Adaptability of selected Montana soils for septic tank sewage disposal
by Alfred Phillip Keppner

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Soils
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Abstract:

Excavation of septic tank filter fields and analysis of soil samples suggested that most nitrogen and phosphorus in sewage effluent accumulated within 5 meters of the point of input to the, soil.

Amsterdam soils were found to be highly adapted to conventional septic tank sewage disposal as was a site located on a gradation between Leavitt and Bigel soils. The Bigel-Bearmouth site examined showed that a mound type system may be utilized to overcome a limitation caused by an impervious layer. Huffine soils are subject to seasonal high water and a system that raises the drain tiles above high water must be used. On the Alluvial soils along the Gallatin River high water table and spring flooding make these soils unacceptable as sites for on-site sewage disposal. From this study and the literature predictions of effluent behaviour were extrapolated to developable soils in Gallatin Canyon where installed systems were unavailable for study. Bearmouth, Bigel, and Hanson soils, being skeletal, are poor filtering media and design criteria such as a mounded system may be needed to overcome this limitation. Hobacker soils are adapted to on-site sewage disposal although sites with slopes in excess of 15 percent should be avoided. Leavitt and Michelson soils will function well as septic tank filter fields.

The total nutrient load, in terms of nitrogen and phosphorus, for the Gallatin Canyon was calculated with respect to present human activity and projected human activity in 1985. Increase in residents appears to be the greatest concern with respect to increases of nitrogen and phosphorus disposal as compared to travellers or the Big Sky development.

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Signature Alfred Phillip Keppner, Jr.

Date 10 August, 1972

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by

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A thesis submitted to the Graduate Faculty in partial
fulfillment of the requirements for the degree

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in

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INTRODUCTION

Green photosynthetic plants in terrestrial and aquatic environments produce their substance from carbon dioxide, water, and minerals with the utilization of solar energy. Directly or indirectly all living creatures derive subsistence from these plants. Part of this material is excreted and all ultimately reverts back to the environment to be decomposed by microorganisms. Compounds of nitrogen and phosphorus are produced which can be utilized by plants once again.

There is no avoiding this cycle which is something man is prone to forget, especially the modern city dweller with his municip~~le~~al sewage system. All organic material is eventually returned to the land, the water, or the air. Man may not be able to escape this cycle, but he can alter it violently.

In sewage treatment the nutrient end-products are produced by controlled microbiological systems. Any factor which is resistant to natural or engineered treatment processes is said to be refractory to such processes. Of particular interest in this group of compounds are common nitrates and phosphates which serve as fertilizers in the natural cycle of growth and decay. By means of improper disposal they may enter an aquatic environment. This can stiumlate a profuse growth of algae in water, thus increasing the biological oxygen demand of lakes and of streams and leading to eutrophication.

The soil mantle has been acknowledged as a natural filter with a capacity to dispose of sewage wastes. Each soil has its own particular chemical and physical properties, and each soil has its own accommodation for constituents of sewage effluents. This axiom is valid for all nutrients including phosphorus and nitrogen.

The primary source of phosphate is synthetic detergents. Their use began in the early 1940's and increased to an approximate 1.8×10^9 kg/yr within the next 25 years. Of this vast amount 75 percent of the active ingredients were alkylbenzenesulfonate or ABS. The U. S. Public Health Service found that biologically active sand systems were capable of degrading ABS (105). The University of California confirmed this with studies on finer soils (69) and in field investigations at Caltech (82).

However, due to the refractory nature of ABS to conventional treatment processes, strong public opinion precipitated proposed legislation prohibiting manufacture and sale of ABS. Industry responded to the situation by an intensive search for a biodegradable substitute for ABS and in 1965 began using a new product, linear alkylsulphorate or LAS. From the standpoint of wastewater disposal in the soil mantle, a septic tank system with a properly engineered drain field can remove up to 97.4 percent of the LAS as compared to only 73.9 percent of the ABS (77). With improperly engineered systems or installation on unsuitable sites, this material may enter groundwater or reach surface water.

It is conceivable that nitrogen in the form of nitrates could enter groundwater or reach surface water if septic tank drain lines are installed in unsuitable soils or are improperly engineered. The addition of phosphorus or nitrates to the surface water could lead to eutrophication.

Nitrate in drinking water has been associated with a sometimes fatal blood disorder in infants called methemoglobinemia. Up to 1970 approximately 2,000 cases have been reported in Europe and North America with about 7 to 8 percent being fatal (144). These figures represent only a fraction of observed cases for the disease is not contagious and need not be reported.

For sewage disposal in the soil the septic tank drain fields is the adsorption system. A subsurface tile structure is installed to facilitate a uniform distribution of effluent into the soil. The effluent is discharged from near the top of the septic tank and passes through these perforated tiles. Criteria used to rate a soils ability to dispose of sewage effluent are based upon its capacity to absorb it.

The 6 most important factors in determining the suitability of a soil as a septic tank absorption field are (a) permeability of the subsoil, (b) depth to impervious layers, (c) flooding hazard, (d) the level of groundwater, (e) slope, and (f) local experience and records of performance of existing filter fields (123). The United States Soil Conservation Service soil limitation classes for septic tank filter fields based upon the above criteria are given in Table 16.

A quarter of all new homes are being equipped with septic tanks, and nearly 15 million families now depend on them (50). If this effluent is improperly disposed of into the soil, compounds of nitrogen and phosphorus can create detrimental environmental circumstances for individuals and society.

It was the purpose of this study to examine 5 Gallatin County soil series to ascertain the extent of nutrient spreading in operating septic tank drain fields and to determine their ability to accommodate nitrates and phosphorus. The conclusions reached from the study combined with counsel from the literature will be used to predict the adaptability of six developable Gallatin Canyon soil series for the disposal of domestic sewage effluent. Operating septic tank systems were unavailable for study on these soils.

With projected development in Gallatin Canyon in the near future, it would be prudent to consider the sources of additional nutrients to the Gallatin Canyon ecosystem from wastes. Therefore, an evaluation of the nutrient load from man and from elk was compiled for the present and for predicted occupation in 1985 and presented in Tables 1 to 15.

Finally, based upon this study and related research reported in the literature some future studies are proposed.

LITERATURE REVIEW

Most studies relating to the soil's ability to dispose of sewage effluent have involved applying domestic sewage, after various degrees of treatment, directly to the soil through the surface or by the use of soil columns of various sizes. Biological contamination was the primary consideration in most of the earlier studies.

One of the earliest experiments was conducted by the city of Los Angeles in the early part of the 1930's (47). In this study sewage was given primary and secondary treatment before being introduced into the ground. In 1949 the County of Los Angeles carried out more extensive tests (6) where bacterial contamination of percolate was reported to be reduced to a level below the maximum permitted by the U.S. Public Health Service Standards after a movement downward of 213 cm. Studies of surface spreading at Whittier and Azusa, California (79) led to the conclusion that water of a bacterial quality suitable for drinking purposes can be obtained by passage through a minimum of 91 to 213 cm of fine textured soil.

One of the most recent and thorough studies of reclamation of water from sewage effluents was the Santee Project near San Diego, California. Here tertiary treated sewage was pumped to 6 percolation beds in parallel across a shallow stratum of sand and gravel confined to an old stream bed. The infiltered water moved down this channel to an interceptor trench dug across the channel at 457 m, passing enroute sampling wells at 61 and 122 m. Most bacteria and virus removal occurred within the first 61 m. This study did not show at what distance the infiltrate reached U. S. Public Health Service drinking water standards, but it did illustrate removal of bacteria in a very coarse medium.

Further biological studies in Colorado by Romero (106) illustrate some outstanding characteristics of movement of pollutants through porus media. Basically he found that (a) pollutants travel with the flow of water; they do not travel or move against the current, (b) that pollutants can move in a direction opposite to that of normal groundwater gradients during times of recharge, (c) that bacteria and virus are removed by their inability to adjust to abrupt temperature changes, by oxygenation and nitrification, and destruction by pre-existing soil microorganisms, (d) that aquifer materials best suited for the removal of biological contaminants are those uniformly composed of very fine grained sand with a high clay content, (e) that for an ideal system the maximum length of travel of biological pollutants with groundwater ranges between 15 and 30 m, (f) that pollution travel in nonsaturated systems is considerable less than that in saturated systems in that maximum lengths of travel appear to be in the vicinity of 3 m, and (g) that bacteria and/or virus infested pollutants might travel farther than predicted if nutrient laden waters are intercepted during the course of penetration for nutrients stimulate reproduction.

In the early 1950's field investigations of sewage reclamation by surface spreading were conducted by the Sanitary Engineering Research Laboratory of the University of California. Extensive chemical and bacteriological investigations were made to determine the efficiency of sewage reclamation (29). On a sandy loam soil sewage could be chemically reclaimed at application rates of 1.5 ml/1 cm^2. They also demonstrated that bacteriologically safe water can be produced by passing effluent from primary treated sewage through a minimum of 122 cm of the soil under study.

An investigation of sewage spreading on 5 California soils was conducted by the University of California Sanitary Engineering Research Laboratory after the conclusion of the studies on the sandy loam soil. Here 91 by 151 cm lysimeters were filled with soil and sewage effluent allowed to pass. It was discovered that coliform bacteria removal was generally higher in the fine textured soils. Also cation exchange took place to a considerable degree during sewage spreading, the most common effect being the substitution of sodium, potassium, and ammonium ions for calcium and magnesium (110).

Extensive studies have been conducted on maintaining the infiltrative capacity of a soil system by the Sanitary Engineering Research Laboratory of the University of California (79). The conclusions reached to date are as follows: (a) the infiltrative surface should be no less permeable than any undisturbed parallel plane within the system, (b) the soil surface should be managed in such a fashion as to disperse clogging material, (c) there should be no abrupt change in particle size between coarse trench fill or surface cover material and the soil at the infiltrative surface, (d) the infiltrative system should provide a maximum of sidewall surface and a minimum of bottom surface, (e) continuous inundation of the infiltrative surface must be avoided, (f) aerobic conditions should be maintained in the soil system, (g) the entire infiltrative surface should be loaded uniformly and simultaneously, and (i) the amount of suspended solids and nutrients in the applied wastewater should be minimized.

The use of sewage effluent for irrigation purposes as a method of disposal has been considered most extensively by the Pennsylvania State University. Pennypacker et. al. (98) showed that using secondary effluent to irrigate forest land ABS concentration decreased below U. S. Public Health Service Standards for potable water after travel through a minimum of 0.9 m of mineral soil when effluent application was 10 cm/wk.

Parizek and Myers (96) summarized the work reported to date by Kardo (62) (63), Sopper (116), and Sopper and Sagmuller (119). They state that uniform distribution of the returned effluent is a necessity throughout the entire year, which frequently includes periods of freezing temperatures. The rate of application must be slow enough and the amount small enough to insure infiltration and removal of the pollutants. In the Pennsylvania State study the application rate was

6.35 mm/hr, the most frequently used amount was 5 cm/wk, and satisfactory distribution was achieved down to temperatures of -24.5°C.

The renovation zone must remain efficient from year to year and throughout the entire year. In properly managed cropland renovation areas, the nutrients taken from the wastewater are removed from the area with the harvested crops. At Pennsylvania State a high degree of renovation is being achieved after over 762 cm of effluent have been applied during 5 years.

Winter irrigation requires special attention to management detail. Nutrients must not be added faster nor in greater amounts than can be adsorbed and retained in the upper soil profile for summer use.

Disposal of sewage effluent through irrigation of forest stands seems to be feasible from the standpoint of tree growth. Coniferous species adapted to moist sites would be the most desirable for use in this type of project (118). Also considered in the Pennsylvania State studies was the beneficial aspects of raising soil p^H on acid sites with sewage effluent, especially strip mined areas (117).

For years percolation tests have been used to estimate the hydraulic conductivity of the soil to give an indication of its ability to accept sewage effluent from septic tanks. The best known and most widely employed estimate of hydraulic conductivity of the soil is the auger hole percolation test which is described in the Public Health Service's "Manual of Septic-Tank Practice" (76). This is an on site attempt to determine the capacity of a soil to accept water. Henry Ryon (108) is considered as the one who first devised the percolation test in 1926. Fedrick (40) published Ryon's work in 1948. His test consisted of digging a hole 31 cm square and 46 cm deep. The hole was saturated and excess water allowed to seep into the ground. The hole was then filled with water to a depth of 15 cm and the time required for the water surface to lower 2.5 cm was observed.

Kiker (66) noted in 1953 that, "Ryon recognized that there was an initial blotting effect at the beginning of tests in dry soil. He emphasized the necessity of having the soil thoroughly wet before measuring the percolation rate". Ryon did not describe an explicit procedure for presoaking a test hole.

To explore the reliability of this method to indicate whether a septic tank installation will fail, the Robert A. Taft Sanitary Engineering Center of the Public Health Service reported results of field studies utilizing the same techniques as Ryon. The loading rate of each system was determined and its history noted (18). A comparison of data on percolation rates, loading rates, and age indicated a large coefficient of variability. They suggested that the variability of the data demonstrated that the relationship between percolation rates and sewage loading rates was a poor indicator for accurate design criterion.

Persinger and Yahner (99) in Indiana found a highly significant correlation on glacial outwash, glacial till, and lucustrine soils between percent sand and percolation rates. They infer that with a knowledge of the characteristics of each soil series, soil texture inferred from soil maps can be a substitute for percolation rates within broad limits.

Ryon's original percolation test has been subject to modification through the years. All state health departments adopted standard procedures. With various modifications these were used by numerous agencies having authority over septic tank installations. The U. S. Public Health Service through the Robert A. Taft Sanitary Engineering Center has modified the procedure as a result of experimental studies (16), (17), (138), (139). This was an attempt to reduce the coefficient of variability. Its current provisions are found in the U. S. Public Health Service's "Manual of Septic-Tank Practice". It can also be found in the Montana State Department of Health regulations (85).

At the University of Wisconsin in Madison, it has been demonstrated that the falling head procedure for the determination of percolation rates can reduce the coefficient of variability to 35 percent (22). The double tube method described by Bouwer (23), (24), (25) and modified in 1967 (26) was used in a Wisconsin study to determine the hydraulic conductivity (K) values for saturated soils being used as seepage beds for septic tank systems. Soil moisture tensions were also recorded around operating, partly filled seepage beds in different soils indicating the occurance of low folow rates through unsaturated soils due to crusting at the soil interface of the seepage beds.

A field experiment (22) with dosing of effluent was made to demonstrate that system management will determine which K values from a measured range applies at any given time. Using the Bouwer double tube method, they proposed that the measurement of hydraulic conductivity in situ as a function of soil moisture tension be used as a field test to determine soil potential for effluent disposal.

It has been well documented that phosphorus from fertilizer moves very little in soils. This implies that soils can be used to reduce the level of phosphorus in sewage effluent. The Pennsylvania State University studies (95) confirmed the validity of that statement. The same mechanism should function either when spreading by sprinkler irrigation to a large area or seepage from the drain field of a septic tank system.

Olsen and Watanabe (91) have suggested a method for the application of the Langmuir isotherm to the study of phosphorus adsorption by soils. The Langmuir equation was developed (73) through the kinetic theory of gases to describe adsorption of gases on solids. Studies in Maine (48) indicate that the Langmuir equation can be used to describe the relationship between phosphorus retention and concentration. Ellis and Erickson (38) present a simplified derivation of the equation for the case of phosphorus adsorption by soils. It is a linear form of the equation expressed as: $\frac{(p)}{x/m} = \frac{1}{Kb} + \frac{(p)}{b}$ where (p) is the activity of phosphorus in solution in moles/liter, x/m is the mg phosphorus adsorbed per 100 grams soil, b is the maximum amount of phosphorus that will be adsorbed by a given soil, and K is a constant.

Removal of phosphorus from sewage effluent by soils depends not only upon the adsorption maximum of soils but also on the level of phosphorus in the soil solution at equilibrium. Ellis and Erickson suggest the use of the method of White and Beckett. Gillham and Webber (46) found that over 90 percent of the inorganic nitrogen in contaminated groundwater was in the nitrate form. To lend credence to this widely accepted idea, Preul and Schroepfer (103) conducted extensive experiments using water containing 25 mg/l ammonium nitrogen and neglibible concentrations of nitrite and nitrate nitrogen as representative of wastewater that might be released for disposal in the soil. This hypothesis was verified by Babbitt and Baumann (7) and McGauhey (77). They found that the major part of nitrification took place in the initial 60 cm from the source with adsorption of ammonia accounting for most of the remainder of nitrogen. After operation of a system for about 2 weeks, which was required to develop the microbial populations, adsorption was of minor significance and nitrification was the totally dominant factor.

METHODS

The Amsterdam series was selected for study because it has developed over extensive areas of Gallatin County. The Amsterdam series consists of Typic Cryoborolls developing from aeolian deposits of Tertiary age. The typical profile (88) has a dark greyish brown silt loam Ap horizon, brown prismatic heavy silt loam B2 horizon, thin light yellowish brown prismatic silt loam B3ca, and a pale yellow silt loam IIC2ca horizon containing considerable shards of volcanic glass.

Residential development is common in Gallatin Canyon at the base of hills where there is a gradation from a soil developed on the slope to a soil developed on the valley floor. One such site was selected in a gradation between Leavitt and Bigel soils. The Leavitt series (88) is a member of the fine-loamy mixed family of Argic Cryoborolls. Generally they have a very dark grey stony loam A horizon, a greyish brown cobbly heavy clay loam B2t horizon, and a strongly calcareous, cobbly, heavy clay loam Cca horizon. The Bigel series (88) is a member of the loamy-skeletal, mixed family of Argic Cryoborolls. They have a dark greyish brown cobbly loam A horizon, a brown very gravelly and cobbly clay loam B2t horizon, and a loamy sand and gravel C horizon.

Extensive areas of Gallatin Canyon are occupied by an association of Bearmouth and Bigel soils. These sites are generally level and are favored for development. Therefore a septic tank system installed on these soils was selected for study. The Bearmouth soils (88) are members of the sandy-skeletal mixed family of Typic Cryoborolls. They have a dark greyish brown very gravelly loam A horizon overlying loamy sand and gravel at depths of around 30 cm.

Extensive areas of Huffine soils exist in Gallatin County. Although these are plagued by seasonal high water, they are favored for development because of their proximity to Bozeman. Therefore, it was deemed advisable to investigate a Huffine site. They are members (88) of the fine-silty over sandy or sandy-skeletal mixed family of Argic Cryoborolls. Typically they consist of granular, dark grey, silt loam A horizons, prismatic-blocky structure, silty clay loam B2t horizons, silt loam C horizons with prominent accumulations of calcium carbonate, and sand or sand and gravel substrata at depths of 50 to 100 cm.

The level areas adjacent to the Gallatin River are coveted as sites for development because of their proximity to aquatic environs. Therefore a septic tank installation on this alluvial material was studied.

Other soils in Gallatin Canyon, not already considered, that have development potential are Hanson, Hobacker, and Michelson. They occupy areas in private ownership and have some areas with slopes of less than 15 percent.

The Hanson soils are members of the loamy-skeletal, carbonatic family of Calcic Cryoborolls. Typically, Hanson soils have a dark greyish brown cobbly loam A horizon overlying very strongly calcareous very cobbly loam C horizons.

The Hobacker series (88) is a member of the loamy-skeletal, mixed family of Pachic Cryoborolls. Typically, they have a very dark greyish brown loam A horizon and very cobbly and gravelly lower A and C horizons that are calcareous.

The Michelson soils (88) are members of the fine-loamy, mixed family of Argic Cryoborolls. Generally they have a dark greyish brown loam A horizon, a brown, clay loam B2t horizon; and a prominent, very pale brown Cca horizon of loam and clay loam.

Field Procedures

A reconnaissance at each site under investigation ascertained the soil limitation class or each soil for the following factors: (a) the depth to impervious layers, (b) flooding hazard, (c) groundwater level, and (d) slope. Since permeability of the subsoil is a determining parameter for the extent to which sewage effluent will spread, percolation tests were performed at each site.

Since the auger hole method is the most universally adopted procedure for indicating percolation rates (27) (54), it was decided to use it in this study.

Excavations of a septic tank filter field at each site provided a method to determine the extent of sewage spreading in both a downward and outward direction. Pits were dug in the downslope direction utilizing hand tools, and soil samples were collected at regular intervals. Unbranched drain lines were selected so the point of sewage input could be determined. Locations of soil samples collected are given in Tables

18, 20, 22, 24, and 26 and in FIGURES 1 to 11.

These samples were analyzed for texture, water retention at saturation, electrical conductivity, pH, sodium bicarbonate soluble phosphorus, nitrate nitrogen, soluble potassium, soluble calcium, soluble magnesium, soluble sodium, and, on samples from one site, total phosphorus.

Laboratory Procedures

In the laboratory mechanical analysis was performed to determine soil particle size for each soil sample utilizing the Bouyoucos hydrometer method as described by Millar et. al. (84). Readings were taken at 40 seconds and 2 hours so results would correspond to the U. S. Department of Agriculture textural classification system.

Saturated moisture percent was determined by measuring the weight of water necessary to bring 100 grams of soil to saturation. Electrical conductivity was measured on saturated extract using a Serfass Conductivity Bridge Model RCM 15B1. Soil pH was determined on saturated paste using a Corning Model 12 Research pH Meter with a glass-calonel electrode pair.

Bicarbonate soluble phosphorus is the form that can be expected to move in the soils under study for they are chemically dominated by calcium. The procedure used is the extraction method of Olsen (89) and the ascorbic acid method of color development (4) (135). Readings were taken on a Bausch and Lomb Spectronic 20 spectrophotometer.

Many methods of nitrate determination are available to the researcher. Ferguson and Sowden (44) give a comparison of methods of determining nitrogen fractions in soils. A rapid method described by West (140) and perfected by Sims and Jackson (113) is a colorimetric determination utilizing chromotropic acid for color development. Being a relatively new procedure few investigators have used it and others may find difficulty in the interpretation of results. The phenoldisulphonic acid method is rapid for nitrate determination and is widely used. The results can be interpreted by many. Therefore, the phenoldisulphonic acid method was the procedure used (21).

Soluble salts may accumulate in soil that has been saturated with effluent. High sodium concentration would cause dispersal of the clays and hence failure of the system to accept effluent. The amounts of calcium would influence precipitation of phosphorus. Soluble salts were determined by standard methods described by Jackson (60) and Black et. al. (21) utilizing the 290-B Perkin-Elmer atomic absorption spectrophotometer to analyze filtrates for potassium, calcium, magnesium, and sodium.

The sodium carbonate fusion method described by Jackson (60) was used to extract total phosphorus from samples at one site. The ascorbic acid method of color development as used in the sodium carbonate soluble phosphorus determination was employed in this analysis. Readings were taken on the Bausch and Lomb Spectronic 20 spectrophotometer.

RESULTS

Amsterdam Soils

The septic tank system on this site was in operation for approximately 12 years serving a family of 5 that uses a washer but no garbage disposal. If the average person produces 200 liters of waste per day (77), approximately 4.38 x 10^6 liters of effluent have been added to the system. Using the average sewage analysis given by Babbitt and Baumann (7) as shown in Appendix Table 17, 219 kg of total nitrogen and 45 kg of phosphorus have entered the filter field. The auger hole percolation rate of the Amsterdam soil at this site was 12.3 cm/hr.

The data indicate that nitrates (Appendix Table 19 and Figure 1) have accumulated in the first 5.5 meters from the point of effluent input as indicated by a slight accumulation of 12.8ppm nitrate at the 267 cm depth located 5.5 meters from the drain line. Most nitrates accumulated within 2.5 meters of the point of input as illustrated by comparison of data for nitrate 1 meter above line and nitrates in the soil at similar depths 2.5 and 7.5 meters from the drain line. At depths of 15, 35, 61, and 91 cm, nitrate concentrations above the line are 51.5, 62.5, 26.5, and 15.5 ppm respectively while at the same depths 2.5 meters from the line, concentrations are 24, 4.4, 2.0, and 3.8 ppm respectively and at 7.5 meters 5.5, 1.0, 1.0, and 1.0 respectively. Figure 1 illustrates that nitrates near the point of input tend to accumulate more in the upper horizons due to upward movement of water as influenced by the vegetation.

Soluble phosphorus has accumulated in the first 2.5 meters from the drain line. The data (Table 19 and Figure 2) shows that at 5.5 meters from the line there is no difference in bicarbonate soluble phosphorus when compared to an unaffected area at 7.5 meters from the drain line. The affected area also shows an increase of total phosphorus (Table 19 and Figure 3) which is reasonable since an estimated 45 kg of phosphorus has been produced over the past 12 years.

From the data (Table 19) it can be seen that pH was not affected significantly by the addition of effluent. This is not surprising as effluent pH averages between 7.2 and 7.6 (77) and the Amsterdam soil is near neutral in the upper horizon to about 7.5 in the C_{ca}. The effluent added is approximately the same pH as the soil. The saturated moisture percent was not changed by the addition of septic tank effluent (Table 19). This would indicate that the system is operating properly and keeping organic material in the septic tank.

The electrical conductivity of the saturation extract ranged from a high of 3.75 mmhos/cm to a low of 0.35 mmhos/cm. The sodium adsorption-ratios were all low ranging from a low of 2.3 to a high of 6.1. This is to be expected as no water softener utilizing sodium salts has been used on the premises.

Leavitt-Bigel Soils

This site is located at the base of a gently slope in a gradation between Leavitt and Bigel soils. The septic tank and drain field have been in operation for approximately 11 years serving a family of 3 with a washer but no garbage disposal. Approximately 2.4×10^6 liters of effluent have been added to the system containing 120 kg of total nitrogen and 24 kg of phosphorus. The auger hole percolation rate at this site is 8.2 cm/hr.

The data (Table 21 and Figure 4) indicate that nitrates have traveled outward approximately 1.5 meters and downward 2 meters. Nitrate concentration at this point is 12.2 ppm while $\frac{1}{2}$ meter below this point it is only 1.5 ppm. Unlike the soil at the Amsterdam site, there was no large accumulation of nitrate in the upper horizon. The vegetation cover was sparse due to heavy use by horses and frequent trampling by men and machinery.

Data on soluble phosphorus (Table 21 and Figure 5) demonstrate little movement or accumulation beyond one half meter from the drain line or 1 meter below the line. Concentration at this point is 38.4 ppm while at 1 meter deep and 1.5 meters from the line the concentration is 33.6 ppm, and at one meter deep and 2.5 meters from the line it is 29.4 ppm. In an unaffected area 3.5 meters from the line and 3 meters deep the concentration of sodium bicarbonate soluble phosphorus is 24.3 ppm indicating little change 1.5 meters from the line when compared to an area unaffected by sewage effluent.

Soil pH within 0.5 meter of the drain line was lower than in samples at similar depth but farther from the drain line. This may be caused by the high reducing conditions created by constant saturation. Since this is not a significant distance from the line to affect management decisions and the first one half meter of soil has been disturbed, this fact has no significance. The saturation moisture percent was not changed by the addition of septic tank effluent.

The electrical conductivity of the saturation extract ranged from a high of 1.5 mmhos/cm at the sampling point nearest the area of effluent input to a low of 0.25 mmhos/cm. At this site the sample most saturated with effluent had the highest electrical conductivity which illustrated the fact that it had the highest concentration of soluble salts. The sodium adsorption ratios ranged from a low of 0.8 to a high of 10.0 indicating accumulations of sodium.

Bigel-Bearmouth Soils

This site is in the Bigel-Bearmouth association where the two soils are intermingled. The septic tank system has been in operation a minimum of 10 years on a seasonal basis by an average of 8 persons for about 4 months of the year. No washer or garbage disposal has been in use. Approximately 9.6 x 10^5 liters of effluent has been introduced into the system containing 48 kg of nitrogen and 9.6 kg of phosphorus. The auger hole percolation rate at this site is 7.1 cm/hr.

Data (Table 23 and Figure 6) indicate that nitrates have travelled at least 3 meters from the input point although this increase (2.5 ppm) is small compared to samples from unaffected areas (1.0 ppm). Most nitrates have accumulated within 2 meters of the drain line as noted by a concentration at 90 cm depth 2 meters from the line of 8.8 ppm. At the same distance from the line and 155 cm deep the concentration is only 3.3 ppm.

At this site rock was encountered at the bottom of each test hole. That is why excavation was not continued to greater depths. It is noted that nitrate has accumulated at the depth of the rock as illustrated in FIGURE 6. One half meter from the drain line and 95 cm deep nitrate concentrations of 14.8 ppm were found. An area unaffected by effluent 5 meters from the line at a depth of 90 cm had a concentration of 1.0 ppm.

Data on sodium bicarbonate soluble phosphorus (Table 23 and Figure 7) demonstrate maximum lateral movement of 3 meters but most accumulation is in the first 2 meters. At 5 meters from the input point in an area unaffected by effluent, bicarbonate soluble phosphorus concentrations at 90 cm was 13.1 ppm as compared to a concentration of 31.8 ppm meters distance and 90 cm deep. Greater accumulations at 2 meters from the line are in evidence. As in the case of nitrate, sodium bicarbonate soluble phosphorus has accumulated at the depth of the rock as illustrated in FIGURE 7.

The soil pH was highest in areas of sewage accumulation which were also calcareous. The electrical conductivity of the saturation extract ranged from a high of 1.4 mmhos to a low of 0.5 mmhos/cm indicating low concentrations of soluble salts. It was highest at the point of sewage input, but was nearly as high in the C_{ca} horizon. The sodium adsorption ratios were low ranging from 7.0 to 3.1.

Huffine Soils

The septic tank system on this site has been in operation for 3 years serving a commercial enterprise with only domestic wastes being disposed of through the system. It has been estimated that $4.4 \cdot 10^5$ liters of effluent have entered the drain field containing 22 kg of nitrogen and 4.4 kg of phosphorus. The auger hole percolation rate at this site was 4.7 cm/hr.

In the spring and during the irrigation season groundwater rises to within 46 cm of the surface. This has a profound effect on the spreading of sewage in the drain field. The movement of nitrates is not in evidence as the concentration in the site is 1.5 ppm or less except in the surface horizon near the drain line where the concentration is 4.4 ppm (Table 25 and Figure 8).

This same phenomenon can be observed (Table 25 and Figure 9) for sodium bicarbonate soluble phosphorus. The highest concentration of bicarbonate soluble phosphorus is at the 20 cm depth only 30 cm on each side of the drainage line. The concentrations are 31.8 and 35.5 ppm respectively. Only 3.5 meters from the line the concentrations at 20, 60, 100, 130, and 135 cm depths are 14.5, 13.8, 20.6, 11.5, and 14.5 ppm respectively giving a rather uniform concentration in the profile.

Soil pH was not significantly affected by the introduction of sewage effluent (Table 25). As in the case of the Amsterdam soils, effluent of pH 7.2 to 7.6 is being introduced into a soil of similar pH. The saturated moisture percent was not changed by the addition of septic tank effluent either.

The electrical conductivity of the saturation extract (Table 25) ranged from a high of 1.6 to a low of 0.4 mmhos. The highest electrical conductivity value was at the sample site nearest the tile line indicating the introduction of soluble salts into the system. The sodium adsorption ratio varied from a high of 10 to a low of 2.7 with the highest value being in the sample profile nearest the line. This indicates the addition of sodium to the soil system by effluent.

Alluvial Soils

This site is located in a low plain near the Gallatin River. It has about 1.0 meter of fine alluvial material over gravels. The groundwater generally was encountered at 60 to 90 cm depth preventing deeper excavation. In the spring of the year water rises to near the surface. The auger hole percolation rate at this site is 3 cm/hr.

The septic tank system at this site has been in operation for approximately 2 years serving 2 people with a washer but no garbage disposal. About 2.9 x 10^5 liters of effluent have been added to the system containing 14.5 kg of nitrogen and 2.9 kg phosphorus.

At the 20 cm depth just one half meter from the input point, the nitrate concentration is 59.1 ppm while concentrations of other samples vary from 9.2 to 1.0 (Table 27 and Figure 10). The only 2 samples with concentrations over 2.5 ppm are in the upper 15 cm where there is an accumulation of organic matter. These concentrations are 9.2 and 7.5 ppm.

Sodium bicarbonate soluble phosphorus (Table 27 and Figure 11) has concentrated near the line (103 ppm) while just 1.5 meters from the line the concentrations at 15, 45, and 65 cm depths are 16.3, 8.3, and 9.8 ppm respectively. The sodium bicarbonate soluble phosphorus has not traveled over a meter at this the most mesic site studied.

The soil pH was higher close to the tile line. The saturation moisture percent has not been affected by the addition of sewage (Table 27).

The electrical conductivity of the saturation extract ranged from a high of 1.80 to a low of 0.85 mmhos/cm. The sodium adsorption ratio varied from a high of 5.4 to a low of 1.5.

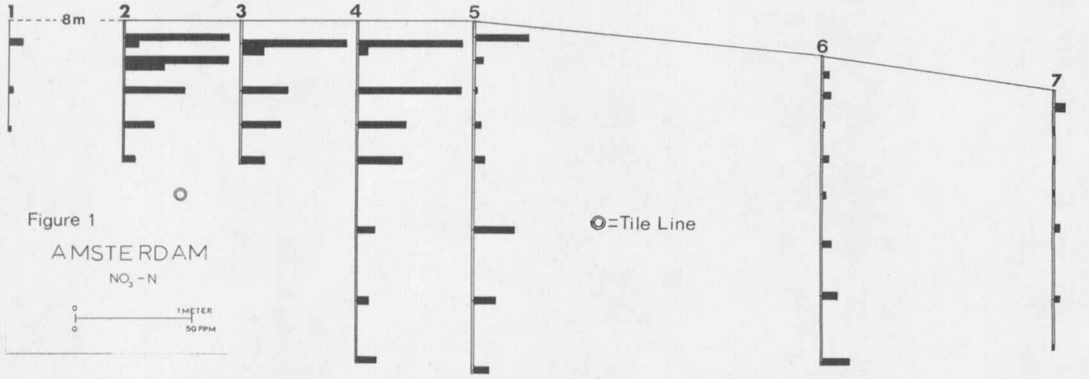


Figure 1

AMSTERDAM

NO_3-N

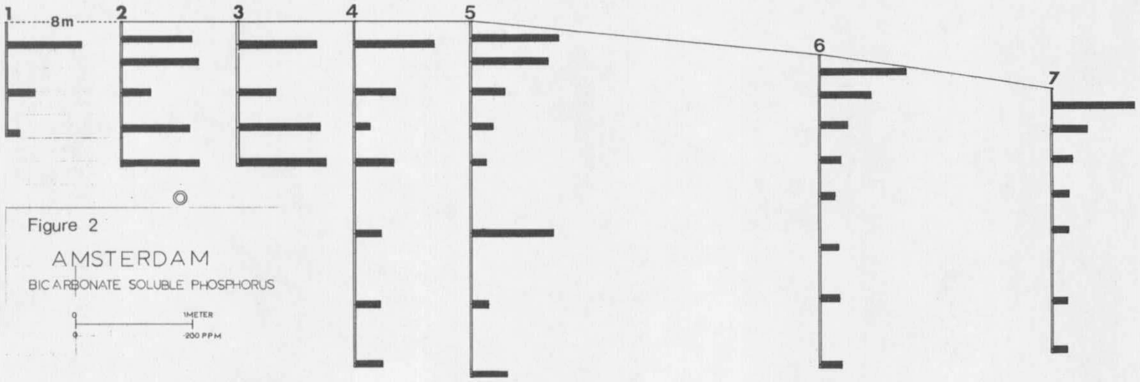


Figure 2

AMSTERDAM

BICARBONATE SOLUBLE PHOSPHORUS

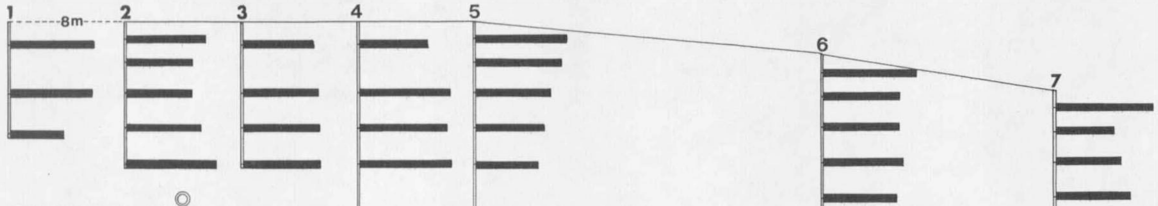


Figure 3

AMSTERDAM

TOTAL PHOSPHORUS

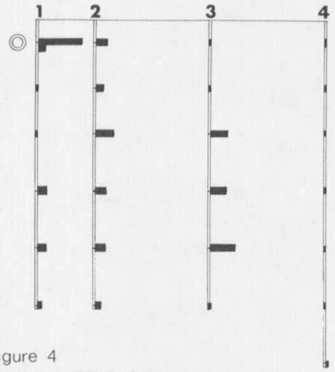


Figure 4
LEAVITT-BIGEL
NO_3 - N

0 1 METER
0 50 PPM

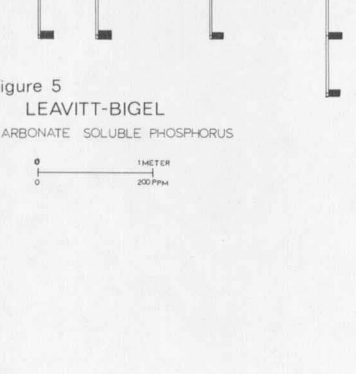


Figure 5
LEAVITT-BIGEL
BICARBONATE SOLUBLE PHOSPHORUS

0 1 METER
0 200 PPM

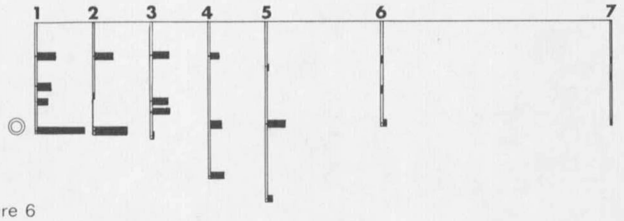


Figure 6
BIGEL-BEARMOUTH
NO_3 - N

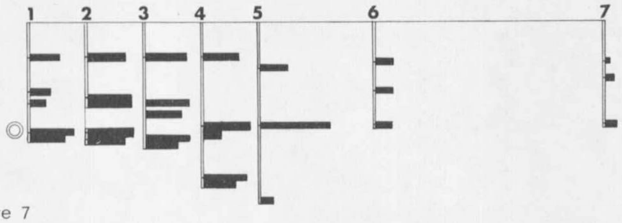


Figure 7
BIGEL-BEARMOUTH
BICARBONATE SOLUBLE PHOSPHORUS

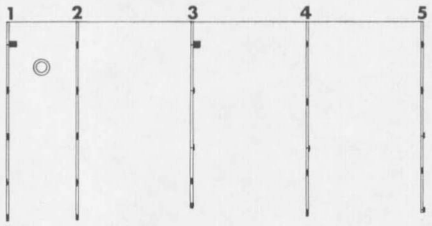


Figure 8
HUFFINE
$NO_3 - N$

0 1 METER
0 50 PPM

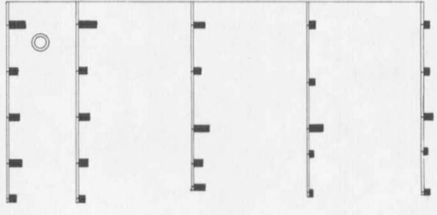


Figure 9
HUFFINE
BICARBONATE SOLUBLE PHOSPHORUS

0 1 METER
0 200 PPM

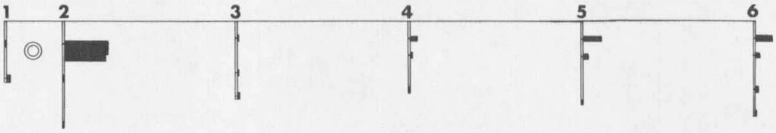


Figure 10

ALLUVIAL

NO_3 - N

Figure 11

ALLUVIAL

BICARBONATE SOLUBLE PHOSPHORUS

DISCUSSION

Amsterdam Soils

Approximately 219 kg of total nitrogen has been introduced into the system during the past 12 years. Organic and ammonium forms of nitrogen in sewage wastes oxidize to the nitrate form (63). Therefore, if we can estimate the amount of nitrate in the effluent sphere of influence and compare this with the amount of nitrate in an equal volume of unaffected soil, we can speculate on the fate of the nitrogen that was introduced.

We observed that nitrates have travelled a maximum of 5.5 meters laterally from the tile line (FIGURE 1). If we take a volumetric cross section 5.5 meters on either side of the drain line, 3 meters in depth, and 30 meters in length, the length of the drain line, this results in a volume of soil 990 m^3. With a bulk density of approximately 1.3 g/cm^3 we have 1.3×10^6 kg of soil. The 219 kg of introduced nitrogen amounts to 170 ppm or 0.017 percent.

From the analysis of nitrate given in Table 19, it is estimated that the sphere of influence contains an average of 25 kg nitrate. A similar volume of soil removed from outside the sphere of influence contains approximately 3 kg of nitrate. The difference between total nitrate in affected and unaffected areas is 22 kg. If we have added 219 kg and have accounted for 22 kg, we then must speculate on the fate of the other 197 kg of nitrate.

Soil nitrates are lost to the soil system by removal in crop, erosion, denitrification, and leaching. Denitrification is related to velocity of flow of soil water and the concentration of soil oxygen. Slow water flow and low oxygen levels favor denitrification. Leaching of nitrates is closely related to the movement of soil water (2).

We know that nitrate nitrogen is the end product of the oxidation chain of nitrogen in soil and in water, and it is the form in which nitrogen is most abundant (103). Adsorption, biological metabolism, and water movement are the primary factors which control the movement of nitrogen through the soil (42). One of these factors may dominate the other, depending upon the soil environment.

Most nitrogen containing organic deposits are quite refractory, the nitrogen being released at rates of only 1 to 3 percent per annum (121). Urea, formed during the degradation of proteins or amino acids, is readily hydrolyzed enzymatically in the soil solution into two molecules of ammonia and one of carbon dioxide (33). In a well functioning septic tank system these reactions occur in the tank, releasing ammonia into the soil where it is subject to nitrification.

Nitrogen removed by crops is usually less than 50 percent of nitrogen added depending upon the kind of crop, texture or soil, and climatic conditions. At Rothamsted Experiment Station, Russell and Watson (107) found that wheat removed 35 percent of the available nitrate under continuous cropping. At the Amsterdam site a heavy stand of bromegrass (Bromus inermis Leyss.) hay is harvested annually and should account for part of the nitrates lost. It is estimated that 45 kg of nitrogen has been removed by the crop.

It has been estimated (75) that an average of 27.1 kg/h of soil is removed from farmlands in the United States annually. Eroded soil contains more nutrients than the soil that remains containing an average of 1 g nitrogen and 0.6 g phosphorus per kg. However, at the Amsterdam site the heavy cover of smooth brome (Bromus ingermis Leyss.) reduces nitrogen loss by this mechanism to insignificance.

To aid in explaining possible loss of nitrates from denitrification let us examine some research. Researchers have shown that denitrification can occur at significant rates in unsaturated soils (94). One would predict that considerably more would occur in more moist soils. No difference was shown in the rate of denitrification in the soils with the 3 moisture levels. Several factors should be examined to aid in an explaination.

Soil pores are grouped into 2 size classes, capillary and noncapillary pores. The gravitational movement of water is a function of the volume of the continuous noncapillary pore system. At field capacity, the noncapillary pores are virtually empty while the capillary pores are full. At this point capillary conductivity approaches zero and water movement essentially ceases.

Denitrification is accomplished by certain bacteria living in primarily anaerobic environment. These bacteria range in size from less than 1u to several u in diameter and are adsorbed on soil pore surfaces. At soil moisture tensions of 1/3-atm, pores larger than 6u in diameter will be empty of water if they are continuous. At a tension of 3-atm, pores larger than 1u will be exhausted of water. Because of the size limitations, it is probable that of all the capillary pores (diameter less than 6u) only those having diameters between 1 and 6u will be inhabited by denitrifying bacteria. From this we can see that most of the bacteria inhabit capillary pores that are water filled whether the soil is at field capacity or saturation. Denitrification could be expected to proceed in these pores at a fairly constant rate, depending upon the rate of oxygen diffusion into the pores. Appreciable denitrification would occur in the noncapillary pores only when the moisture level rises considerably above field capacity.

Alternating aerobic and anaerobic soil conditions should result in greater nitrogen losses than would be found under strict anaerobiosis due to the rapid oxidation of ammonia to nitrate during temporary aerobic conditions (141). Paterick and Ronald (97) claim the effect of repeated submergence and drying of a soil on the loss of nitrogen can result in up to a 20 percent reduction in total soil nitrogen. When a soil containing a high energy source such as decomposed plant residue is submerged, nitrate nitrogen in the soil appears to be almostly completely lost in gaseous form.

To illustrate the effect that the partial pressure of oxygen may have on denitrification in soil, Allison, Carter, and Sterling (3) conducted laboratory experiments with a sandy loam fertilized with nitrate salts. In a normal atmosphere only trace losses of nitrogen occurred by denitrification when samples were kept at 1/3-atm moisture content. This was true in the presence or absence of 1 percent glucose or 2 percent wheat straw. When soils were aerated with nitrogen gas containing 2.27 percent oxygen, nitrate loss was significant in one half of the tests. When oxygen partial pressure was only 0.46 percent, the loss of nitrogen was 10 percent in the absence of an energy source and 50 percent in the presence of 0.5 percent glucose.

The amount of nitrate immobilized and denitrified by microbial activity is related to the velocity of flow of soil water. Corey, Nielsen, and Kirkham (34) found that a velocity of 1.32 cm/hr inhibited the denitrification of soil nitrates, but at a velocity of 0.11 cm/hr, 21 percent of the nitrates were immobilized by denitrification. In the use of a septic tank system there are long periods, especially at night, when no moisture is being added to the system. This has a tendency to encourage slow velocity rates of soil moisture and encourage denitrification.

Elevation of temperature increases the rate of nitrification of ammonia to nitrate in the soil. In one study (5) after 12 weeks of incubation, nitrate accumulation expressed as a percentage of that occurring at 11°C was 93, 51, and 8 percent at 8°C, 6°C, and 3°C respectively in samples treated with 50 ppm ammonia nitrogen. Sewage effluent from septic tanks have temperatures in the vicinity of 14°C which keeps the soil in a temperature range to encourage the nitrification of ammonia and ultimately denitrification.

Wagner and Smith (134) established that nitrogen losses involve volatilization of nitrogen gasses other than elemental nitrogen. Small amounts volatilize as ammonia. Small losses may occur in the form of nitric oxide or nitrogen dioxide. Nitrous oxide, on the other hand, may occount for a larger part of the nitrogen loss under certain anaerobic conditions that facilitate denitrification. Further reduction of nitrous oxide would give rise to elemental nitrogen as the major gas evolved.

Woldendrop (145) found denitrification to occur under grassland conditions and concluded that grass culture produces sufficient oxygen acceptors to reduce the oxygen content of the soil and thereby permit considerable losses of nitrogen through denitrification.

The living root system has a quantitative influence on nitrogen loss. The major influence of the living root system on denitrification is a reduction of the oxygen partial pressure in the soil solution near the root system. The oxygen consumption, in addition to uptake by the plant roots, is caused by the rhizosphere organisms during breakdown of root excretions. Amino acids are a favorable substrate for denitrification.

It can be concluded that denitrification is a factor in the loss of added nitrates at the Amsterdam site. (a) The addition of effluent keeps the moisture content high, (b) the temperature of effluent is in the range that encourages denitrification, (c) the periods of nonuse keeps the flow rate slow, and (d) we have a heavy grass cover which increases nitrogen loss.

It can also be pointed out that Schwartzbeck, MacGregor, and Schmidt, (112) found that gaseous losses of nitrogen are greater in fine textured soils than in sands. The Amsterdam site has a silty loam soil which would be favourable to denitrification.

Although an attempt was made to excavate to the extent of sewage percolation through the profile, the possibility of loss through leaching beyond the effective root zone should be considered. Let us look at some of the important variables that influence nitrate leaching and see if the environment at the site would tend to increase or decrease the chances of loss via this mechanism.

The more important variables that influence nitrate leaching are (a) the amount present in the soil system, (b) amount and intensity of moisture added to the system, (c) infiltration and percolation rates which are affected by soil composition, texture, structure, depth of profile, and surface treatment, (d) water holding capacity of the soil and moisture content at the time of precipitation, (e) rate of nitrogen removal by vegetation, (f) extent of upward movement of nitrogen during dry periods, and (g) whether nitrogen has moved past the root zone, expecially to the water table (111).

To illustrate how some of the more important variables that influence nitrate movement operate, let us examine the work of Karraker, Bartner, and Fergus (65). Nitrates were collected in lysimeters over an 11 year period under various vegetative treatments. The species of vegetation had a marked effect upon the leaching of nitrates. Nitrate leaching was slight (2.5 kg/h/yr) in lysimeters located at 1 meter under grass cover. The amount increased as the percent of ground cover decreased. The heavy grass cover at the Amsterdam site would tend to minimize losses of nitrate due to leaching beyond the root zone.

In a study of nitrate distribution on deep loess derived soils (53) there was no evidence of nitrate leaching below 180 cm until nitrates were added in excess of 225 kg/h/yr. Because of deep rooting of crops on this type of soil, water and nutrients are available for vegetative use to depths of 180 cm. This may contrast to areas where penetration of plant roots may be limited to shallow depths by bedrock, compact layers, or other conditions. Under these conditions nitrate nitrogen would be considered lost to plant utilization and thereby pose a threat to groundwater supplies. On the Amsterdam site we have a loess derived soil that allows deep penetration of plant roots and utilization of soil water and soil nitrates.

Stewart and Eck (122) claim that nitrate nitrogen moves into the soil at all moisture levels, but the amount and depth are increased with increased moisture content. Movement in a loamy fine sand is mostly downward and lateral while in a loam it is nearly symmetrical with slightly greater upward and lateral movement than downward (104). Movement in silt loam is intermediate between these soil textures. At the Amsterdam site we would have a tendency towards some upward movement to aid in keeping nitrates in the upper horizons.

At low pH values adsorption of nitrate may occur (103). However at the pH values of the Amsterdam soils no significant amount of nitrate adsorpiton would be in evidence. In this temperate region, clay types are predominately 2:1 type silicate clays. Nitrate is repelled by the negatively charged soil particles, resulting in a negative adsorption effect (67) (68). Therefore, no impedment to leaching is offered by this mechanism. However from evidence in the literature, it can be concluded that most of the nitrate loss at the Amsterdam site is due to removal in crop and from denitrification.

Approximately 45kg of phosphorus has entered the system during the past 12 years. From the data on bicarbonate soluble phosphorus we observed that the increase in phosphorus was found in the first 2.5 meters from the line. If we take a volumetric cross section 2.5 meters on either side of the drain line, 3 meters deep and 30 meters in length, we have a volume of soil 450 m^3 weighing 5.85×10^5 kg. From the analysis of total phosphorus given in Table 19, it is calculated that the sphere of influence contains approximately 45 kg of phosphorus. A similar volume of soil outside the sphere of influence contains 26 kg of phosphorus. This means there was an increase in the sphere of influence of approximately 19 kg. Since 45 kg have been produced, we shall ponder the fate of the remainder.

Land disposal of effluent water has been considered a suitable method of phosphorus removal (63). This was demonstrated by Hook and Kardos (58) where municipal sewage effluent was sprayed on cropland and woodland at a weekly rate of 5.1 cm for a period of 7 years. Percolate samples were collected at depths of 15, 61, and 122 cm and analyzed for phosphorus. Soils were sampled at 30 cm intervals to a depth of 152 cm. Phosphorus increased in the upper 30 cm of effluent treated soils. Soluble phosphorus in percolate samples at the 122 cm depth has not increased after 7 years of application. The soil plant system continues to remove more than 99 percent of the phosphorus from the percolating effluent.

There are some conflicting evidence as to why phosphorus is retained in the soil. Hemwall (52) and Wild (142) claim the major factor affecting phosphorus retention in the soils is active aluminum. Saini and MacLean (104) found iron influenced phosphorus retention as did Ahenkorah (1). John (61) found that the highest correlation of retention capacity of soils was with base saturation (r=0.80) and that exchange calcium was correlated significantly (r=0.52). More acid soils showed significant correlation between retention of phosphorus and aluminum.

Soil texture was found useful in determining the efficiency of soils for effluent phosphorus removal. An increase in sand is associated with an increase of phosphorus remaining in effluent after treatment with soil. The inverse relationship exists with clay. This can be explained by the increase of reaction surface for fine textured soils (61).

In most Montana soils, exclusive of sodic soils and the pedons of the more mesic high altitude areas, calcium dominates the exchange complex. In the presence of this calcium, phosphate forms the slightly soluble dicalcium phosphate, and in the strongly calcic soils the highly insoluble tricalcium phosphate precipitates (35).

In sodic soils dominated by sodium, the sodium phosphates formed would be highly soluble, but these sites would not be used for effluent disposal due to the poor physical properties of the soil.

In the more mesic soils with lower pH, the precipitation and/or adsorption of phosphorus is by iron and/or aluminum. Most of this iron or aluminum is in the colloidal state, but significant amounts are in solution, depending on pH and solubility product of minerals present. The lower the pH the greater the expectation that more iron and aluminum would dissolve. This increases the amount of insoluble phosphorus that will precipitate.

With respect to the phosphorus that has not been accounted for, there are three possible explanations. It may have been carried away with runoff and eroded soil. But as in the case of nitrates, the heavy bromegrass (Bromus inermis Leyss.) cover reduces losses by this mechanism to insignificance.

Another possible explanation is that the phosphorus was transported from the site in the harvested hay. We have a surface area of 0.015 h over the sphere of influence and assuming a high yield of 8,000 kg/h and an average composition of 0.2 percent phosphorus (87), this results in less than 2 kg phosphorus removed in hay in 12 years.

The most acceptable theory is that the phosphorus that has not been accounted for is in the sludge in the septic tank. It has been estimated (77) that the septic process brings phosphorus in the sludge to concentrations of 0.6 to 0.7 percent which is far greater than that of the incoming sewage.

Noting the 6 most important factors in determining the suitability of a soil as a septic tank absorption field (Table 16), the percolation rate of 12.3 cm/hr for Amsterdam soils shows no moderate or severe limitations for this use. The depth to the water table is more than 183 cm, there is no flooding hazard, the slope of the land is less than 8 percent, and the depth to impervious materials is greater than 183 cm. These characteristics all indicate an appropriate site for septic tank sewage disposal. As shown previously the local experience on the site examined suggested efficient disposal of effluent. Therefore Amsterdam soils would be rated as having only slight limitations for on site sewage disposal.

As to design criteria, a standard septic tank installation would function efficiently on this site. The drain line should be placed approximately 60 cm deep rather than the 1.3 to 1.5 meters as at the site under study.

Leavitt-Bigel Soils

The site characteristics indicate that this location is highly suitable for on site sewage disposal. The percolation rate (8.2 cm/hr) indicates no severe or moderate limitations to sewage spreading. The depth to the water table far exceeds 183 cm, there is no flooding hazard, the slope of the landscape is less than 8 percent, and the depth to impervious materials is greater than 183 cm.

The on site investigation illustrated the fact that nitrates travelled no more than 2 meters and that phosphorus moved no more than 1 meter. This record of performance supports the other criteria in the conclusion that this is an appropriate site for sewage disposal.

Bearmouth-Bigel Soils

The percolation rate of 7.1 cm/hr, the depth to water table being greater than 183 cm, no flooding hazard, and gentle slopes are favorable characteristics for the site. As shown in the results, impervious materials were encountered between 90 and 155 cm. This indicates an unfavorable characteristic for on-site sewage disposal. This is supported by the fact that nitrates and phosphorus accumulated at the soil-impervious layer interface. There is the possibility that these nutrients may move downward in a fissure in the impervious layer.

This one severe to moderate limitation does not mean that the site is unusable for the purpose of on-site sewage disposal. Additional design criteria need to be taken into consideration. A mound system as described in the Montana State Septic Tank Manual (85) raises the absorption field and would be one solution to the problem. The other solution would be the use of an Armon system where an impervious layer is installed to prevent effluent from travelling beyond a desired distance. Both these alternatives cost more than a conventional installation and illustrate the fact that a site may not be unusable for on-site disposal of sewage, but design criteria or maintenance designed to overcome the limitation may be more expensive than standard systems.

Huffine Soils

At this site the investigation has revealed a serious problem with respect to on-site sewage disposal. The percolation rate, flood-hazard, slope, and depth to impervious materials characteristics of this site are well within the range of slight limitations. However, the depth to the water table in the spring and during the irrigation season is less than 46 cm. This represents a severe hazard to groundwater from nutrient contamination, especially nitrates.

The on-site investigation revealed that the 22 kg of nitrogen added to the system had mostly disappeared. Nitrates are highly soluble in water. It is reasonable to expect that some travelled out of the system with the groundwater. Two other possibilities bear consideration.

One possible explanation is that ammonia in the sewage was not nitrified to nitrate due to anaerobic conditions in the soil. It is noted that high water is not a continuous phenomenom but exists for only a few months of the year. Late in the summer when soil temperatures are the highest and biological activity the most intense, the water table is not as high as during the irrigation season. Ammonia can be rapidly nitrified to nitrate which is then present in the soil when the next period of high water occurs.

The nitrates may have been denitrified and lost to the atmosphere. During anaerobic periods when the water table is high, this mechanism is operating. To say that all the nitrates that have been added to the system were denitrified would be presumptuous without further studies.

Since the evidence indicates the possibility of groundwater contamination, what engineering designs can be employed to overcome this severe limitation? A mound system may raise the absorption field far enough above high water to allow for proper disposal of sewage effluent. An Armon type system may be considered but it is not as yet approved by the Montana State Board of Health for use to prevent the contamination of groundwater.

Alluvial Soils

This site has the severe limitations of a high water table near the surface most of the year and the threat of spring flooding. No known design criteria can overcome this severe limitation. The site is totally unacceptable as a site for sewage disposal. However this does not mean that the site is unusable for domestic habitation. A holding tank that is non-porous can be installed at the site and wastes periodically removed for disposal at another site. Here is a high cost of maintenance as the price to pay to overcome a prohibitive limitation.

Gallatin Canyon Soils

In an attempt to predict the adaptability of 6 Gallatin Canyon soils as sites for the disposal of domestic sewage effluent, data concerning the soils must be compiled. The soil survey map, with its accompanying report, is usually the most detailed source of information about the physical and chemical properties of a given area (92). Soil survey maps must be used with full realization of how the maps were made what standards of accuracy were set up to prepare and interpret the data (93). Detailed soil maps can be made more accurate with supplemental research (90).

Morris et. al. (86) claim that soil maps can substitute for a percolation test provided correlation has been established between soil texture and percolation rates. This does not eliminate the need for an on-site inspection. The soils of Gallatin Canyon have been recently surveyed (1970) but intensive physical and chemical testing has not as yet been performed. Using the soil series descriptions and observations from the field, an attempt is made to ascertain the suitability of 6 Gallatin Canyon soils as sites for domestic on-site sewage disposal.

It has been demonstrated that nitrates accumulated approximately 5.5 meters laterally and 2.5 meters downward from the drain line in the soils studied and phosphorus travelled less. From the literature it was shown that biological contaminants in unsaturated soil are generally removed within 3 meters (106) from the point of entry. One would expect these 6 soils to function similarily if they consisted of soil particles similar to those being studied. Unfortunately these soils have a high percentage of coarse fragments. If just the fine material is considered, and the coarse fragment fraction assumed to offer no impediment to sewage spreading, then an estimate of the maximum distance that pollutants would spread could be calculated.

Bearmouth Soils

The Bearmouth series is a member of a sandy-skeletal family of Typic Cryoborolls. The soil profile below 60 cm, where the drain line would be placed, consists of 60 percent coarse fragments with a sandy matrix. This material would accept effluent readily but would be a poor filtering media, possibly having no more than one fourth the water holding capacity of the medium textured soils.

Therefore, sewage could move up to 22 meters laterally and 10 meters downward. There could exist the possibility of groundwater contamination although the groundwater is generally below 10 meters in this glacial outwash material. On-site investigations need to be made for each installation. Perhaps the utilization of one of the designs which prohibits excessive movement of effluent by installation of an impervious layer should be used on sites on the Bearmouth series.

Bigel Soils

The Bigel series is a member of a loamy-skeletal, mixed family of Argic Cryoborolls. They have 70 percent coarse fragments in the substratum below 60 cm. Sewage would spread to not as great a distance as in the Bearmouth soils due to the finer material in the matrix. However on-site inspection would be needed to determine the depth to groundwater.

The upper B21t and B22t horizons are composed of clay loam which would accept effluent but not allow it to spread excessive distances. If a system were installed mounded above the present soil solum, advantage could be taken of the desirable characteristics of the B horizon.

Hanson Soils

The Hanson series is a member of a loamy-skeletal, carbonatic family of Calcic Cryoborolls. The substratum consists of 60 to 70 percent coarse fragments. Sewage spreading on Hanson soils would be similar to that on the Bigel soils as would design criteria. Caution must be excercised in the placement of a system as slopes in excess of 15 percent can be encountered. Mechanical problems of layout and construction increase with steepness of slope. Lateral seep or down slope flow of effluent is a problem.

Hobacker Soils

The Hobacker series is a member of a loamy-skeletal, mixed family of Pachic Cryoborolls. There is a mollic epipedon up to 127 cm in thickness which contains about 40 percent coarse fragments while the substratum contains 50 to 60 percent coarse fragments. Sewage will probably spread no more than 11 meters laterally and 5 meters downward. There should be no problem of groundwater contamination as the water table is well below 5 meters. However there are slopes in excess of 15 percent and these sites should be avoided if possible.

Leavitt Soils

The Leavitt series is a member of the fine-loamy mixed family of Argic Cryoborolls. The B2t horizon contains from 32 to 36 percent clay. Coarse fragments range from 15 to 30 percent in the surface layers to over 40 percent below one meter. Sewage will probably not spread more than 8 meters laterally or 3 to 4 meters downward. There should be no danger of groundwater contamination although land with excessive slopes should be avoided as sites for waste disposal.

Michelson Soils

The Michelson series is a member of the fine-loamy, mixed family of Argic Cryoborolls. The solum thickness ranges from one half meter to less than 1 meter. Coarse fragments range from a few pebbles in some pedons to 30 percent in the first meter of the profile. Below this gravels can range up to 80 percent. If advantage is taken of the first meter of soil in the design of the disposal system, the clay loams will prevent excessive movement of sewage effluent. One could predict movement similar to that of Leavitt soils. On-site investigations can avoid the use of the most gravelly of the pedons. Caution should be used to avoid installation on sites with excessive slope.

On site investigations can reveal sites that are exceptionally suited for on-site sewage disposal. A case in point is the Leavitt-Bigel site investigated in this study. The site was located in the gradation between Bigel soils and Leavitt soils, however the fine material over the gravels was 3 meters deep due to local microrelief.

If the leaching system were divided into at least 2 equal sectors so that alternate periods of loading and resting are provided, the extent of effluent travel would be limited and the travel of nitrates restricted. Also periods favorable to nitrification of ammonia to nitrates and other periods favorable to denitrification of the nitrates would be provided.

Another consideration is biological clogging or the development of an impervious organic mat. Bacteria feed on particulates and organic matter forming ferrous sulphide. The avoidance of continuous inundation would allow aerobic conditions to be maintained and ferrous sulphide to be oxidized to soluble sulphates which are carried away by the percolating liquid during the next loading cycle.

It is equally important to know the source of pollutants as it is to know the ability of the soil system to dispose of them. As Beecroft said, "We can no longer afford the luxury of political irresponsibility among professionals, nor the luxury of scientific innocence among politicians, laymen, and entrepreneurs (13). We are encouraging the convergence of community politics and environmental science". Therefore an estimate was made of the amount of nitrogen and phosphorus produced by residents and travellers. An attempt is made to compare current conditions with those that may be expected in 1985, and an evaluation of the nutrient load from elk in the Gallatin Canyon was made for a comparison with human activity.

Table 1. Gallatin Canyon Resident Occupation 1/

	No.	Man Days/Year
Permanent Residents	141	51,456
Resident 1-2 Weeks	45	495
Resident 3-4 Weeks	212	5,300
Resident 5-6 Weeks	81	3,240
Resident Intermittent	19	209
	498	60,709

1/ Resident population data from Gallatin Canyon Study Team, Sociology Subgroup, 1970 questionaire. This does not include travelers who use food and beverage facilities, occupy motels, lodges, or campgrounds, or those who travel the back country, whether with pack string or back pack.

Using the average sewage analysis from Table 17, a daily waste production of 200 liters/person/day (77), we can estimate the amount of nitrogen and phosphorus entering the Gallatin Canyon annually from resident domestic wastes.

Table 2. Amount of Nitrogen and Phosphorus Entering the Gallatin Canyon Ecosystem Annually from Resident Domestic Wastes.

Sewage Constituent	Amount (kg) from Residents		
	Strong	Medium	Weak
Total-N	1044	607	304
Organic-N	425	243	122
NH_4^+-N	607	365	182
NO_2^--N	1.2	0.6	0
NO_3^--N	4.9	2.5	1.2
P	243	122	61

There are 2,800 acres in the Gallatin Canyon with high potential for residential development. The criteria for classification of land into this catagory are as follows, (a) private land, (b) less than 15 percent slope, (c) no severe limitations for septic drain fields, and (d) no severe limitations for building foundations. We will project one residence per acre as the maximum that would ever be realized. With an average of our persons per household this intensive residential use would result in a population of 11,200 or 4,088,000 man days/year.

Table 3. Amount of Nitrogen and Phosphorus that Would Enter the Gallatin Canyon Ecosystem Annually Under Maximum Residential Development.

Sewage Constituent	Projected Amount (kg) Strong	 Medium	 Weak
Total-N	70,314	40,880	20,440
Organic-N	28,616	16,352	8,176
NH_4^+-N	40,880	24,528	12,264
NO_2^--N	82	41	0
NO_3^--N	327	164	82
P	16,352	8,176	4,088

Table 4. Gallatin Canyon Traveller Use (1971)

USE	Man Days/Year
Automobile Driving	33,800 1/
Unique Environment	1,400 2/
Angling - Rivers and Streams	18,200
Lakes and Ponds	2,400
Hiking	5,700
Ski	25
Hunting	12,561
Snowmobilers	2,000
Total	76,086

1/ Gallatin Canyon Study team, Economics Subgroup.
2/ Squaw Creek Ranger Station and Charles Bradley Estimates.

Travellers do not produce the same volume of effluent as a resident. It has been estimated (Keppner, 1972) that they produce approximately 1/3 the amount. Therefore, we will consider the total number of man days as 76,086 X 1/3 or 28,043 and operate under the same set of assumptions as for resident use.

Table 5. Nitrogen and Phosphorus Entering the Gallatin Canyon Ecosystem Annually From Traveller Wastes.

Sewage Constituent	Amount (kg) from Travellers Strong	Medium	Weak
Total-N	482	280	140
Organic-N	196	112	56
NH_4-N	280	168	84
NO_2^--N	0.6	0.3	0
NO_3^--N	2.2	1.1	0.6
P	112	56	28

Table 6. Gallatin Canyon Traveller Use Projected to 1985.

Season	Travellers/Day	Days	Man Days
Winter (ave)	2,467	140	345,380
Spring	2,467	81	199,827
Summer	7,400	62	458,800
Autumn	2,467	82	202,294
Total			1,206,301

We will consider the total number of man days as 1,206,301 X 1/3 or 361,890 and operate under the same set of assumptions as for resident use.

Table 7. Nitrogen and Phosphorus Entering the Gallatin Canyon Ecosystem Annually from Traveller Wastes (1985).

Sewage Constituent	Amount (kg) from Traveller Use-1985 Strong	Medium	Weak
Total-N	6,224	3,619	1,809
Organic-N	2,533	1,448	724
NH_4^+-N	3,619	2,171	1,085
NO_2^--N	7.2	3.6	0
NO_3^--N	28.8	14.4	7.2
P	1,443	723	362

Table 8. Nitrogen and Phosphorus Entering the Gallatin Canyon Ecosystem Seasonally From Traveller Wastes (1985).

Winter

Sewage Constituent	Amount (kg) from Travellers		
	Strong	Medium	Weak
Total-N	1,980	1,151	576
Organic-N	806	460	230
NH_4^+-N	1,151	691	345
NO_2^--N	2.3	1.1	0
NO_3^--N	9.2	4.6	2.3
P	460	230	115

Spring

Sewage Constituent	Amount (kg) from Travellers		
	Strong	Medium	Weak
Total-N	1,145	666	333
Organic-N	466	266	133
NH_4^+-N	666	400	200
NO_2^--N	1.3	0.7	0
NO_3^--N	5.3	2.7	1.3
P	266	133	67

Summer

Sewage Constituent	Amount (kg) from Travellers		
	Strong	Medium	Weak
Total-N	2,630	1,529	765
Organic-N	1,071	612	306
NH_4^+-N	1,529	918	459
NO_2^--N	3.1	1.5	0
NO_3^--N	12.2	6.1	3.1
P	612	306	153

Autumn

Sewage Constituent	Amount (kg) from Travellers		
	Strong	Medium	Weak
Total-N	1,160	674	337
Organic-N	472	270	135
NH_4^+-N	674	405	202
NO_2^--N	1.3	0.7	0
NO_3^--N	5.4	2.7	1.3
P	270	135	67

Table 9. Big Sky Guest Use Projected to 1985.

Season	Guests/Days	Days	Man Days
Winter (ave)	5,400	140	756,000
Spring	1,400	81	113,400
Summer	1,400	62	86,800
Autumn	4,500	82	369,000
Total			1,325,200

Table 10. Nitrogen and Phosphorus Produced Annually by Big Sky of Montana, Inc. Projected to 1985.

Sewage Constituent	Amount (kg) from Big Sky Strong	Medium	Weak
Total-N	22,793	13,252	6,626
Organic-N	9,276	5,301	2,650
NH_4^+-N	13,252	7,951	3,976
NO_2-N	26.5	13.2	0
NO_3-N	106.0	53	26.5
P	5,301	2,650	1,325

Table 11. Nitrogen and Phosphorus Produced Seasonally by Big Sky of Montana, Inc. Projected to 1985.

Winter

Sewage Constituent	Amount (kg) from Big Sky		
	Strong	Medium	Weak
Total-N	13,003	7,560	3,780
Organic-N	5,290	3,024	1,512
NH_4^+-N	7,560	4,536	2,268
NO_2^--N	15.1	7.6	0
NO_3^--N	60.5	30.2	15.1
P	3,024	1,512	756

Spring

Sewage Constituent	Amount (kg) from Big Sky		
	Strong	Medium	Weak
Total-N	1,950	1,134	567
Organic-N	794	454	227
NH_4^+-N	1,134	680	340
NO_2^--N	2.3	1.1	0
NO_3^--N	9.1	4.5	2.3
P	454	227	113

Summer

Sewage Constituent	Amount (kg) from Big Sky		
	Strong	Medium	Weak
Total-N	1,493	868	434
Organic-N	608	347	174
NH_4^+-N	868	520	260
NO_2^--N	1.7	0.8	0
NO_3^--N	6.9	3.5	1.7
P	347	174	87

Autumn

Sewage Constituent	Amount (kg) from Big Sky		
	Strong	Medium	Weak
Total-N	6,347	3,690	1,845
Organic-N	2,583	1,476	738
NH_4^+-N	3,690	2,214	1,107
NO_2^--N	7.4	3.7	0
NO_3^--N	29.5	14.8	7.4
P	1,476	738	369

It was deemed desirable to estimate the nutrient load produced by elk in the Gallatin Canyon and to compare this with that produced by human activity. The Montana Fish and Game Commision city the present Gallatin Canyon elk herd at 2,185 head with 49 percent cows weighing 501 pounds each, 19 percent adult bulls averaging 730 pounds each, 20 percent calves weighing between 40 and 240 pounds, and 10 percent yearling makes averaging 400 pounds each. Although elk move in and out of the Park and few move back and forth over the Madison divide, it is believed that the censes figure is valid as a year around figure for the Gallatin drainage. The Montana Fish and Game Commission believes that 1,500 head would be the most desirable number with respect to the available winter range.

Table 12. Quantity and Composition of Fresh Manure (84).

			H_2O		Pounds		Tons Excreted/Year/
Animal	Excretment	lb/ton	%	N	P_2O_5	K_2O	1,000 lbs of Animal
Cattle	Liquid	400	-	4.8	Tr.	8.1	
	Solid	1,600	-	4.9	2.8	1.4	13.5
	Total	2,000	86	9.7	2.8	9.5	
Sheep	Liquid	660	-	9.9	0.3	13.8	
	Solid	1,340	-	10.7	6.7	6.0	6.3
	Total	2,000	68	20.6	7.0	19.8	
Average	Liquid	530	-	7.3	0.2	10.9	
	Solid	1,470	-	7.8	4.7	3.7	9.9
	Total	2,000	77	15.1	4.9	14.6	

Since elk metabolism is more rapid than that of cattle although they have many of the same feeding habits, it was deemed advisable to extrapolate the figures from an average quality and composition of cattle and sheep manure rather than from cattle alone. However figures extrapolated from cattle will also be given. Calculations will be made for the present herd of 2,185 head and for the desired 1,500 head.

Table 13. Nitrogen and Phosphorus Produced by Gallatin Canyon Elk Herd - 2,185 Head.

			Animal Weight (lbs)		Excrement Produced Annually (tons)					
					Estimate #1			Estimate #2		
Class	% Herd	No.	Each	Total	Exc	N	P_2O_5	Exc	N	P_2O_5
Cows	49	1071	561	600,831	5940	44.8	14.5	8100	39.3	11.3
Adult Bull	19	415	730	302,950	2999	22.6	7.4	4090	19.8	5.7
Calves	20	437	180	78,660	781	5.9	1.9	1067	5.1	1.5
Yearl. Male	10	219	400	87,600	871	6.6	2.2	1188	5.8	1.6
	2	43	468	20,124	198	1.5	0.5	270	1.2	0.3
Total	100	2185		1,090,165	10789	81.4	26.5	14715	71.2	20.4

Estimate #1 = Cattle Basis.
Estimate #2 = Cattle-Sheep Average Basis.

Table 14. Nitrogen and Phosphorus Produced by Gallatin Canyon Elk Herd - 1,500 Head.

			Animal Weight (lbs)		Excrement Produced Annually (tons)					
					Estimate #1			Estimate #2		
Class	% Herd	No.	Each	Total	Exc	N	P_2O_5	Exc	N	P_2O_5
Cows	49	735	561	412,335	4079	30.8	10.0	5562	26.9	7.8
Adult Bull	19	285	730	208,050	2059	15.5	5.0	2808	13.6	3.9
Calves	20	300	180	54,000	535	4.0	1.3	729	3.5	1.0
Yearl. Male	10	150	400	60,000	594	4.5	1.5	810	3.9	1.1
	2	30	468	14,040	139	1.0	0.3	189	0.9	0.3
Total	100	1500		748,425	7406	55.8	18.1	10098	48.8	14.1

Table 15. Summary of Nutrient Load from Elk in Gallatin Canyon.

	Estimate #1		Estimate #2	
Herd Size	N(kg)	P(kg)	N(kg)	P(kg)
2,185	73,846	10,519	64,592	8,080
1,500	50,622	7,169	44,271	5,585

FIGURE 12: ESTIMATES OF ANNUAL TOTAL NITROGEN LOAD FROM MAN AND ELK IN GALLATIN CANYON

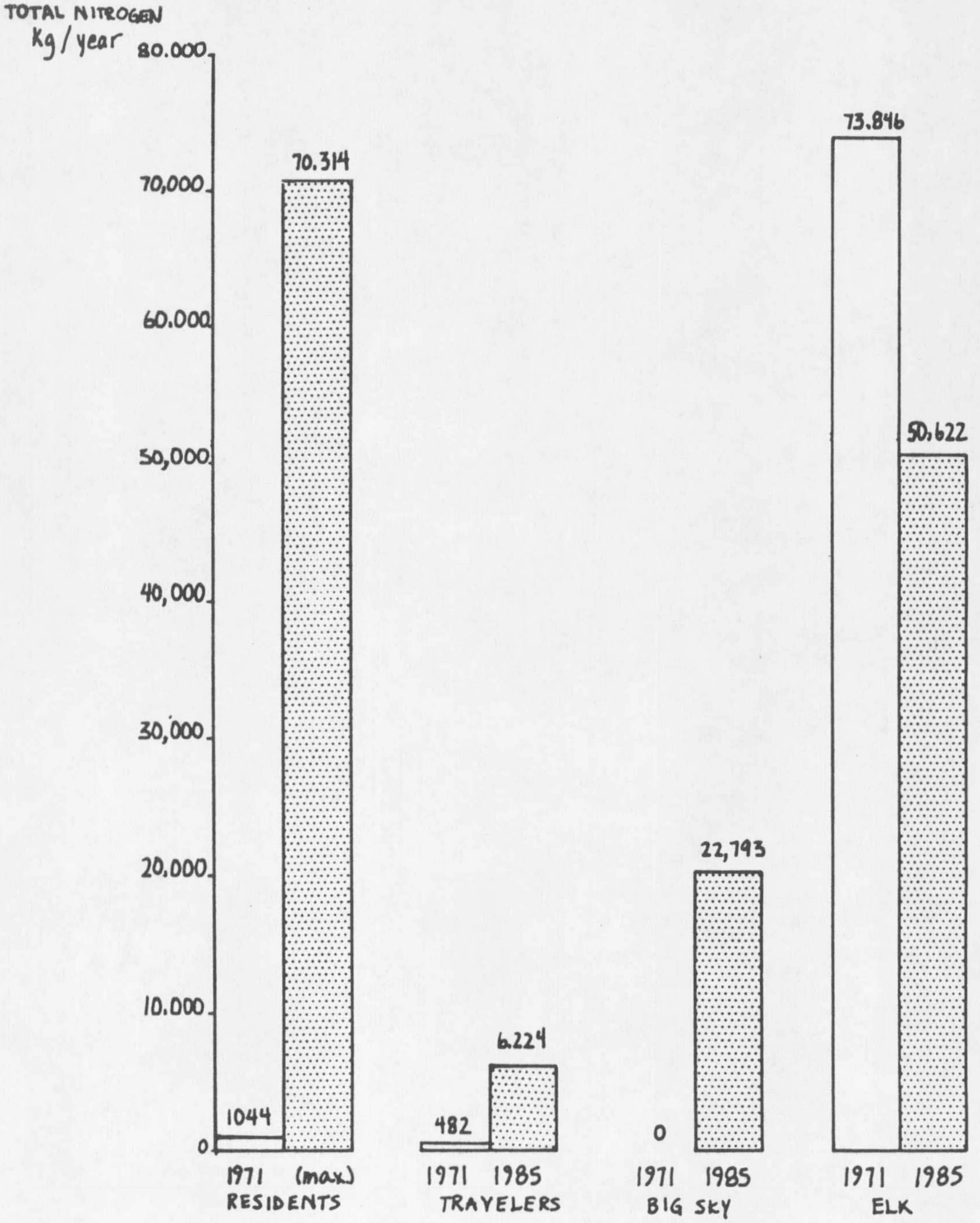
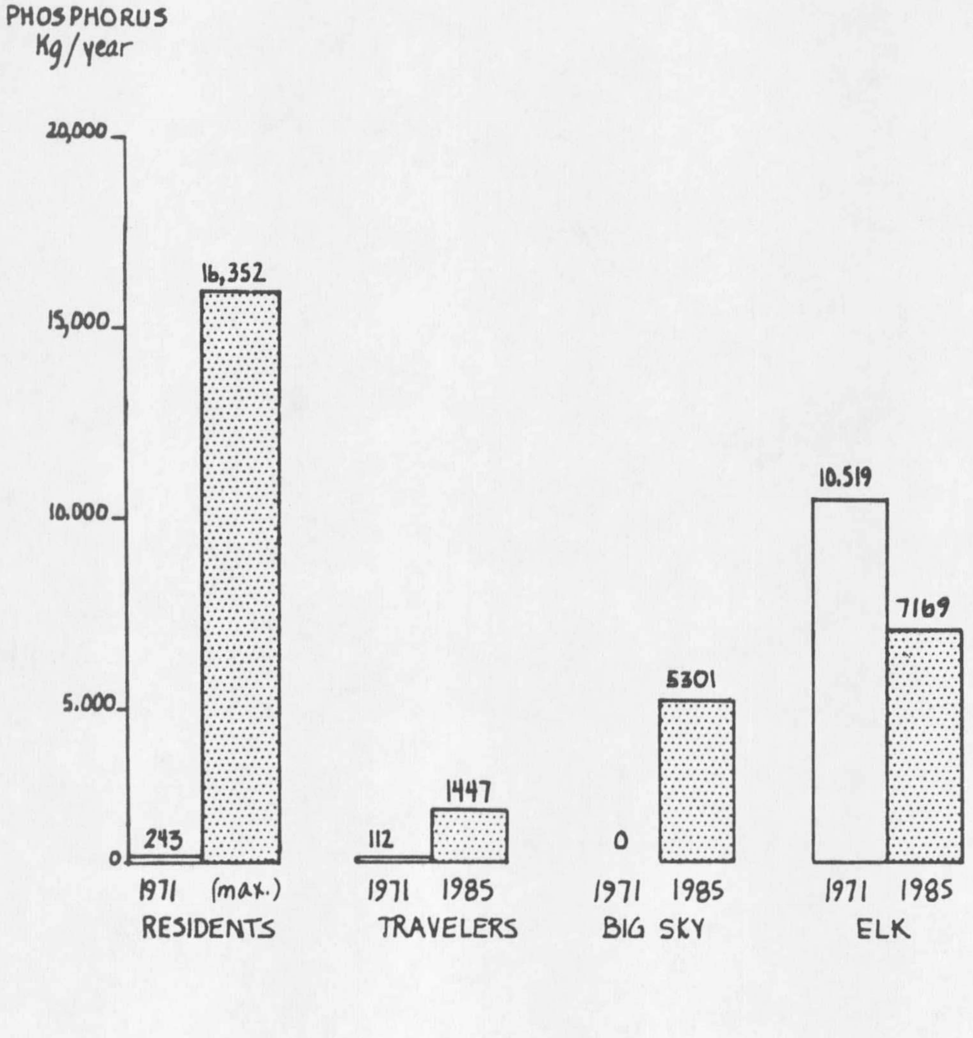


FIGURE 13: ESTIMATES OF ANNUAL PHOSPHORUS LOAD FROM MAN AND ELK IN GALLATIN CANYON



From Figures 12 and 13 it is evident that more nutrients are being put into the ecosystem by elk than by human activity. If maximum development should occur in the Gallatin Canyon then the resident population will produce the greater amount of nutrients.

PROPOSAL FOR FURTHER RESEARCH

Wastewater Spreading in Soil
Systems and Vegetative Utilization

The rationale underlying the proposed investigative work derives from general needs applicable to all science-based engineered systems and from specific needs in the area of the soil mantle as a wastewater treatment system. In the general needs there are 3 that are highly significant: (a) a need to establish fundamental principles in order that engineered systems may be soundly conceived, (b) a need to summarize and evaluate what is already known in order to define areas in which scientific knowledge is lacking and thereby direct research to productive ends, and (c) a need to narrow the gap between research findings and engineering practice by interpreting what is known in terms of design parameters.

The more specific scientific needs that are proposed for investigation are centered around the vegetative utilization of wastewater that has been injected into the soil system for treatment and disposal. The objectives are to determine what volume of wastewater various species of vegetation utilize in their metabolic processes and what proportion of the phosphorus and nitrogen in the wastewater the vegetation utilizes.

The first objective of an engineered system is to optimize conditions under which a given process of nature occurs. A second objective is to accomplish the purpose in a manner economically acceptable under conditions of current technology and urgency of need. The goal of this proposed research is to interpret the findings in terms of engineering design parameters that will prevent wastewater from moving through soil systems below the effective root zone.

The approach to realizing the objectives involves two major components. One is the field determination of the soil hydraulic conductivity in situ as a function of soil moisture tension. This will determine the soil potential for wastewater disposal and the extent to which it may be expected to move in the absence of vegetative cover.

The second component involves the determination of the quantity of wastewater various vegetative covers can utilize. Of the various ways in which this could be determined, a determination of soil moisture at time zero and moisture determinations at various intervals until the conclusion of field work is suggested. A determination of nitrogen and phosphorus content of the vegetation is also suggested.

The double tube method described by Bouwer (23) (24) (25) and modified in 1967 (26) is proposed as the method to determine hydraulic conductivity as the coefficient of variability has proven less than 25 percent. This general method has been used at the University of Wisconsin in Madison (22) and has proved satisfactory.

Soil moisture tension is to be measured in connection with the determination of hydraulic conductivity. General techniques are given by Richards. It is suggested to use pencil sized tensiometers with 1/8" plastic tubing. With the development of the field psychrometer it is now possible to measure dY outside tensiometer range and it is suggested this tool be employed instead of tensiometer if the budget permits.

The reason for measuring both these parameters is that hydraulic conductivity decreases sharply with increasing soil moisture tension. A mechanical analysis needs to be made as the relationship of decreasing hydraulic conductivity with increasing soil moisture tension is most evident in coarse textured soils and less so in fine porous clays (22). A quantitative analysis of the flow system can now be estimated as the quantitative measurements necessary to determine velocity and quantity of wastewater movement have been determined.

The quantity of wastewater that can flow through each system under study and the velocity of flow are now known. The next procedure is to determine what quantity of that flow can various vegetative covers utilize. Greater quantities of water are made available to plants by root growth to water than by water movement to plants (114). There is also a decrease in transpiration with time and the decrease is greater for plants with dense roots. This is without replenishing the water supply. Since, under normal conditions, continued supplies of wastewater are provided and the rapid utilization of this moisture is desirable, plant species that exhibit extensive dense root systems will be studied.

Utilizing the neutron probe for analysis of soil moisture, initial soil moisture levels will be determined. As the season progresses soil moisture levels will be determined to see what effect the vegetative cover had in reducing it and preventing the spread of the wastewater beyond the effective root zone. If wastewater is added to the system, the quantity needs to be noted so that this then becomes a known variable.

It is suggested that an analysis of the plants be made to determine nitrogen and phosphorus content as compared to plants that were not grown under the influence of wastewater. This will give a quantitative indication of the greater utilization of nutrients by plants grown in the wastewater.

CONCLUSION

Excavation of septic tank filter fields and analysis of soil samples suggest that most sewage effluent accumulates within 5 meters of the point of input in the soils examined.

a) Amsterdam: These soils are highly adapted to conventional septic tank sewage disposal. Maximum extent of nitrate movement was less than 7 meters and of phosphorus less than 4 meters. Not all the nitrate added to the system over the years could be accounted for. It was concluded that denitrification was an important factor in the loss of nitrates. Not all of the phosphorus produced over the 12 year existence of the system was found in the soil. The most acceptable theory considered was that the phosphorus that has not been accounted for was in the sludge in the septic tank.

b) Leavitt-Bigel: The study indicated that this location is highly suitable for on site sewage disposal. Nitrates moved approximately 2 meters and phosphorus approximately 1 meter from the input point.

c) Bearmouth-Bigel: Nitrates and phosphorus accumulated at the interface between the soil and an impervious layer at depths of from 90 to 155 cm. This severe to moderate limitation to on-site sewage disposal can be overcome by the use of a mound system or an Armon installation.

d) Huffine: Seasonal high groundwater levels create a serious problem with respect to on-site sewage disposal. The use of a mound system may raise the adsorption field far enough above high water to allow for proper effluent disposal.

e) Alluvial: A high water table most of the year and the threat of spring flooding make these soils unacceptable as a site for on-site sewage disposal. A non-porus holding tank that allows for sewage disposal at another site is the only approved method that can be used.

Utilizing the results of this study and knowledge from the literature, the suitability of 6 Gallatin Canyon soils for on-site sewage disposal was ascertained.

a) Bearmouth: Being a sandy-skeletal soil with 60 percent coarse fragments and with a sandy matrix, these soils will readily accept effluent but be a poor filtering media. Utilizing one of the design criteria which prohibits excessive movement of effluent offers the most feasible means of utilizing these soils.

b) Bigel: These loamy-skeletal soils have 70 percent coarse fragments in the substratum. A system installed above the present soil solum would enable a developer to use these soils for on-site sewage disposal.

c) Hanson: These are also loamy-skeletal soils with 60 to 70 percent coarse fragments and are similar to Bigel soils with respect to design criteria.

d) Hobacker: This loamy-skeletal soil should be satisfactory as a site for on-site sewage disposal although steep slopes should be avoided.

e) Leavitt: These fine-loamy soils present no serious limitations for on-site sewage disposal as coarse fragments are only 15 to 30 percent in the upper horizons and 40 percent below 1 meter.

f) Michelson: These fine-loamy soils are similar to Leavitt soils in their characteristics for on-site sewage disposal although some sites contain considerable amounts of gravel.

In the Gallatin Canyon the future increase in resident population appears to be the greatest concern with respect to increases of sewage effluent that must be disposed of properly.

APPENDIX

Table 16. Soil Limitation Classes for Septic Tank Absorption Fields 1/

Soil Properties	Soil Ratings in Terms of Limitations Slight	 Moderate	 Severe
Percolation Rate 2/	Faster than 45.0 min/2.5 cm	45 to 60 min/2.5 cm	Slower than 60 min/2.5 cm 3/
Depth to Water 2/ Table	More than 183 cm	123 to 183 cm	Less than 123 cm
Flooding Hazard	Not subject to flooding	Not subject to flooding	Subject to flooding
Slopes	0 to 8%	8 to 15%	More than 15%
Depth to Impervious 2/ Materials	Over 183 cm	123 to 183 cm	Less than 123 cm

1/ Class limits are those suggested by the Work-Planning Conference of the National Cooperative Soil Survey. The limitation ratings should be related to the soil layers at and below depth of the tile line.

2/ Indicates where pollution to water supplies is a hazard. Note that coarse textured soils (loamy samd, samd, and gravel) are relatively poor filtering materials.

3/ In arid or semiarid areas soils with moderately slow permeability may have a moderate limitation.

Table 17. Average Sewage Analysis 1/

Sewage 2/ Constituent	Strong	Medium	Weak
	mg/l		
Total-N	86	50	25
Organic-N	35	20	10
NH_4^+-N	50	30	15
NO_2-N	0.10	0.05	0
NO_3-N	0.40	0.20	0.10
P	20	10	5

1/ Sewage analysis from Babbitt and Baumann (1958) and McGauhey (1968) except phosphorus from Ellis and Erickson (1969). Phosphorus can vary from 5 to 10 mg/l depending on detergent use.

2/ Sewage concentration is rated according to its 5-day 20°C BOD.

Weak - BOD 180 mg/l
Medium - BOD 200-250 mg/l
Strong - BOD 280 mg/l

Table 18. Location of Amsterdam Samples

Test Hole	Sample	Horizontal Distance from Drain Line	Depth Below Soil Surface
		m	cm
1	1	8.5	20
1	2	8.5	61
1	3	8.5	96
2	4	0.5	15
2	5	0.5	35
2	6	0.5	61
2	7	0.5	91
2	8	0.5	122
3	9	0.5	20
3	10	0.5	61
3	11	0.5	91
3	12	0.5	122
4	13	1.5	20
4	14	1.5	61
4	15	1.5	91
4	16	1.5	122
4	17	1.5	183
4	18	1.5	244
4	19	1.5	295
5	20	2.5	15
5	21	2.5	35
5	22	2.5	61
5	23	2.5	91
5	24	2.5	122
5	25	2.5	183
5	26	2.5	244
5	27	2.5	304
5	28	2.5	304
6	29	5.5	15
6	30	5.5	35
6	31	5.5	61
6	32	5.5	91
6	33	5.5	122
6	34	5.5	165
6	35	5.5	210
6	36	5.5	267
7	37	7.5	15
7	38	7.5	35

Table 18 Continued

Test Hole	Sample	Horizontal Distance from Drain Line	Depth Below Soil Surface
		m	cm
7	39	7.5	61
7	40	7.5	91
7	41	7.5	122
7	42	7.5	183
7	43	7.5	225

Table 19. Analysis of Amsterdam Samples.

Laboratory Sample	S.M.%[2]	E.C. mmhos/cm	pH	HCO_3-P ppm	Total-P ppm	NO_3-N ppm	Soluble Cations-meq/100g				
							K	Ca	Mg	Na	SAR
1	46.9	3.69	6.85	126.3	932	5.9	0.5	2.8	0.8	1.5	3.5
2	41.6	0.98	7.65	50.6	932	2.9	0.3	1.0	0.8	0.7	2.3
3	38.1	1.30	7.86	25.0	685	2.0	0.2	2.3	1.0	1.5	3.7
4	49.1	2.10	6.74	120.0	902	51.5	0.4	2.3	0.8	1.7	4.4
5	42.6	2.05	7.31	131.9	796	62.5	0.4	2.3	0.8	1.7	4.4
6	40.6	1.01	7.76	51.5	788	26.5	0.4	2.8	1.0	2.2	5.1
7	33.6	0.60	7.56	115.4	856	13.5	0.3	2.3	0.8	1.7	4.4
8	54.6	0.40	7.48	131.9	994	5.5	0.3	2.0	0.5	1.7	4.8
9	45.6	2.10	7.44	133.5	821	55.3	0.4	2.3	0.8	1.7	4.4
10	41.2	1.30	7.29	63.5	874	20.8	0.4	1.8	0.5	1.5	3.8
11	40.3	1.02	7.74	139.6	882	17.4	0.3	2.0	0.5	1.7	4.8
12	30.2	1.03	7.14	149.8	882	11.0	0.6	2.3	0.5	2.6	7.0
13	45.6	2.05	7.48	131.2	803	49.1	0.4	2.3	0.8	1.7	4.4
14	45.1	3.30	7.55	69.2	1000	45.0	0.8	2.8	0.8	2.2	5.6
15	33.3	1.90	7.75	25.3	972	21.6	0.1	2.0	0.5	1.7	4.8
16	33.8	1.30	7.90	66.2	1012	20.0	0.2	1.8	0.8	1.1	3.1
17	33.5	1.05	7.68	44.1	936	8.4	0.6	1.8	0.8	1.1	6.1
18	29.5	0.80	7.80	41.7	924	6.0	0.3	0.8	0.8	0.7	4.6
19	33.0	1.05	7.73	45.9	828	9.0	0.3	2.0	0.4	1.3	3.8
20	57.8	1.70	7.56	149.8	1110	24.0	0.3	1.8	0.5	1.1	3.3
21	45.2	1.75	7.81	131.9	962	4.4	0.2	2.0	0.5	1.5	3.8
22	41.8	4.25	7.62	57.7	874	2.0	0.4	2.3	0.8	1.7	4.4
23	29.7	2.10	7.76	36.0	810	3.8	0.3	1.8	0.8	1.5	4.2
24	35.8	1.05	7.98	24.7	766	5.5	0.3	2.0	0.8	1.5	4.0
25	31.4	1.60	7.26	139.6	882	18.5	0.3	2.0	0.4	1.1	3.2
26	32.6	0.75	7.75	29.0	715	10.3	0.3	2.0	0.8	2.6	7.0
27	31.4	0.85	6.61	60.0	924	7.8	0.4	1.0	0.8	1.5	5.0
28	31.4	0.85	7.60	68.5	912	7.8	0.4	1.0	0.8	1.5	5.0
29	54.1	1.35	7.34	146.9	1008	3.8	0.5	2.0	0.8	1.5	4.0
30	42.2	1.05	7.43	88.1	874	4.4	0.4	2.3	0.8	2.2	5.6
31	37.6	0.95	7.62	48.1	874	2.0	0.5	2.3	1.1	2.2	5.6
32	36.7	2.40	7.64	36.0	902	3.8	0.4	1.8	0.5	1.5	3.8

Table 19. Continued

Laboratory Sample	S.M.%2/	E.C. mmhos/cm	pH	HCO_3-P ppm	Total-P ppm	NO_3-N ppm	Soluble Cations-meq/100g				SAR
							K	Ca	Mg	Na	
33	36.8	1.40	7.89	26.4	846	2.5	0.3	2.0	0.8	1.5	4.0
34	37.3	0.70	7.42	29.3	905	4.1	0.2	1.0	0.8	0.7	5.7
35	26.9	0.80	7.77	32.8	846	7.8	0.3	1.0	0.4	0.7	2.6
36	30.2	1.10	7.77	36.6	735	12.8	0.1	2.3	0.5	1.7	4.5
37	47.6	3.75	6.57	141.8	1056	5.5	0.5	2.8	0.8	1.5	3.5
38	42.6	1.00	7.59	61.2	728	1.0	0.6	1.0	0.4	1.5	5.7
39	39.4	1.25	7.62	35.5	780	1.0	0.5	1.8	0.5	1.5	4.5
40	37.7	1.30	7.66	29.0	860	1.0	0.2	1.0	0.8	0.7	2.3
41	41.0	0.60	7.59	28.3	880	3.3	0.2	1.0	0.4	0.9	3.4
42	31.7	0.55	7.52	25.7	872	3.3	0.2	1.0	0.8	0.7	2.3
43	38.8	0.45	7.53	24.7	772	1.0	0.2	1.0	0.4	1.1	4.2

2/ % Moisture at saturation.

Table 20. Location of Leavitt-Bigel Samples

Test Hole	Sample	Horizontal Distance from Drain Line	Depth Below Soil Surface
		m	cm
1	1	0.5	20
1	2	0.5	60
1	3	0.5	100
1	4	0.5	150
1	5	0.5	200
1	6	0.5	250
2	7	1.0	20
2	8	1.0	60
2	9	1.0	100
2	10	1.0	150
2	11	1.0	200
2	12	1.0	250
3	13	2.0	20
3	14	2.0	60
3	15	2.0	100
3	16	2.0	150
3	17	2.0	200
3	18	2.0	250
4	19	3.0	20
4	20	3.0	60
4	21	3.0	100
4	22	3.0	150
4	23	3.0	200
4	24	3.0	250
4	25	3.0	300

Table 21. Analysis of Leavitt-Bigel Samples.

Laboratory		E.C.		HCO_3-P	NO_3-N		Soluble Cations-meq/100g			
Sample	S.M.%	mmhos/cm	pH	ppm	ppm	K	Ca	Mg	Na	SAR
1	43.6	1.50	5.58	109.6	24.0	0.3	5.3	1.6	4.6	7.8
2	34.9	0.50	5.64	62.4	11.0	0.3	3.3	1.0	2.2	4.8
3	41.2	0.45	6.07	38.4	7.0	0.3	4.8	1.6	3.5	6.2
4	39.2	0.05	6.25	34.8	5.5	0.4	6.8	1.3	5.2	8.2
5	38.8	0.50	6.20	28.1	5.0	0.2	4.0	1.6	2.6	4.9
6	39.0	0.40	6.38	24.2	2.0	0.3	3.8	1.3	1.3	2.6
7	44.4	0.55	5.93	43.2	6.0	0.3	2.3	0.8	0.4	1.0
8	34.3	0.85	5.56	62.4	4.4	0.4	3.8	1.0	2.2	4.5
9	45.8	0.70	5.89	33.6	9.0	0.1	3.3	0.4	1.1	2.6
10	40.9	0.45	6.37	23.6	7.5	0.3	6.8	1.3	5.2	8.2
11	39.6	0.60	6.35	26.3	10.1	0.2	4.0	1.6	2.6	4.9
12	38.2	0.40	6.34	25.6	4.0	0.3	3.8	1.3	1.3	2.6
13	47.7	0.60	6.18	40.8	1.0	0.1	4.0	1.0	2.2	4.4
14	35.4	0.40	6.19	33.6	1.0	0.1	3.8	0.8	1.3	2.7
15	36.6	0.60	6.25	29.4	8.4	0.2	3.3	0.8	2.1	4.6
16	49.9	0.45	6.17	21.3	7.8	0.2	4.0	1.0	2.6	5.2
17	41.4	0.60	6.26	27.9	12.2	0.2	2.0	0.8	0.4	1.1
18	44.1	0.50	6.33	23.1	1.5	0.2	1.8	0.5	0.4	1.2
19	43.9	0.60	6.08	41.9	1.0	0.2	4.0	1.0	1.3	2.6
20	36.3	0.30	6.22	30.2	0.5	0.1	2.0	0.5	0.3	0.8
21	44.1	0.40	6.17	30.3	0.5	0.5	6.8	1.3	5.2	8.2
22	37.9	0.25	6.53	25.0	1.0	0.5	7.3	1.3	5.9	9.0
23	38.1	1.25	6.33	27.9	0.5	0.4	8.0	1.6	6.9	10.0
24	37.4	0.25	6.39	27.2	0.5	0.3	3.8	1.3	2.2	4.4
25	36.6	0.35	6.25	24.3	2.0	0.3	3.3	1.2	0.9	1.9

Table 22. Location of Bigel-Bearmouth Samples

Test Hole	Sample	Horizontal Distance from Drain Line	Depth Below Soil Surface
		m	cm
1	1	0.5	30
1	2	0.5	60
1	3	0.5	70
1	4	0.5	95
2	5	1.0	30
2	6	1.0	65
2	7	1.0	95
3	8	1.5	30
3	9	1.5	70
3	10	1.5	80
3	11	1.5	100
4	12	2.0	30
4	13	2.0	90
4	14	2.0	135
5	15	2.5	40
5	16	2.5	90
5	17	2.5	155
6	18	3.5	35
6	19	3.5	60
6	20	3.5	90
7	21	5.5	35
7	22	5.5	50
7	23	5.5	90

Table 23. Analysis of Bigel-Bearmouth Samples.

Laboratory		E.C.		HCO_3-P	NO_3-N		Soluble Cations-meq/100g			
Sample	S.M.%	mmhos/cm	pH	ppm	ppm	K	Ca	Mg	Na	SAR
1	45.2	1.05	6.55	55.5	9.1	0.2	1.8	0.5	1.5	4.4
2	45.3	0.90	6.82	39.4	7.4	0.2	2.0	0.5	1.5	4.3
3	40.3	0.80	6.93	31.1	5.5	0.2	1.8	0.5	1.3	3.8
4	42.7	1.40	6.62	146.9	21.6	0.2	1.0	0.4	0.9	3.4
5	46.4	0.95	6.75	66.3	8.7	0.3	2.0	0.5	1.3	3.7
6	41.4	0.80	6.54	162.0	1.0	0.3	2.0	0.5	1.1	3.1
7	41.9	1.20	6.88	143.6	14.8	0.2	1.8	0.4	1.3	4.2
8	49.4	0.90	6.95	77.9	8.4	0.3	2.0	0.5	1.3	3.7
9	46.3	1.00	6.78	127.0	7.8	0.1	2.3	0.5	1.3	3.5
10	43.1	0.80	6.95	67.2	8.4	0.3	2.0	0.5	1.5	4.3
11	41.2	1.10	7.39	141.8	5.5	0.2	1.8	0.4	1.1	3.5
12	40.7	0.60	6.67	63.4	4.5	0.3	1.5	0.5	1.3	4.1
13	41.3	0.50	6.72	110.1	5.2	0.3	2.0	0.8	1.5	4.0
14	31.5	1.05	7.23	139.6	7.2	0.2	1.8	0.5	1.3	3.8
15	35.9	0.40	6.51	50.6	1.5	0.2	1.0	0.5	1.1	4.0
16	41.7	0.60	6.57	124.6	8.8	0.2	2.0	0.8	1.5	4.0
17	28.8	0.80	7.94	26.4	3.3	0.2	2.3	0.5	1.5	4.0
18	38.4	0.50	6.87	34.6	0.7	0.2	1.8	0.5	1.3	3.2
19	41.4	0.50	6.95	32.2	1.7	0.2	2.0	0.8	1.3	3.5
20	36.6	0.55	7.09	31.8	2.5	0.4	2.3	0.8	2.2	5.6
21	35.8	0.55	6.84	22.8	1.8	0.5	2.0	1.0	2.6	7.0
22	34.8	0.50	7.69	20.4	1.0	0.3	1.8	0.8	2.4	6.7
23	36.9	0.95	7.69	13.1	1.0	0.1	2.8	1.2	2.4	4.0

Table 24. Location of Huffine Samples

Test Hole	Sample	Horizontal Distance from Drain Line	Depth Below Soil Surface
		m	cm
1	1	0.5	20
1	2	0.5	60
1	3	0.5	100
1	4	0.5	140
1	5	0.5	170
2	6	0.5	20
2	7	0.5	60
2	8	0.5	100
2	9	0.5	140
2	10	0.5	170
3	11	1.5	20
3	12	1.5	60
3	13	1.5	110
3	14	1.5	140
3	15	1.5	160
4	16	2.5	20
4	17	2.5	70
4	18	2.5	110
4	19	2.5	132
4	20	2.5	165
5	21	3.5	20
5	22	3.5	60
5	23	3.5	100
5	24	3.5	130
5	25	3.5	165

Table 25. Analysis of Huffine Samples.

Laboratory Sample	S.M.%	E.C. mmhos/cm	pH	HCO_3-P ppm	NO_3-N ppm	K	Soluble Cations-meq/100g			SAR
							Ca	Mg	Na	
1	52.0	1.6	7.24	31.8	4.4	0.3	6.0	2.0	5.2	8.3
2	46.0	0.5	7.60	19.1	1.0	0.3	3.8	1.3	2.4	4.8
3	40.1	1.3	7.87	22.5	1.0	0.6	8.8	1.6	7.8	10.8
4	35.1	0.4	7.97	26.4	0.5	0.3	4.3	1.3	2.8	5.3
5	31.8	1.2	7.67	17.4	0.5	0.3	4.8	1.3	2.4	4.4
6	43.0	0.7	7.65	35.5	1.0	0.3	3.3	1.2	2.2	4.6
7	45.2	0.4	7.61	18.9	1.0	0.3	3.8	1.3	2.4	4.8
8	40.2	1.2	7.76	22.7	1.0	0.6	8.8	1.6	4.3	6.0
9	36.3	0.5	7.86	25.0	0.5	0.3	4.3	1.3	2.8	5.3
10	33.7	1.1	7.59	16.5	0.5	0.3	4.8	1.3	2.2	4.0
11	48.2	0.8	7.38	24.3	4.4	0.4	4.0	1.3	2.4	4.7
12	33.3	0.5	7.64	17.0	1.5	0.2	4.3	1.2	2.8	5.4
13	37.6	0.8	7.78	29.4	1.5	0.2	3.8	1.0	2.2	4.5
14	35.4	1.0	7.69	19.5	1.0	0.3	4.3	1.6	2.4	4.4
15	32.9	0.6	7.71	24.3	1.0	0.2	5.3	1.6	3.0	5.1
16	41.5	0.6	7.28	15.1	0.5	0.3	3.3	1.0	1.3	2.8
17	40.3	0.4	8.05	14.5	1.0	0.3	5.3	1.8	4.3	7.2
18	38.1	0.9	7.68	28.3	1.5	0.2	3.8	1.0	1.3	2.7
19	33.8	1.1	7.89	12.0	1.0	0.3	4.3	1.6	3.3	6.1
20	36.7	0.7	7.91	12.8	0.5	0.2	3.8	1.2	2.4	4.8
21	41.4	0.6	7.30	14.5	1.0	0.3	3.3	1.0	1.3	2.8
22	20.2	0.5	7.90	13.8	1.0	0.3	5.3	1.8	3.3	5.5
23	38.8	0.9	7.71	20.6	1.5	0.2	3.8	1.0	1.3	2.7
24	34.4	1.1	7.85	14.5	1.0	0.3	4.3	1.6	2.4	4.4
25	33.6	1.1	7.85	13.7	1.5	0.2	4.3	1.6	3.3	6.1

Table 26. Location of Alluvial Samples

Test Hole	Sample	Horizontal Distance from Drain Line	Depth Below Soil Surface
		m	cm
1	1	0.5	20
1	2	0.5	50
2	3	0.5	20
2	4	0.5	50
2	5	0.5	90
3	6	2.5	15
3	7	2.5	45
3	8	2.5	65
4	9	4.5	15
4	10	4.5	30
4	11	4.5	60
5	12	6.5	15
5	13	6.5	30
5	14	6.5	70
6	15	8.5	15
6	16	8.5	30
6	17	8.5	60
6	18	8.5	80

Table 27. Analysis of Alluvial Soils.

Laboratory Sample	S.M.%	E.C. mmhos/cm	pH	HCO_3-P ppm	NO_3-N ppm	K	Soluble Cations–meq/100g Ca	Mg	Na	SAR
1	58.9	1.45	8.07	103.0	1.0	0.2	1.8	0.5	1.1	3.3
2	53.0	1.95	8.02	57.7	2.5	0.1	1.8	0.4	0.7	2.2
3	62.1	2.10	7.87	23.4	59.1	0.2	3.3	1.2	2.4	5.1
4	43.1	0.90	8.01	103.0	1.0	0.1	0.8	0.1	0.7	3.3
5	31.1	0.90	7.98	96.2	1.0	0.1	1.0	0.8	1.3	4.3
6	66.4	1.15	8.09	16.3	1.5	0.4	0.8	0.4	0.7	2.9
7	51.6	1.10	7.95	8.3	1.5	0.3	2.0	0.4	1.3	3.8
8	44.6	0.85	7.94	9.8	2.0	0.2	1.8	0.5	1.1	3.3
9	62.0	1.25	7.90	15.6	2.5	0.4	0.8	0.4	0.7	2.9
10	58.9	1.40	7.76	18.9	2.0	0.1	0.8	0.1	0.4	1.9
11	58.6	1.15	7.74	8.8	1.0	0.1	2.3	1.0	2.2	5.4
12	63.0	1.37	7.93	14.8	9.2	0.4	0.8	0.4	0.7	2.9
13	59.9	1.35	7.68	17.4	2.5	0.1	2.3	1.0	2.2	5.4
14	40.8	0.95	7.60	9.8	1.0	0.2	1.8	0.5	1.3	3.8
15	61.3	1.41	7.88	14.1	7.5	0.4	0.8	0.4	0.7	2.9
16	59.6	1.28	7.65	18.3	2.5	0.1	2.3	1.0	2.0	4.9
17	55.5	1.20	7.65	9.1	1.0	0.2	1.0	0.5	0.4	1.5
18	65.0	1.80	7.65	9.0	1.5	0.1	2.3	0.8	1.5	3.8

Table 28. Soil Textural Analysis

Soil	Depth	Percent Sand	Percent Silt	Percent Clay	U. S. D. A. Texture
	- cm -				
Amsterdam	15	32	58	10	Silt Loam
	35	28	58	14	Silt Loam
	61	26	66	8	Silt Loam
	91	26	64	10	Silt Loam
	120	8	80	12	Silt Loam
	183	26	66	8	Silt Loam
	250	34	58	8	Silt Loam
	300	32	58	10	Silt Loam
Leavitt-Bigel	20	36	42	22	Loam
	60	38	36	26	Loam
	100	42	36	22	Loam
	150	32	40	28	Loam
	200	52	26	22	Sandy Clay Loam
	250	40	40	20	Loam
	300	50	38	12	Loam
Bigel-Bearmouth	35	38	40	22	Loam
	70	46	36	18	Loam
	90	52	26	22	Sandy Clay Loam
	135	58	28	14	Sandy Loam
Huffine	20	28	58	14	Silt Loam
	60	24	62	14	Silt Loam
	100	26	54	20	Silt Loam
	130	40	50	10	Loam
	140	36	52	12	Silt Loam
	165	46	46	8	Loam
Alluvial	20	46	40	14	Loam
	50	44	38	18	Loam
	70	44	40	16	Loam
	90	32	44	24	Loam

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