SEP			31OCT		5.2
16AUG			24SEP	1.5		OCT T	2.9	7.4
17AUG			25SEP	0.0				
18AUG			26SEP			01NOV		
19AUG			27SEP			02NOV		
20AUG	0.4		28SEP			03NOV		
21AUG	0.0	0.4	29SEP			04NOV		
22AUG			30SEP			05NOV	5.1	
23AUG		0.7	SEP T	1.5	1.3	06NOV	0.0	
24AUG						07NOV		
25AUG			01OCT	0.0		08NOV		1.1
26AUG			02OCT	0.0		09NOV		3.0
27AUG	0.9							

Appendix Table A-4. Detailed rainfall at the experimental site and at Fayetteville, Arkansas. (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1979			1979			1980		
10NOV			19DEC			26JAN		
11NOV			20DEC			27JAN		
12NOV	3.9		21DEC			28JAN		
13NOV	0.0		22DEC		0.4	29JAN	0.1	
14NOV			23DEC	0.0		30JAN		0.2
15NOV			24DEC		2.3	31JAN		
16NOV			25DEC			JAN T	2.9	2.3
17NOV			26DEC					
18NOV			27DEC			01FEB		
19NOV	0.0		28DEC			02FEB		
20NOV	0.3	0.3	29DEC			03FEB		
21NOV		2.6	30DEC			04FEB	0.3	
22NOV			31DEC			05FEB	0.1	
23NOV			DEC T	0.3	2.8	06FEB		
24NOV						07FEB		
25NOV			1980			08FEB		1.0
26NOV	4.0		01JAN			09FEB		
27NOV	0.0		02JAN	0.0		10FEB		
28NOV			03JAN	1.5	0.8	11FEB	2.2	
29NOV			04JAN			12FEB	0.0	
30NOV			05JAN			13FEB		
NOV T	13.3	7.0	06JAN		0.2	14FEB		
			07JAN	0.0		15FEB		
01DEC			08JAN	0.0		16FEB		
02DEC			09JAN			17FEB		
03DEC	0.0		10JAN			18FEB	0.3	
04DEC	0.0		11JAN			19FEB	0.0	
05DEC			12JAN			20FEB		
06DEC			13JAN			21FEB		
07DEC			14JAN	0.0		22FEB		
08DEC			15JAN	0.0		23FEB		
09DEC			16JAN		0.4	24FEB		
10DEC	0.0		17JAN			25FEB	0.5	0.3
11DEC	0.0		18JAN			26FEB	0.0	
12DEC			19JAN			27FEB		
13DEC		0.1	20JAN		0.6	28FEB		
14DEC			21JAN	1.3		29FEB		
15DEC			22JAN	0.0	0.1	FEB T	3.4	1.3
16DEC			23JAN					
17DEC	0.3		24JAN			01MAR		
18DEC	0.0		25JAN			02MAR		

Appendix Table A-4. Detailed rainfall at the experimental site and at Fayetteville, Arkansas. (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1980			1980			1980		
03MAR	0.3		13APR			24MAY		
04MAR	0.1		14APR	0.0		25MAY		
05MAR			15APR	0.0		26MAY	0.8	
06MAR			16APR			27MAY	0.0	
07MAR			17APR		0.9	28MAY		
08MAR			18APR			29MAY		
09MAR			19APR			30MAY		0.1
10MAR	0.0		20APR			31MAY		
11MAR	0.0		21APR	0.9		MAY T	8.1	8.7
12MAR		1.6	22APR	0.0				
13MAR			23APR			01JUN		0.9
14MAR			24APR			02JUN	1.5	
15MAR			25APR		0.8	03JUN	0.0	
16MAR			26APR		1.5	04JUN		
17MAR	3.5	3.2	27APR		0.1	05JUN		
18MAR	0.0		28APR	1.8		06JUN		
19MAR			29APR	0.0		07JUN		
20MAR			30APR			08JUN		
21MAR		0.1	APR T	2.8	3.5	09JUN	0.0	
22MAR						10JUN	0.0	
23MAR		0.1	01MAY			11JUN		
24MAR	5.8	1.2	02MAY			12JUN		
25MAR	0.0		03MAY			13JUN		
26MAR			04MAY			14JUN		
27MAR			05MAY	0.4		15JUN		
28MAR		0.6	06MAY	0.3	0.2	16JUN	0.0	
29MAR			07MAY			17JUN	3.6	4.1
30MAR		3.2	08MAY			18JUN		1.0
31MAR	3.3		09MAY			19JUN		0.9
MAR T	13.0	10.0	10MAY			20JUN		
			11MAY			21JUN		1.6
01APR	0.0		12MAY	0.0		22JUN		5.9
02APR			13MAY	0.6	1.4	23JUN	7.5	
03APR		0.2	14MAY			24JUN	0.0	
04APR			15MAY			25JUN		
05APR			16MAY		3.5	26JUN		
06APR			17MAY			27JUN		
07APR	0.1		18MAY		1.9	28JUN		
08APR	0.0		19MAY	6.0	0.8	29JUN		
09APR			20MAY	0.0		30JUN	0.4	
10APR			21MAY		0.6	JUN T	13.0	14.4
11APR			22MAY					
12APR			23MAY		0.2	01JUL	0.0	0.6
						02JUL		

Appendix Table A-4: Detailed rainfall at the experimental site and at Fayetteville, Arkansas. (Continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1980			1980			1980		
03JUL			02AUG			01SEP		
04JUL			03AUG			02SEP	1.7	0.2
05JUL			04AUG	0.0		03SEP	0.0	0.8
06JUL			05AUG	0.0		04SEP		0.3
07JUL	0.0		06AUG			05SEP		
08JUL	0.0		07AUG			06SEP		
09JUL			08AUG			07SEP		
10JUL			09AUG			08SEP	0.0	
11JUL			10AUG			09SEP	0.0	
12JUL			11AUG	0.0		10SEP		3.9
13JUL			12AUG	0.0		11SEP		
14JUL	0.0		13AUG			12SEP		
15JUL	0.0		14AUG		0.4	13SEP		
16JUL			15AUG			14SEP		
17JUL			16AUG			15SEP	1.9	0.2
18JUL		0.1	17AUG			16SEP	0.0	
19JUL			18AUG	1.5	0.5	17SEP		0.7
20JUL			19AUG	0.3	0.4	18SEP		
21JUL	0.0		20AUG			19SEP		
22JUL	0.1	1.7	21AUG			20SEP		
23JUL			22AUG			21SEP		
24JUL			23AUG			22SEP	0.6	
25JUL			24AUG			23SEP	1.0	0.7
26JUL		0.7	25AUG	0.0		24SEP		0.5
27JUL		0.1	26AUG	0.0		25SEP		1.9
28JUL	0.6		27AUG			26SEP		
29JUL	0.0		28AUG			27SEP		
30JUL			29AUG			28SEP		0.8
31JUL			30AUG			29SSP	1.3	
JUL T	0.7	3.2	31AUG			30SEP	0.0	
			AUG T	1.8	1.3	SEP T	6.5	10.0
01AUG								

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[1] Savoy is the experimental site. It is located about 4.5 km north-northwest of Fayetteville.

[2] Fay is an abbreviation for Fayetteville. Fayetteville data are from NOAA, 1978-80.

[3] Rainfall measurements at Savoy are cumulative since the previous observation. Oil was first used (to prevent evaporation) in the rain gauge on July 7, 1979.

[4] The rain gauge was inoperative June 27 through July 10, 1978.

[5] Snow was converted to rainfall by dividing by 12.

Appendix Table A-5. Inbed effluent depths as indicated by tensiometer measurements for the standard filter field.

Date	Mean[1] cm[2]	Date	Mean cm
28APR78	56.5	25JUL78	52.1
01MAY78	29.5	26JUL78	51.7
02MAY78	43.1	31JUL78	50.4
03MAY78	19.3	01AUG78	50.9
05MAY78	40.9	07AUG78	46.9
11MAY78	47.0	08AUG78	48.9
16MAY78	45.4	14AUG78	44.4
25MAY78	39.5	15AUG78	44.2
08JUN78	36.0	21AUG78	47.3
09JUN78	38.5	22AUG78	49.9
15JUN78	43.1	28AUG78	44.6
20JUN78[3]	23.0	29AUG78	44.7
21JUN78[3]	21.0	03SEP78	47.2
27JUN78[3]	44.5	04SEP78	45.4
28JUN78[3]	43.4	09SEP78	46.9
29JUN78[3]	43.1	10SEP78	45.0
05JUL78	44.4	20SEP78	43.9
10JUL78	47.4	21SEP78	45.6
11JUL78	49.5	23SEP78	46.3
17JUL78	52.1	24SEP78	44.7
18JUL78	49.8	30SEP78[4]	43.8

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[1] Reported values are for tensiometers placed at 76 cm below the soil surface.

[2] Depths are measured from the soil surface.

[3] Data influenced by disruption of effluent delivery system. Details of this and other disruptions of effluent delivery are given in Appendix Table

[4] Inbed effluent depths were obtained from inbed well measurements after September 30, 1978.

Appendix Table A-6. Inbed effluent depths and selected exbed ground water depths in the standard filter field.

Date	Water depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	C1	D1	Mean	A1	B1	B2	Mean
20SEP78[1]	35.6	34.3	35.0	68.6	50.8	54.6	58.0
23SEP78	47.2	45.6	46.0	62.8	53.9	59.4	58.7
30SEP78	44.6	43.6	44.1	83.7	97.5	72.8	84.7
10OCT78	45.4	45.7	45.6	102.7	77.5	59.4	79.9
14OCT78	45.0	45.4	45.2	75.2	D[2]	67.8	
21OCT78	43.0	41.3	42.2	105.7	D	68.7	
28OCT78	36.5	40.5	38.5	61.2	91.4	60.2	70.9
14NOV78	33.0	36.8	34.9	52.1	54.6	45.7	50.8
20NOV78	42.2	42.8	42.5	54.7	56.6	62.2	57.8
27NOV78	30.2	27.8	29.0	39.7	30.6	26.2	32.2
04DEC78	36.2	35.8	36.0	45.7	36.6	33.2	38.5
11DEC78	40.2	42.8	41.5	51.7	50.6	50.2	50.8
18DEC78	44.2	43.8	44.0	66.7	70.6	63.2	66.8
03JAN79	40.2	39.8	40.0	63.5	55.8	56.1	58.5
11JAN79	34.4	35.1	34.8	60.5	69.0	59.2	62.9
16JAN79	29.4	28.8	29.1	41.8	52.2	31.3	41.8
22JAN79	23.3	23.5	23.4	36.2	31.5	27.6	31.8
05FEB79	28.0	28.0	28.0	42.1	43.4	44.0	43.2
12FEB79	18.9	19.0	19.0	31.6	49.6	22.1	34.4
19FEB79	32.2	31.9	32.1	47.9	44.6	45.5	46.0
26FEB79	11.7	11.6	11.7	23.2	17.7	11.6	17.5
04MAR79	20.0	19.7	19.9	33.9	28.1	21.6	27.9
12MAR79	33.3	33.0	33.2	50.0	50.6	54.0	51.5
19MAR79	19.6	19.4	19.5	33.0	31.2	19.6	27.9
26MAR79	31.1	31.0	31.1	43.9	42.7	41.1	42.6
02APR79	24.9	24.7	24.8	35.2	29.0	24.3	29.5
09APR79	34.0	33.6	33.8	47.5	54.6	54.4	52.2
16APR79	32.9	32.7	32.8	49.0	45.2	48.2	47.5
23APR79	34.1	33.9	34.0	61.1	D	60.7	
30APR79	33.3	34.2	33.8	60.5	86.9	61.3	69.6
07MAY79	31.2	31.0	31.1	44.1	42.5	40.2	42.3
13MAY79	29.2	32.0	30.6	46.2	43.0	41.9	43.7
20MAY79	30.2	30.5	30.4	42.6	37.4	32.4	37.5

Appendix Table A-6. Inbed effluent depths and selected exbed ground water depths in the standard filter field. (continued)

Date	Water depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	C1	D1	Mean	A1	B1	B2	Mean
27MAY79	33.6	31.2	32.4	59.8	72.7	58.4	63.6
04JUN79	31.5	31.4	31.5	44.7	42.4	42.8	43.3
12JUN79	32.6	32.4	32.5	54.5	52.6	50.3	52.5
18JUN79	35.9	36.1	36.0	81.7	D	77.6	
24JUN79	37.1	36.8	37.0	D	D	86.2	
02JUL79	38.8	38.6	38.7	57.7	57.7	55.2	56.9
08JUL79	37.2	37.5	37.4	51.6	42.8	45.3	46.6
16JUL79	37.7	37.7	37.7	80.3	83.0	72.3	78.5
22JUL79	38.2	38.1	38.2	70.8	75.2	69.5	71.8
29JUL79	37.2	37.2	37.2	51.8	44.4	48.4	48.2
06AUG79	36.7	36.3	36.5	63.5	59.7	57.1	60.1
13AUG79	36.9	36.7	36.8	79.8	99.6	69.4	82.9
20AUG79[3/]	51.5	51.5	51.5	95.2	99.3	87.7	94.1
27AUG79	45.0	44.8	44.9	94.5	100.0	103.2	99.2
04SEP79	44.2	44.0	44.1	95.0	98.4	84.5	92.6
10SEP79	45.7	47.4	46.6	95.9	D	D	
17SEP79	47.0	48.1	47.6	96.4	D	D	
24SEP79	48.3	47.7	48.0	D	D	D	
01OCT79	47.5	47.9	47.7	D	D	D	
08OCT79	50.9	51.9	51.4	D	D	D	
15OCT79	47.7	50.2	49.0	93.3	D	D	
22OCT79	46.1	44.9	45.5	94.1	D	56.3	
29OCT79	46.5	47.4	47.0	89.7	98.0	74.0	87.2
05NOV79	43.4	45.0	44.2	63.7	57.9	56.4	59.3
12NOV79	42.9	42.3	42.6	54.8	49.6	51.6	52.0
19NOV79	41.2	41.4	41.3	58.1	73.9	58.9	63.6
26NOV79	41.4	40.8	41.1	55.9	50.0	53.9	53.3
03DEC79[3/]	46.9	47.4	47.2	69.8	98.0	69.3	79.1
10DEC79	40.8	40.0	40.4	63.5	70.0	55.2	62.9
17DEC79	40.5	40.9	40.7	62.9	66.4	54.8	61.4
23DEC79	35.5	35.6	35.6	44.1	50.1	32.2	42.1
02JAN80	38.7	38.1	38.4	53.2	56.1	49.2	52.8
07JAN80	36.8	36.8	36.8	49.8	58.4	42.7	50.3

Appendix Table A-6. Inbed effluent depths and selected exbed ground water depths in the standard filter field. (continued)

Date	Water depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	C1	D1	Mean	A1	B1	B2	Mean
14JAN80	37.6	37.3	37.5	57.8	64.9	53.8	58.8
21JAN80	33.0	30.0	31.5	46.7	59.1	40.5	48.8
29JAN80	36.6	36.4	36.5	60.9	68.5	55.5	61.6
04FEB80	35.7	35.5	35.6	61.2	67.7	54.7	61.2
11FEB80	34.4	34.6	34.5	49.5	64.2	48.8	54.2
18FEB80	33.5	35.0	34.3	47.2	43.8	42.7	44.6
25FEB80	34.4	34.1	34.3	49.2	62.1	48.6	53.3
03FEB80	35.8	34.8	35.3	63.1	69.4	57.4	63.3
10MAR80	35.1	35.4	35.3	64.8	72.0	60.3	65.7
17MAR80	11.9	10.8	11.4	27.2	18.9	16.0	20.7
24MAR80	13.2	13.2	13.2	26.3	19.5	14.5	20.1
31MAR80	18.6	18.0	18.3	31.1	26.8	20.6	26.2
07APR80	34.6	34.5	34.6	54.0	54.5	54.7	54.4
14APR80	34.6	34.8	34.7	71.3	70.5	60.9	67.6
21APR80	34.2	33.9	34.1	70.4	99.3	62.8	77.5
28APR80	34.0	34.3	34.2	57.8	94.9	55.9	69.5
05MAY80	32.8	33.6	33.2	104.2	98.5	62.6	88.4
12MAY80	35.4	36.2	35.8	105.2	99.8	72.1	92.4
19MAY80	29.1	28.6	28.9	38.8	35.6	30.8	35.1
26MAY80	34.3	33.5	33.9	56.2	62.4	54.2	57.6
02JUN80	33.3	33.1	33.2	56.8	65.9	57.1	59.9
09JUN80	35.9	35.4	35.7	81.5	99.3	77.9	86.2
23JUN80	26.5	26.0	26.3	35.9	28.1	28.3	30.8
30JUN80	39.4	34.4	36.9	70.7	58.0	58.4	62.4
07JUL80	39.1	38.3	38.7	103.2	73.1	73.8	83.4
14JUL70	40.7	40.7	40.7	D	94.6	113.1	
21JUL80	45.3	44.9	45.1	D	D	D	
28JUL80[3/]	53.1	54.6	53.9	D	D	D	
04AUG80[3/]	49.7	48.0	48.9	D	D	D	
11AUG80	49.4	48.8	49.1	D	D	D	
18AUG80	46.1	45.8	46.0	D	D	D	
25AUG80	48.7	48.1	48.4	D	D	88.7	
01SEP80	49.9	48.9	49.4	D	D	80.9	

Appendix Table A-6. Inbed effluent depths and selected exbed ground water depths in the standard filter field. (continued)

Date	Water depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	C1	D1	Mean	A1	B1	B2	Mean
08SEP80	53.6	58.6	56.1	D	D	93.2	
15SEP80	50.8	49.7	50.3	D	D	69.7	
22SEP80	50.2	51.1	50.7	D	D	66.1	
29SEP80	42.2	47.7	45.0	D	D	72.3	

[1] Values assumed to be erroneous.

[2] D indicates the well was dry.

[3] Data significantly influenced by disruption of effluent delivery system. Values not used in regression model relating inbed levels to exbed levels. Details of these and other disruptions of effluent delivery are given in Appendix Table A-3.

Appendix Table A-7. Inbed effluent depths and selected exbed ground water depths in the modified standard filter field.

Date	Well depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	A1	B1	Mean	C2	C3	D3	Mean
20SEP78[1/]	26.7	27.9	27.3	D	45.8	57.2	
23SEP78	D[2/]	D		D	62.4	60.3	
30SEP78	D	D		D	62.1	65.1	
10OCT78	D	D		56.1	59.0	60.9	58.7
14OCT78	D	D		55.7	64.6	62.5	60.9
21OCT78	D	D		55.7	61.3	63.8	60.3
28OCT78	D	D		D	59.5	55.2	
14NOV78	25.5	25.4	25.5	D	45.8	44.6	
20NOV78	D	D		D	62.8	55.8	
27NOV78	D	D		37.5	36.8	37.8	37.4
04DEC78	D	D		49.5	56.8	40.8	49.0
11DEC78	D	D		D	61.8	49.8	
18DEC78	D	D		55.5	62.8	53.8	57.4
03JAN79	D	D		56.1	62.1	50.1	56.1
11JAN79	D	D		51.3	55.3	38.3	48.3
16JAN79	D	D		52.5	54.0	30.9	45.8
22JAN79	28.9	28.3	28.6	47.8	45.5	36.8	43.4
05FEB79	D	30.0		54.6	55.1	43.3	51.0
12FEB79	28.6	26.9	27.8	31.8	31.7	29.6	31.0
19FEB79	D	D		54.7	55.1	44.6	51.5
26FEB79	27.2	26.3	26.8	36.5	34.8	27.6	33.0
04MAR79	26.7	25.5	26.1	44.1	40.3	33.6	39.3
12MAR79	D	D		55.2	57.0	46.8	53.0
19MAR79	26.8	26.8	26.8	38.2	38.0	36.0	37.4
26MAR79	D	D		54.0	56.0	47.0	52.3
02APR79	26.1	25.1	25.6	39.9	39.6	38.5	39.3
09APR79	D	D		D	55.3	52.6	
16APR79	D	D		D	D	48.5	
23APR79	D	D		D	56.9	61.7	
30APR79	D	D		D	59.4	61.3	
07MAY79	D	D		51.7	55.6	46.9	51.4
13MAY79	D	D		50.5	55.9	47.1	51.2
20MAY79	D	D		44.5	45.1	42.2	43.9

Appendix Table A-7. Inbed effluent depths and selected exbed ground water depths in the modified standard filter field. (continued)

Date	Well depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	A1	B1	Mean	C2	C3	D3	Mean
27MAY79	D	D		D	59.2	65.2	
04JUN79	D	D		53.1	54.9	47.1	51.7
12JUN79	D	D		53.4	56.1	44.4	51.3
18JUN79	D	D		D	71.7	86.3	
24JUN79	D	D		D	D	D	
02JUL79	D	D		57.6	58.4	55.8	57.3
08JUL79	D	D		49.0	55.9	46.7	50.5
16JUL79	D	D		D	64.4	90.1	
22JUL79	D	D		D	61.2	71.8	
29JUL79	D	D		51.8	57.3	51.2	53.4
06AUG79	D	D		56.7	58.4	59.5	58.2
13AUG79	D	D		D	79.7	D	
20AUG79[3/]	D	D		D	78.5	D	
27AUG79	D	D		D	79.1	D	
04SEP79	D	D		D	64.1	94.4	
10SEP79	D	D		D	82.1	D	
17SEP79	D	D		D	83.1	D	
24SEP79	D	D		D	82.6	D	
01OCT79	D	D		D	D	D	
08OCT79	D	D		D	D	D	
15OCT79	D	D		D	D	D	
22OCT79	D	D		D	64.2	D	
29OCT79	D	D		D	81.8	93.8	
05NOV79	D	D		D	64.2	D	
12NOV79	D	D		D	64.2	66.5	
19NOV79	D	D		D	D	D	
26NOV79	D	D		D	64.6	67.4	
03DEC79[3/]	D	D		D	D	D	
10DEC79	D	D		D	D	D	
17DEC79	D	D		D	D	D	
23DEC79	D	D		41.0	41.8	45.9	42.9
02JAN80	D	D		52.7	61.6	52.3	55.5
07JAN80	D	D		48.5	64.1	46.5	53.0

Appendix Table A-7. Inbed effluent depths and selected exbed ground water depths in the modified standard filter field. (continued)

Date	Well depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	A1	B1	Mean	C2	C3	D3	Mean
14JAN80	D	D		D	61.6	61.2	
21JAN80	D	D		D	57.6	48.3	
29JAN80	D	D		D	63.5	66.7	
04FEB80	D	D		D	63.9	60.9	
11FEB80	D	D		D	D	D	
18FEB80	D	D		D	64.9	55.8	
25FEB80	D	D		D	D	63.9	
03MAR80	D	D		D	D	D	
10MAR80	D	D		D	D	D	
17MAR80	19.7	19.1	19.4	23.4	20.6	19.3	21.1
24MAR80	23.0	22.2	22.6	26.4	26.9	22.3	25.2
31MAR80	D	D		41.1	40.9	34.7	38.9
07APR80	D	D		D	55.2	60.7	
14APR80	D	D		54.4	55.6	64.9	58.3
21APR80	D	29.2		54.7	55.6	64.0	58.1
28APR80	D	D		52.8	56.6	55.6	55.0
05MAY80	D	D		D	61.2	80.8	
12MAY80	D	D		D	D	93.4	
19MAY80	D	D		42.5	44.4	36.6	41.2
26MAY80	D	D		53.9	59.8	57.6	57.1
02JUN80	D	D		D	62.8	62.0	
09JUN80	D	D		D	D	94.7	
23JUN80	D	D		44.1	40.6	32.9	39.2
30JUN80	D	D		D	64.9	68.8	
07JUL80	D	D		D	D	18.8	
14JUL80	D	D		D	D	71.0	
21JUL80	D	D		D	D	72.0	
28JUL80[3/]	D	D		D	D	D	
04AUG80[3/]	D	D		D	D	D	
11AUG80	D	D		D	D	D	
18AUG80	D	29.1		D	D	D	
25AUG80	D	D		D	D	D	
01SEP80	D	D		D	D	94.6	

Appendix Table A-7. Inbed effluent depths and selected exbed ground water depths in the modified standard filter field. (continued)

Date	Well depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	A1	B1	Mean	C2	C3	D3	Mean
08SEP80	D	D		D	D	D	
15SEP80	D	D		D	D	D	
22SEP80	D	D		D	D	D	
29SEP80	D	D		D	D	D	

[1] Values assumed to be erroneous.

[2] D indicates the well was dry.

[3] Data significantly influenced by disruption of effluent delivery system. Details of these and other disruptions of effluent delivery are given in Appendix Table A-3.

Appendix Table A-8. Criteria for excluding well data from the regression model of inbed and exbed well depths for the standard filter field.

Length of time that no effluent was delivered	Minimum time between termination of effluent delivery failure and well level measurement
Days	Days[1]
0.3	1
0.5	2
1	3
2	4
3	5
4	6
5	7
6	8
7	9
8	10
9-13	13
13-21	20

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[1] Exclude data if minimum time is not met.