THESIS

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NITRATE CONTAMINATION OF THE GROUNDWATER OF OLD MISSION PENINSULA: CONTRIBUTING EFFECTS OF ORCHARD FERTILIZATION PRACTICES, SEPTIC SYSTEMS AND LAND RESHAPING OPERATIONS

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NITRATE CONTAMINATION OF THE GROUNDWATER OF OLD MISSION PENINSULA: CONTRIBUTING EFFECTS OF ORCHARD FERTILIZATION PRACTICES, SEPTIC SYSTEMS AND LAND RESHAPING OPERATIONS

By

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ABSTRACT

NITRATE CONTAMINATION OF THE GROUNDWATER OF OLD MISSION PENINSULA: CONTRIBUTING EFFECTS OF ORCHARD FERTILIZATION PRACTICES, SEPTIC SYSTEMS, AND LAND RESHAPING OPERATIONS

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Two orchards situated on Emmet sandy loams (coarse-loamy, mixed, frigid Alfic Haplorthod) were fertilized in April 1981 with increasing rates of ammonium nitrate and the soil profiles sampled on a monthly basis through October 1981. Residual NO_3-N was detected in all profiles of sites fertilized with more than 112 kg N/ha. The residual NO_3 was leached by April 1982. A positive correlation was noted between N applied and N leached.

Three septic drainfields were monitored from September 1981 through February 1982. Effluent samples collected from a 1.53 m depth contained an average 28.6 mg NO_3-N/l. Nitrate concentrations did not significantly decrease during the winter.

Deep profile samples were obtained in seven areas reshaped to establish orchards. Nitrate released as a result of reshaping was not serious unless heavy fill was used to depths exceeding 1.22 m.

To my parents and family

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And last, but hardly least, the co-operation of the home owners and the orchard growers of Old Mission Peninsula is gratefully acknowledged. Without that, this venture would never have been accomplished.

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INTRODUCTION

In recent years, concern regarding groundwater pollution has increased substantially. Of particular concern is the problem of nitrate (NO_3^-) contamination. While increased concentrations of NO_3^- may lead to the eutrophication and potential loss of surface waters, a comparable increase in groundwater may have more serious implications.

In less densely populated areas, where much of the water for domestic use is supplied via the groundwater, high NO_3^- concentrations may become a serious health hazard. A condition known as methemoglobinemia is associated with high NO_3^- concentrations in drinking water. While relatively harmless to adults, it may be fatal to children less than 18 months old. Because of the potentially lethal nature of methemoglobinemia, the U. S. Health Department (1962) has established the maximum concentration of NO_3-N in potable water to be 10 mg N/l. Waters with concentrations in excess of that standard are suitable for agricultural or industrial purposes. But, because NO_3^- contamination is considered a health hazard, steps need to be taken to identify and control sources of contamination.

In the early 1970's, it was discovered that the groundwater of Peninsula township on Michigan's Old Mission Peninsula was contaminated with NO_3^-. As a result of studies by Rajagopal (1978) and Iversen (1979), the Northwest Michigan Regional Planning and Development

Commission surveyed 1,212 wells on the Peninsula and found that approximately 11 percent exceeded the Federal standard of 10 mg NO_3-N/l (Weaver and Grant, 1980).

Old Mission Peninsula is an area of intensive agricultural activity and residential development, realizing a population increase of 78 per cent since 1960. Of the 7,724 ha that comprise the Peninsula, 871 ha are residential and 3,115 are devoted to agricultural interests (Weaver and Grant, 1980). Because of this, several possible sources of contamination exist:

(1) Since several of the sites of contamination were in close proximity to soils used for cherry production, NO_3^- contamination may be a result of the fertilization practices in the orchards on the Peninsula. Average yearly applications of 336 to 448 kg/ha of ammonium nitrate fertilizer are not uncommon in the orchards, and may be as high as 560 to 784 kg/ha (Iversen, 1979).

(2) Areas that have historically had high concentrations of NO_3^- in the drinking water are residential subdivisions. Since no central collection of wastes exists on the Peninsula, all residences utilize private septic systems. Nitrogen compounds discharged from these systems readily convert to NO_3^- in soils. Because they are continually adding water, NO_3^- is likely to move deep in the soil profile beneath septic systems.

(3) In establishing new orchards or residential subdivisions, land is often reshaped, exposing soil organic matter to the atmosphere thereby enhancing its decomposition. Organic N is converted to NO_3^- which is readily leached.

(4) Nitrate contamination may also be a result of industry process waste. It is unlikely this is a significant source, however, since process waste is reported to contain less than 1.5 mg NO_3-N/1 (Weaver and Grant, 1980).

(5) Because the underlying formation is an organic rich Antrim shale, the nitrate source may be geologic (Weaver and Grant, 1980). If the source is geologic, it is more difficult to identify and nearly impossible to control.

The specific objectives of this study were to (1) determine if NO_3^- leaches from fertilized cherry orchards; (2) determine the levels of N fertilizers that may be applied without significant loss of NO_3^- from the profile; (3) determine the concentration of NO_3^- leaching from septic system drainfields; (4) determine the distribution of NO_3^- in soil profiles, as affected by land reshaping.

LITERATURE REVIEW

Nitrogen is frequently the most limiting nutrient in cultivated soils. In recent years, the use of synthetic fertilizers to achieve optimal nutrient levels has increased significantly. It has been estimated that in 1980 alone, 9.07 to 10.9 million metric tons of synthetic nitrogen fertilizers will have been applied to crops in the United States (Tisdale and Nelson, 1975).

Most crops, except legumes, require additional N fertilization to achieve and maintain optimum yields (Saxton et al, 1977). Annual additions of 100 kg N/ha are not uncommon for highly productive, intensively cultivated crops (Fried et al, 1976). However, in order to minimize N pollution, it is necessary to apply the minimum to achieve maximum yield (Hills et al, 1978; Schuman et al, 1975). Above this level, the amount of N that may potentially leach increases rapidly (Fried et al, 1976).

Ammonium based fertilizers readily complex with soil colloids. However, unless cold or waterlogged conditions exist, the NH_4^+ will rapidly undergo nitrification to the highly soluble NO_3^- which will remain in the soil solution. The anionic nature of NO_3^- precludes adsorption onto the soil particle--rather, because of anion exclusion (Thomas and Swoboda, 1970), NO_3^- occurs in increased concentrations toward the exterior of the water film where it is subsequently subject to loss by leaching (Saxton et al, 1977).

Within a soil profile, NO_3^- movement is dependent upon the amount of water moving through the profile. Smika et al (1977) noted a high correlation ($r = 0.95$) between water loss and NO_3-N loss from a profile. They found that an average 10.2 kg N/ha was carried to a profile depth of 150 cm by each cm of water percolating through the profile. Owens (1960) found that the amount of N lost by leaching was directly proportional to the amount of water traversing the profile in the spring months.

Another factor affecting NO_3^- leaching appears to be the time of application of nitrogenous fertilizers. Several studies have examined the fate of fall applied N fertilizers (Bauder and Montgomery, 1979; Felizardo et al, 1972; Gambrell et al, 1975; Krause and Batsch, 1968; Larsen and Kohnke, 1946; Olsen et al, 1970). Olsen et al (1970) found that, in general, more leaching occurred during the winter than during the growing season. Canadian researchers, Krause and Batsch (1968), found that 88 per cent of the N applied to a sandy soil in mid-September was lost by December. Gambrell et al (1975) found that an average 46 kg NO_3-N/ha was leached from a moderately well drained soil, over the winter months. Bauder and Montgomery (1979) also concluded that NO_3^- based N fertilizers should not be applied in the fall on well drained sandy soils since significant leaching may result.

While much of the past research addresses NO_3^- leaching in relation to row crops (Adriano et al, 1972a; Adriano et al, 1972b; Hills et al, 1978; Olsen et al, 1970; Saxton et al, 1977; Schuman et al, 1975), several significant works have examined the leaching losses from sandy orchard soils (Bingham et al, 1971; Felizardo et al, 1972; Nightingale, 1972; Pratt et al, 1972).

Sandy soils have the greatest potential for NO_3^- leaching since, because of their naturally low fertility and water holding capabilities, they are often intensely fertilized and irrigated. Nightingale (1972) found that while increased soil NO_3-N concentrations were associated with both agronomic crops and orchards, concentrations were greater under orchards 78 per cent of the time. Bingham et al (1971) found that approximately 45 percent of the nitrogen applied (or 67.2 kg N/ha) to a citrus orchard was leached from the soil profile, as nitrate, yearly. Effluents in their study area contained an average 50 to 60 mg NO_3-N/l.

Extensive work by Walker et al (1973a, 1973b) examines the N transformations that occur during the disposal of septic system effluents in sandy soils.

Walker et al (1973a) found that effluent was ponded in all the seepage beds examined, due to a "crust" between the gravel bed and the adjacent soil. The organic N fraction of the septic tank effluent was mainly concentrated in the crust region while nitrification of the NH_4-N fraction (approximately 80 per cent of the total N occurring in the effluent) was basically complete, beginning in the unsaturated zone within approximately 2 cm of the crust. They concluded denitrification to be the only feasible means for reducing the nitrate content in the percolating effluent, and that it would not likely occur if the seepage beds were built in deep sandy soils. They also found that the average system input was approximately equivalent to 8.2 kg N per person yearly. For an average family of four, approximately 33 kg N would be produced yearly, most of which would be nitrified and reach the groundwater as NO_3-N.

Walker et al (1973b) also studied the groundwater quality in relation to the disposal of septic tank effluents in sandy soils. They found that NO_3^- concentrations in the groundwater below and adjacent to septic drainfields (located well above the groundwater) were considerably higher than the U. S. Public Health Department (1962) limit of 10 mg N/l. They determined dilution with NO_3^- free water to be the only means of reducing the NO_3-N concentration in the groundwater.

While numerous studies have addressed the contribution of agriculture and septic systems to the groundwater contamination problem, few have investigated the consequences of land reshaping.

When the Muskegon (Michigan) Wastewater Treatment Facility was constructed, artificial drainage was established on the site and the land surface was reshaped to a certain extent to enable suitable crop growth. As a result of improved soil drainage and aeration, decomposition of soil organic matter occurred, with a subsequent release of nitrogen. This ultimately increased the nitrate within the soil profile and was observed in bands throughout the profile (Ellis et al, 1979).

It is apparent from the literature that fertilization practices, septic systems and land reshaping operations influence the quality of groundwater. By contributing additional NO_3-N to a profile, whether as a result of mistimed or excessive fertilization, nitrification of septic system effluents or the mineralization of organic N following land reshaping, the potential for loss by leaching increases, as does the degree of NO_3^- contamination.

MATERIALS AND METHODS

Orchard Study

On the basis of preliminary soil tests, two orchard sites (A and B) were selected in Peninsula township. Both sites were situated on soils of the Emmet-Leelanau series, Emmet sandy loam (coarse-loamy, mixed, frigid Alfic Haplorthod).

Site A was a well established (trees > 25 years old), non-irrigated site with a plot size of 12.2 m by 12.2 m (four trees per plot). Site B was a relatively new stand (trees < 10 years old) employing trickle irrigation. Plot size for site B was 11.0 m by 13.4 m (four trees per plot).

Treatments were arranged in a randomized complete block design, with four replications of the three treatments per site (24 plots total). Ammonium nitrate fertilizer (34-0-0) was broadcast using a whirl-wind spreader. Rates of 56, 112 and 224 kg N/ha were applied in April 1981, after obtaining an initial non-treated soil sampling.

Soil samples were a composite of ten samples per plot, each 2.54 cm in diameter, taken in 30.5 cm increments to a depth of 1.83 m. The composite samples were placed in polyethylene bags, sealed, stored on ice and transported to Michigan State University for analysis. Samples were obtained on a monthly basis through October 1981.

In July 1981, field conditions were very dry so that sampling below the 1.53 m depth was impossible. This persisted throughout the remainder of the 1981 sampling period. A final sampling, to 1.83 m, was made in April 1982.

Twenty five grams of field moist soil was extracted with 25 ml of 2 N KCl by shaking for one half hour on a rotary shaker. Samples were then filtered through Whatman No. 2 filter paper. The filtrate was analyzed for nitrate and ammonium using a Technicon Autoanalyzer and standard Technicon procedures (1973a, b). A field moist subsample was also dried at 105° C to determine moisture content. Nitrate and ammonium values were reported on a dry soil weight basis.

Septic Drainfield Study

The septic systems on the Peninsula are apparently designed and constructed as shown in Figure 1. As can be seen in Figure 1, the nature of the drainfield is such that the following procedure was necessarily developed to provide access below the drainfield for installation of the suction lysimeters:

Using a post hole digger, a 20.3 cm (diameter) hole was opened to the depth of the drainfield. The hole was sleeved with stovepipe and stones removed manually while forcing the piping through the stone layer. Upon penetration of the coarse stone layer, a 7.62 cm bucket auger was used to bore to the appropriate subsurface depth. A ceramic cup suction lysimeter was embedded in the wet sand at the bottom of each hole and access tubes were connected to the top of each lysimeter. Sand was packed around and on top of the lysimeters to the stone layer; stones that had been removed were replaced. The stove pipe was removed and the upper soil replaced. The lysimeter tubes were terminated in a chamber (Figure 2) and the unit was capped at the soil surface.

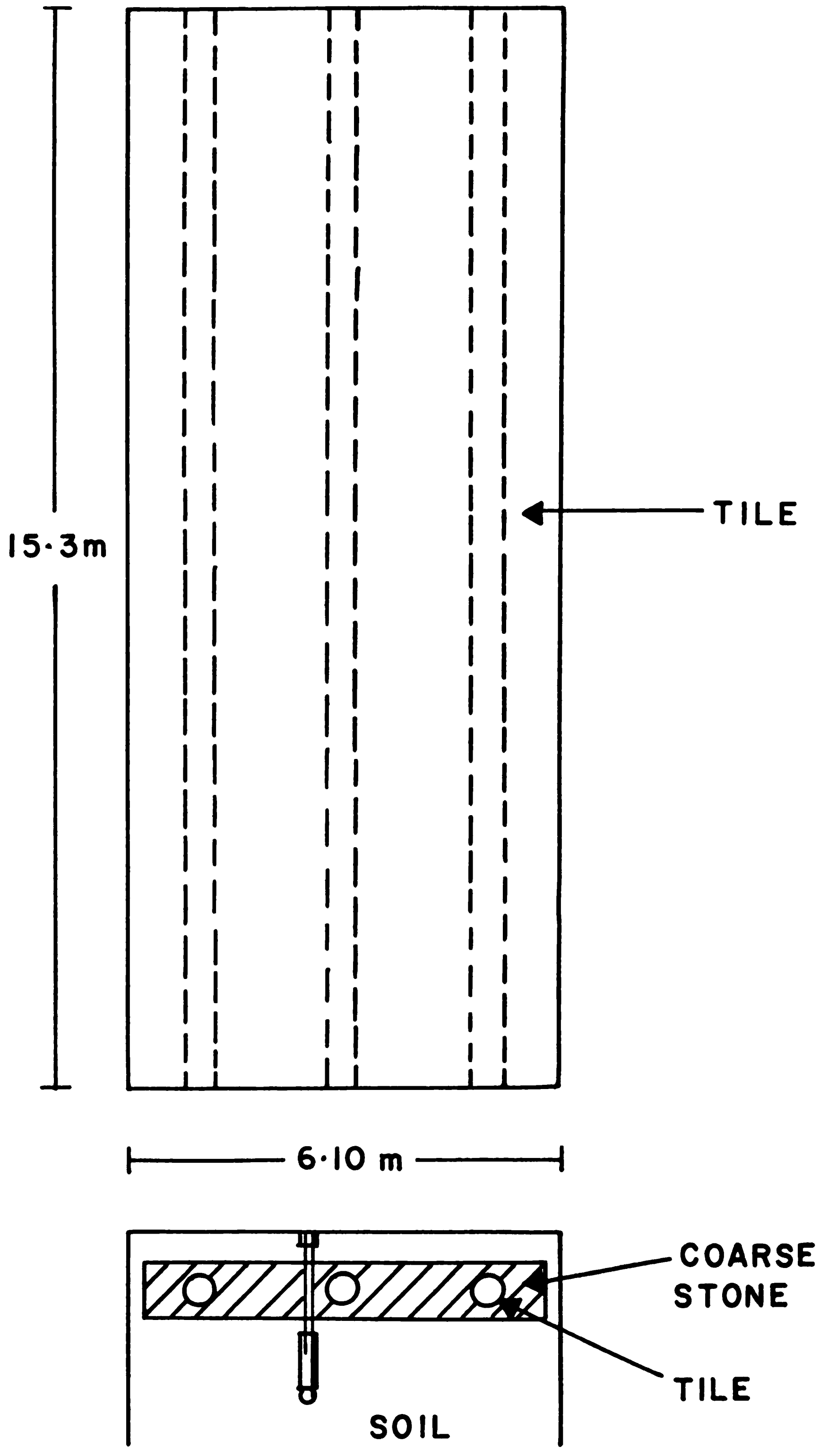

Figure 1. Diagram of septic drainfields and position of the suction lysimeter.

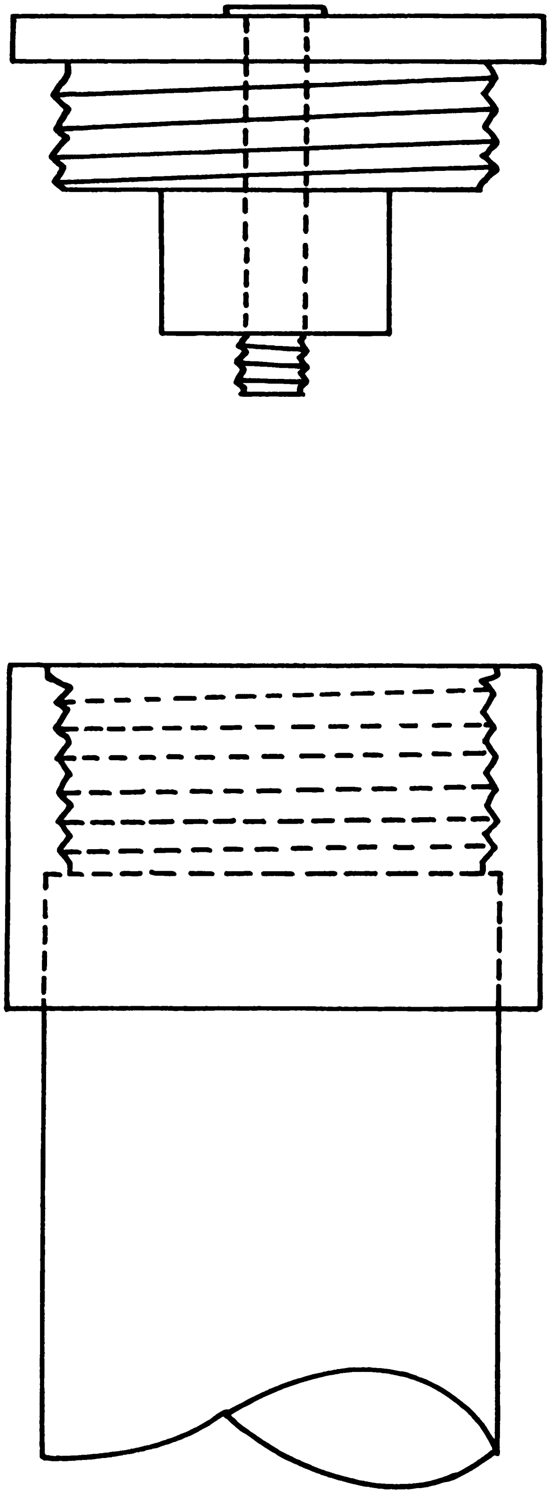

Figure 2. Diagram of the chamber holding sample tubes.

Seven lysimeters were located on three sites in the Bay East Subdivision. Site SA had one at a depth of 0.92 m and two at a depth of 1.53 m. Sites SB and SC had two each at depths of 1.53 m only. All lysimeters were located in sandy soils.

Samples were obtained by putting 0.08 MPa vacuum on the lysimeters for approximately 24 hours, after which time they were pumped to remove the samples. Upon evacuation of the (24 hour) samples, 0.08 MPa vacuum was maintained on the lysimeters. At the next sampling period (approximately one month later) the resulting samples were collected immediately prior to the subsequent 24 hour samples. Samples were placed in plastic bottles on ice and transported to MSU for analysis. Samples were analyzed for nitrate content using a Technicon Autoanalyzer and standard Technicon procedures.

Samples were obtained on a monthly basis from September 1981 through February 1982

Land Reshaping Study

Sites were selected in Peninsula township in areas where land surfaces had been reworked and reshaped in order to establish orchards.

Seven sites were selected on the basis of soil type, degree of fill and relative age of the reshaped area. Degree of fill was characterized as light (top soil as fill $<$ 1.22 m deep or fill containing little organic material), medium (top soil as fill from 1.22 m to 2.44 m deep or fill containing a moderate amount of organic material) or heavy (top soil as fill $>$ 2.44 m deep or fill having a high organic matter content). Borings were made in the fill areas as well as in adjacent control areas where cuts were made and the soil surface removed.

Sites subject to reshaping prior to 1980 were sampled using a split spoon sampler (subcontracted with Technical Drilling Associates of Traverse City, Michigan). A 45.7 cm split spoon was driven ahead of a 20.3 cm hollow stem drill to obtain an undisturbed sample. After each 45.7 cm sample, the excess soil to that depth was removed using the 20.3 cm hollow stem drill. Each sample was subdivided into 30.5 cm increments, described in the field, placed in polyethylene bags and sealed. Samples were placed on ice and transported to MSU for analysis.

Sites that had been reshaped in 1980 or later were sampled using a 7.62 cm bucket auger.

Samples were extracted and analyzed for NO_3^- as described previously.

RESULTS AND DISCUSSION

Orchard Study

Upon analysis of the initial unfertilized soil sampling, it was evident that a sizable portion of site A had been previously and uniformly fertilized by the grower with approximately 73 kg/ha of a NO_3^- based N fertilizer. Instead of the three planned treatments (56, 112 and 224 kg N/ha), site A had thus been modified to contain five treatments:

Treatment 1 - 112 kg N/ha

Treatment 2 - 129 kg N/ha (56 + 73)

Treatment 3 - 185 kg N/ha (112 + 73)

Treatment 4 - 224 kg N/ha

Treatment 5 - 297 kg N/ha (224 + 73)

Utilization of the randomized complete block design was possible, with slight modification. Instead of the four replications of each treatment as planned, Treatments 1, 3, 4 and 5 were replicated twice and Treatment 2 was replicated four times (twice per block).

Nitrate data for site A can be found in Appendix A, Tables A1 through A5. Ammonium data can be found in Appendix A, Tables A6 through A10.

With the exception of the 112 kg rate, NO_3^- concentrations were higher in the profiles through the September 1981 sampling than they were in April 1981 and often the October 1981 sampling was higher as well. Nitrate concentrations detected in the October 1981 sampling of the 112 kg rate were uniformly low, approaching the levels observed in the initial (April 1981) profile sampling. In all cases, the residual NO_3^- had been flushed (leached) from the profiles by the following April, presumably as a result of the excess moisture (due to snowmelt, etc.) moving through the soil during the winter and spring months.

There is some evidence of NO_3^- movement within the profile during the summer months. Bands of increasing NO_3^- concentrations were observed migrating downward in the soil profiles, presumably moving with water in the profile.

It is also interesting to note that in several instances the NO_3^- concentrations increased in the surface depths. This may have been a result of capillary action (Harding, 1954; Krantz et al, 1943; Wetselaar, 1961): as surface soil dried out, moisture containing NO_3-N from deeper in the profile was drawn to the surface, thereby increasing the NO_3-N found in the surface samples. Or it may have been a result of nitrification.

Ammonium-N was observed to persist in the soil through the summer and into the fall for all treatments on this site, but especially for those treatments receiving 185 kg N/ha or more. However for the most part, the NH_4-N was readily converted to NO_3-N.

Some NH_4-N also persisted in the soil profiles of site B, a relatively young orchard irrigated by trickle irrigation. But most of the NH_4-N had been nitrified by July 1981.

For the 56 kg rate, essentially all of the NO_3-N had been removed from the profile by the September 1981 sampling, indicating the treatment level may have been too low to maximize production potential.

Increased profile concentrations, relative to the April 1981 sampling, were observed for the 112 and 224 kg rates, through the October 1981 sampling. As for site A, the residual NO_3^- had been flushed from the profile by the following April.

Observation of migratory bands of increased NO_3^- concentration in these profiles also suggests the distinct possibility of leaching during the summer months. As with site A, increased NO_3^- concentrations were detected in the surface soils as well.

Nitrate data for site B can be found in Appendix B, Tables B1 through B3; ammonium data can be found in Appendix B, Tables B4 through B6.

The estimated utilization of NO_3-N by cherry trees is illustrated in Table 1. Several assumptions were made in the preparation of Table 1, particularly in the definition of residual profile NO_3^-. For the purpose of this study, residual profile NO_3^- has been defined as the quantity of NO_3-N remaining in the profile in the final fall sampling (October 1981) plus the quantity of NO_3-N not readily accessible to the trees (i.e. beneath the estimated effective root zone) of the sampling immediately prior to the final fall sampling (September 1981). Estimates of the quantity of NO_3-N used by the trees as well as the concentrations of NO_3-N that would be expected in the water moving through the fertilized profiles are also found in Table 1.

Table 1. Estimation of nitrate leached from cherry orchards.

Location	Initial Profile NO_3	Total NO_3 Applied	Profile NO_3 Residual	Profile NO_3 Apr. 82	NO_3 Used*	NO_3 Leached**	NO_3 in Water+
	---------	---------	kg NO_3-N/ha	---------	---------	---------	mg/l
A	19	112	60	16	71	45	14 d
	19	129	120	13	28	106	32 c
	19	185	123	13	81	110	33 c
	19	224	180	20	63	160	48 b
	19	297	267	13	49	253	76 a
B	27	56	36	24	47	12	3.7b
	30	112	100	27	43	73	22 ab
	39	224	158	30	105	128	39 a

* The quantity of nitrate used was estimated as the initial nitrate plus the added nitrate minus the residual nitrate.

** The nitrate leached is the difference between the residual nitrate and the April sampling.

\+ To calculate the concentration of nitrate in the water it is assumed that the nitrate is distributed uniformily in the 33.0 cm of water that leaches each year. Means identified with the same letter(s) are not significantly different for $lsd_{.05}$. Sites A and B were examined independently.

It is apparent from Table 1 that the optimum fertilization level, from the standpoints of production and groundwater quality, lies somewhere between 56 and 112 kg N/ha.

It is also apparent from Table 1 that cherry trees remove approximately 56 to 67.2 kg NO_3-N/ha. The inordinately high amount of NO_3-N used for the 224 kg rate at site B may be due in part to a vigorous growth of grass rather than increased utilization by the trees.

Rates of application in excess of that required by the cherry trees resulted in residual profile NO_3^- which was subject to leaching by water moving through the profile. The estimated NO_3^- concentration expected in the water moving through a profile correlates highly with the rate of N applied (Figure 3).

It has been recommended that N fertilizers be applied in the fall in this area (Kenworthy et al, 1978). The data contained in Appendices A and B, Tables A1 through A5 and B1 through B3, suggests this practice may result in NO_3^-leaching to depths well below the effective root zone by the following spring. While growers applying N fertilizers in mid-November or later may lessen the degree of leaching, the data suggests the practice of fall fertilization is questionable, at best.

Septic Drainfield Study

Three sites in Bay East Subdivision were monitored throughout the fall and winter of 1981. Lysimeters at site SA were used to collect effluent samples from profile depths of 0.92 m (immediately beneath the seepage bed) and 1.53 m. Lysimeters at sites SB and SC were located at depths of 1.53 m only. Table 2 contains data obtained throughout the course of this study

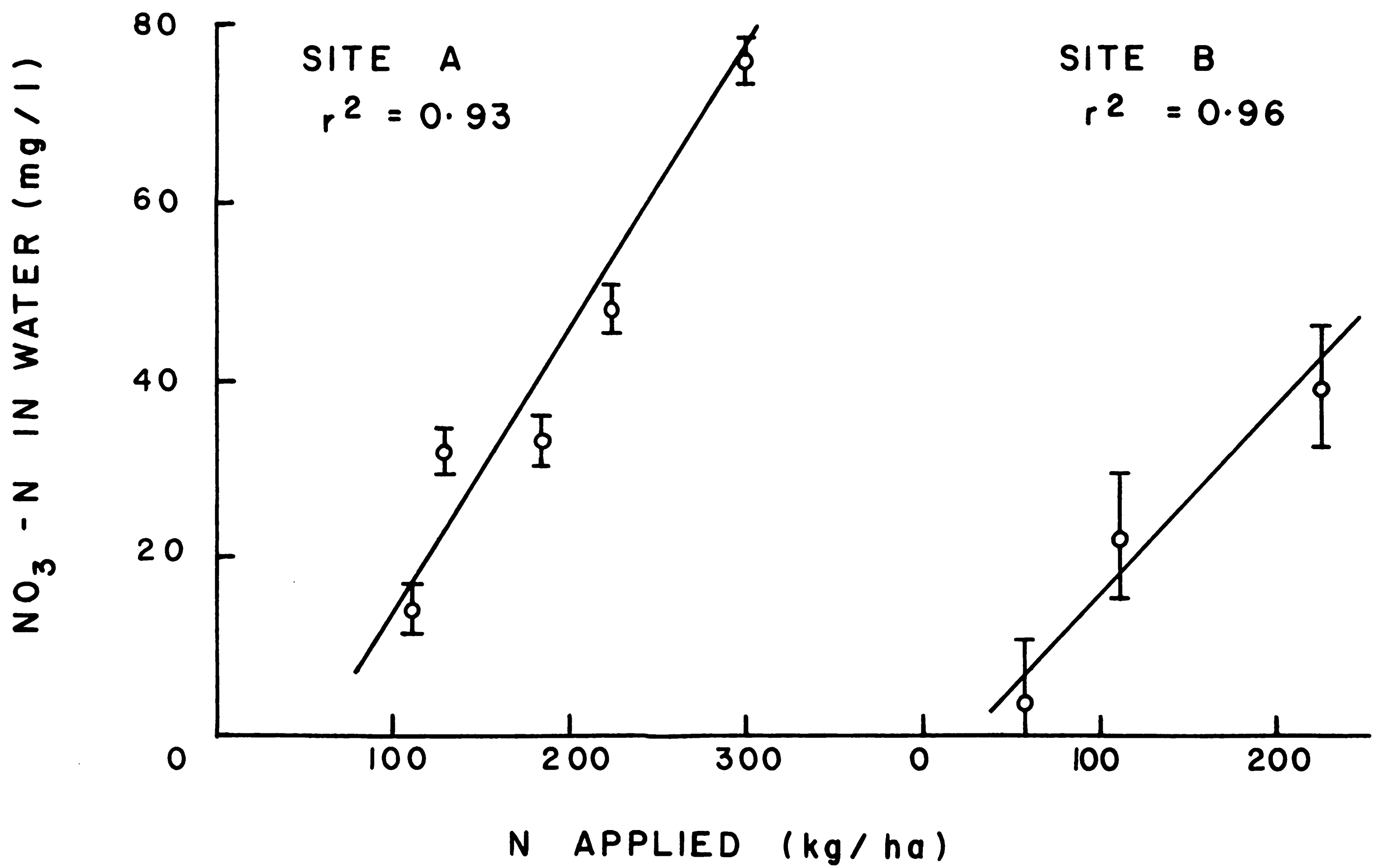

Figure 3. Effect of N application rate on the estimated NO3-N concentration in soil water for sites A and B.

Table 2. Nitrate concentration of water below septic drainfields in Bay East Subdivision.

Location	Date					
	9/24/81	10/6/81	10/14/81	11/18/81	12/22/81	2/11/82
	mg NO_3-N/l					
SA-1*	0.24	0.21	nd	nd	0.48	0.40
2	22.4	8.61	11.4	15.1	16.0	--
3	--	--	33.1	21.6	21.6	26.4
SB-1	--	31.1	39.5	33.0	28.7	--
2	--	--	20.1	--	--	--
SC-1	42.9	40.6	37.6	31.0	30.7	27.4
2	43.4	39.6	34.1	29.5	22.8	24.9

*The last number indicates a different location within the same drainfield. SA-1 is at a 0.92 m depth, near the discharge point. All other samples are extracted from a 1.53 m depth. A -- indicates the sample was not obtained in sufficient quantites to analyze.

At the 0.92 m depth, samples obtained were presumed taken from just beneath the base of the seepage bed or crust area (Walker et al, 1973a). The extremely low NO_3^- concentrations observed (an average 0.22 mg NO_3-N/l) suggest that N present at this depth is present as NH_4-N or simple amine instead. A significant increase in NO_3^-concentration was observed in effluent obtained from the 1.53 m depths. An average NO_3^- concentration of 28.6 mg/l for the three sites indicates most of the NH_4-N had been nitrified by this depth.

A slight decrease in the NO_3^- concentration of the effluent was also observed during the later samples, indicating a possible slowing of the nitrification process. Early fall samples contained an average 31.1 mg/l NO_3-N, while the late fall and winter samples contained an average 26.0 mg/l NO_3-N. This difference does not indicate a significant reduction in the rate of nitrification, however. It is apparent from this study that nitrification of septic system effluents continues throughout the winter, with little reduction in the rate of conversion.

To better understand the magnitude of septic systems in contributing to the NO_3^- contamination of groundwater, it is necessary to obtain an estimate of the quantity of NO_3-N reaching the groundwater from this source.

As with other sources of NO_3^- contamination, it is important to recognize the potential for dilution (within the profile) by natural precipitation as it moves to the groundwater. In 1981, the total precipitation recorded for the area was approximately 68.6 cm. Of this, an estimated 33.0 cm of water per year would be expected to leach through a soil profile in this area (U. S. Geological Service, personal communication). The degree of dilution that occurs depends not only on the natural precipitation, but also upon family size and lot size. Table 3 shows the effect of family size and lot size on the NO_3^- concentration expected to reach the groundwater. An average lot size of

Table 3. Nitrate concentration expected to reach groundwater as effected by effluent concentration and family size.*

Effluent Concentration	Family size 2	Family size 4	Family size 6
mg NO_3-N/l	mg NO_3-N/l		
20	4.73	7.64	9.63
30	7.09	11.5	14.4
40	9.45	15.3	19.3

*A lot size of 0.41 ha and daily effluent discharge of 567 liters per person was assumed.

0.41 ha was assumed in the preparation of this table but, by adjusting for actual lot size, it is possible to observe the expected effects on an individual basis. It is clearly apparent that septic systems contribute to the problem of NO_3^- contamination, through the continuous discharge of N compounds that readily convert to NO_3^-.

To control the degree of contamination from this source, it would be most desirable to denitrify the effluent as it traverses the soil profile. Unfortunately, this is not likely to happen naturally in the sandy profiles of the study area. Systems capable of denitrifying the effluent exist, but are expensive to install and maintain. Installation of sewers is also possible, but this only transfers the problem to another area. Again, the expense may be prohibitive, especially for smaller subdivisions.

Another alternative is dilution of the NO_3^- contaminated groundwater with NO_3^--free water, suggested by Walker et al (1973b). Unfortunately, to accomplish the desired dilution, this alternative requires large areas, not readily available in established subdivisions.

Land Reshaping Study

Seven locations were sampled in a effort to study the effects of land reshaping operations (cut and fill) on the NO_3^- distribution of deep soil profiles. Because of the diversity in degree of fill and relative age of the reshaped areas, each location (pair of sites) will be discussed independently. Nitrate data obtained from the deep samples can be found in the Appendix C, Tables D1 through D10 and Tables H11 through H14. Locations 1 through 5, reshaped two or more years prior to sampling, were sampled using the split spoon sampler. Locations 6 and 7, reshaped less than two years prior to sampling, were sampled by hand using a 7.62 cm bucket auger.

Location 1, Sites A and B. This area had been reshaped in 1978-1979. While it was not an area of extensive reshaping, it was possible to identify areas of fill inclusion (site A) as well as areas where the surface soil had been removed or cut (site B).

The highest NO_3^- concentrations were observed in the upper 1.53 m of the fill site profile. Although classified as a light fill site, concentrations approached an estimated 50 mg NO_3-N/l in the soil solution, nearly five times the 10 mg NO_3-N/l limit. The remainder of the profile contained concentrations within the limit, although in many instances concentrations were noted in the 7 to 9 mg/l range. With the exception of an anomolous value at the 10.7 to 11.0 m depth (15.4 mg NO_3-N/l), the NO_3^- concentrations observed in the accompanying cut profile were generally less than 5 mg NO_3-N/l.

Location 2, Sites C and D. The area encompassing sites C and D was extensively reshaped in the spring of 1979. Heavy fill was observed to a depth of at least 3.05 m (site C).

Nitrate concentrations in the upper 6.10 m of the fill profile exceeded the 10 mg/l standard without exception. The remainder of the profile generally exhibited concentrations within the limit. The upper 0.61 m of the cut profile contained appreciable amounts of NO_3-N; concentrations in the remainder of the profile were generally less than 10 mg/l.

Location 3, Sites E and F. This area was reshaped in 1955, with site E receiving a moderate degree of fill matepial. It was apparent that top soil was returned to the cut area (site F) as well.

Nitrate concentrations were moderately high (less than 20 mg/l) in the upper 0.61 m of both profiles. Fill site E also exhibited a band of increased NO_3^- concentration between the 3.05 and 4.58 m depths. The remainder of both profiles contained little NO_3-N.

Location 4, Sites M and N. This area, like locations 1 and 2, was also reshaped in 1979. Site N was an area of light fill which, with the exception of the surface 0.31 m, did not appear to contain excessive quantities of organic material.

A band of NO_3^- exceeding 10 mg/l was observed between 1.53 m and 2.44 m at site N, but concentrations were lower throughout the remainder of the profile. The cut profile was low throughout.

Location 5, Sites O and P. Site P, reshaped prior to 1980, contained a light degree of fill. With the exception of samples from the 1.53 m to 2.14 m depths, the upper 3.66 m of the profile contained NO_3^- in concentrations within the set standard. The remainder of the profile was saturated; values obtained in this region were very low, indicating the possibility of denitrification. Concentrations in the cut profile (site O) were uniformly low.

Location 6, Sites G and H. This area had been reshaped less than one year prior to sampling and had been seeded to a cover crop.

With the exception of the 0.92m to 1.53m depths, NO_3^-concentrations in the area of medium fill (site H) exceeded the nitrate standard at all depths. Nitrate concentrations approached or exceeded the standard throughout the cut profile also.

Location 7, Sites J and K. This area was also reshaped less than one year prior to sampling, but had not been seeded to a cover crop.

Concentrations in the area of medium fill (site J) approached or exceeded the nitrate standard at all depths. Maximum concentrations in the cut profile approached, but did not exceed, the standard.

Because sampling of the profiles occurred in August, it is probable that some of the nitrate present would have been utilized by the end of the growing season by vegetation present on the sites. The residual NO_3^-, however, would have been subject to leaching, especially in the sandier profiles.

It is apparent from the data that, generally, NO_3^- is released as a result of the reshaping operations, whether for the establishment of new orchards or the development of residential subdivisions. It does not appear to be a serious problem unless soil containing organic matter (i.e. top soil) is used as fill material and the area is filled to depths exceeding 1.22 m. In excess of this depth, NO_3^- contamination becomes a serious threat. Figure 4 and Figure 5 illustrate the differences in NO_3-N distribution within the 6.10 m profiles for areas containing light fill and heavy fill. Table 4 illustrates the quantity of excess soluble NO_3^-present in an area of heavy fill. To a depth of 6.10 m, the filled profile contained more than twice as much NO_3^- as did the adjacent cut profile. Additional NO_3^- may also be released for several years as the organic matter decomposes and is nitrified.

The utilization of two management techniques may subsequently reduce the amount of NO_3^- contamination from this source. As much as possible, the use of top soil as fill material should be discontinued except as fill for the surface 0.31 m. If necessary, top soil may need to be stock piled until the reshaping operation is nearly complete, then used as fill in the final stages. The practice of seeding the reshaped area to a vigorously growing grass, oats, rye or other suitable cover crop should also be maintained, to utilize the NO_3^- present in the soil.

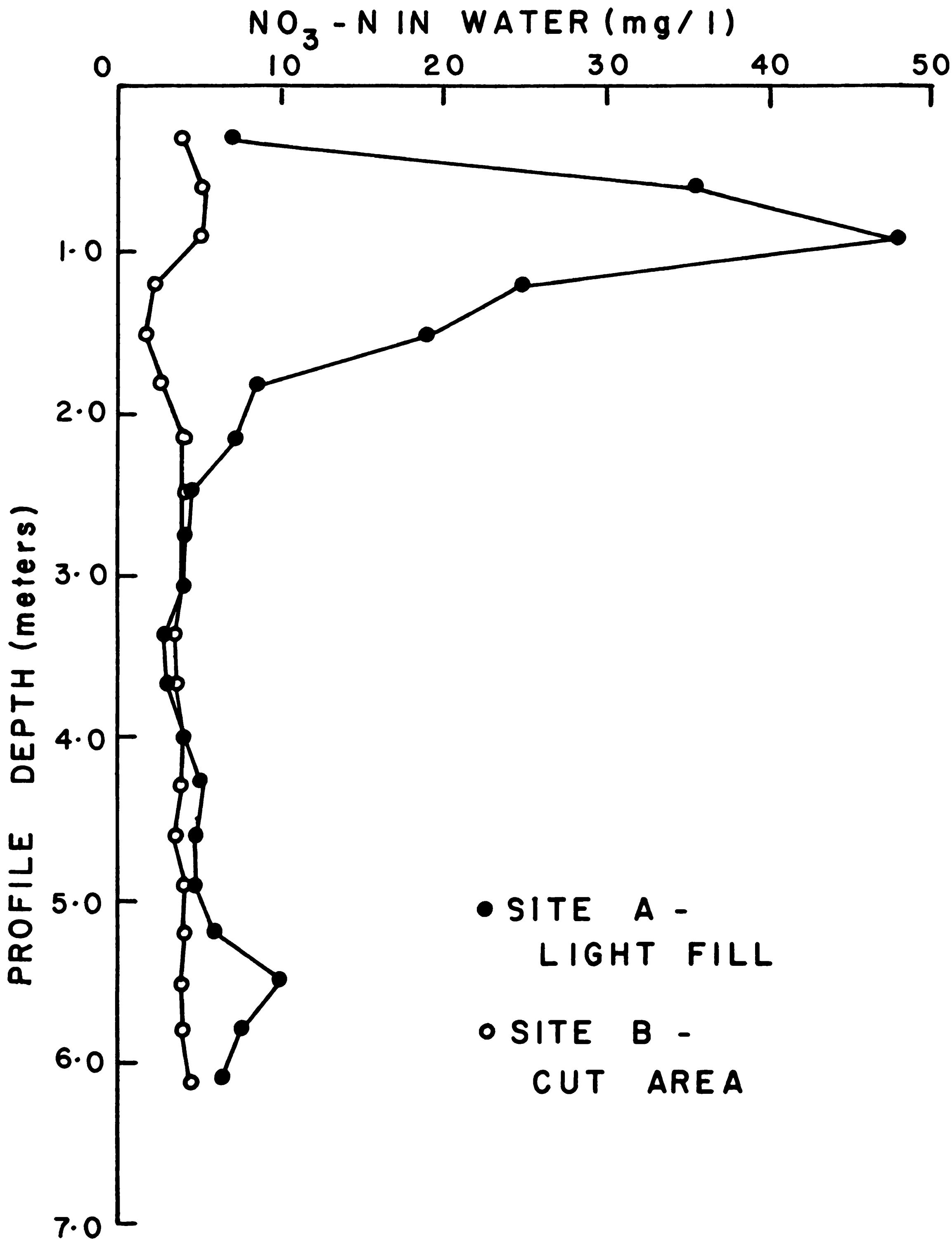

Figure 4. Effect of light fill on estimated NO_3-N in water: Location 1.

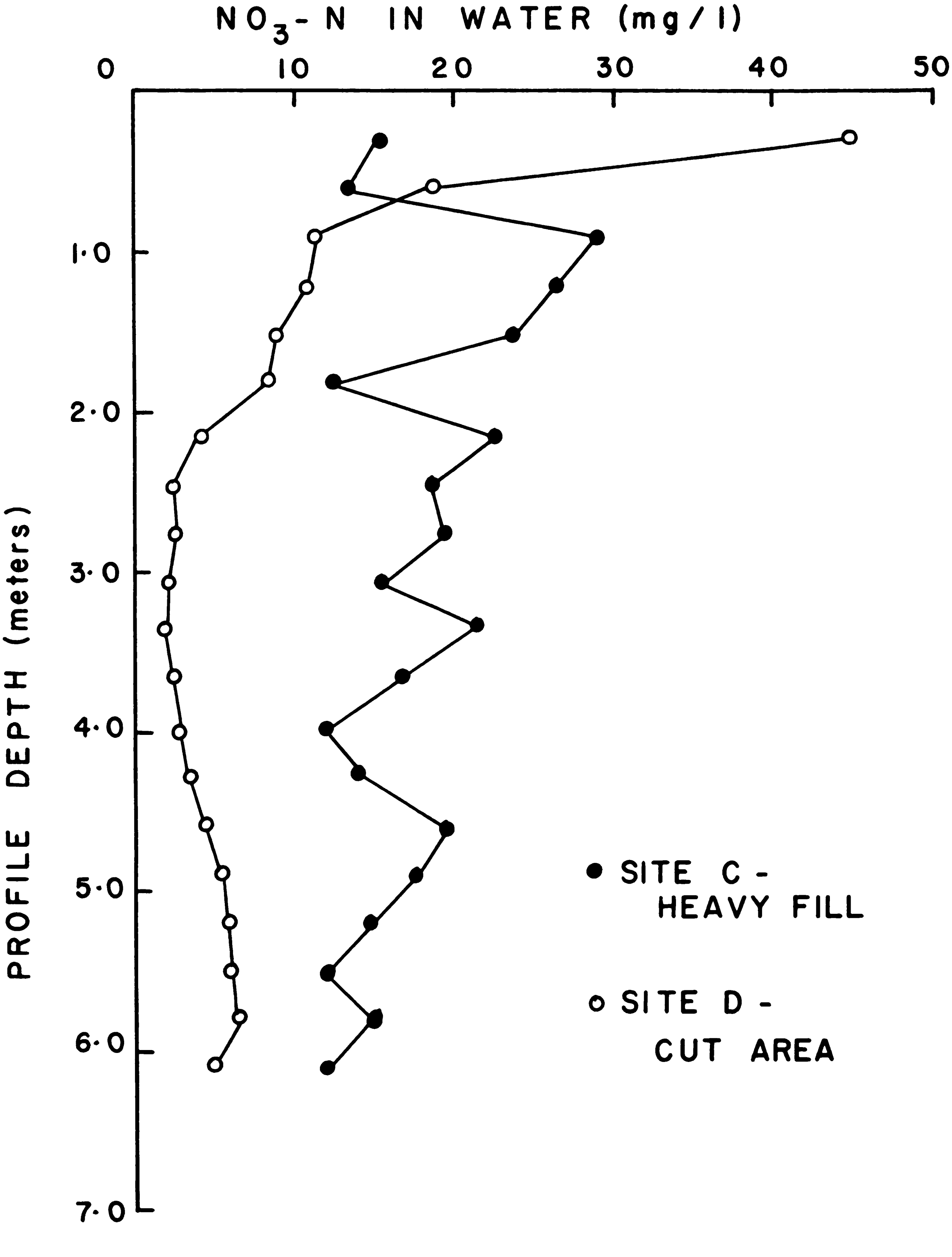

Figure 5. Effect of heavy fill on estimated NO_3-N in water: Location 2.

Table 4. Quantity of nitrate in soils at Location 2, Sites C and D.

Depth	Nitrate in Each Layer	
	Site C	Site D
meters	kg NO_3-N/ha	
0.00-0.31	11.3	32.8
0.31-0.61	9.78	13.7
0.61-0.92	21.3	8.36
0.92-1.22	19.5	8.00
1.22-1.53	17.4	6.62
1.53-1.83	9.13	6.14
1.83-2.14	16.6	3.15
2.14-2.44	17.0	1.74
2.44-2.75	17.9	1.96
2.75-3.05	11.3	1.74
3.05-3.36	15.8	1.46
3.36-3.66	(12.2)*	(1.71)
3.66-3.97	8.72	1.96
3.97-4.27	10.3	2.64
4.27-4.58	14.3	3.34
4.58-4.88	12.9	4.02
4.88-5.19	10.7	4.29
5.19-5.49	8.64	4.52
5.49-5.80	10.8	4.75
5.80-6.10	(8.86)	3.56
Total	264.43	116.42

*( ) indicates a missing sample and the mean of the layer above and the layer below was used.

SUMMARY AND CONCLUSIONS

Studies were conducted to investigate the effects of orchard fertilization, septic systems and land reshaping on the NO_3^-contamination of the groundwater of Old Mission Peninsula.

Two orchard sites were fertilized with increasing rates of N and the NO_3^- movement monitored during the course of this study. Soil profiles were sampled on a monthly basis to a depth of 1.83 m, from April 1981 (prior to fertilization) through October 1981. A final sampling was made in April 1982.

Application rates of less than 112 kg N/ha resulted in little or no residual NO_3^- in the October profiles. Rates in excess of 112 kg/ha resulted in appreciable quantities of NO_3-N remaining in the profile in October. The sampling in April 1982 indicated that the residual NO_3-N had been leached from the profile over the winter months.

Suction lysimeters were established in three septic drainfields in Bay East Subdivision in September 1981, and were sampled on a regular basis through February 1982.

Samples obtained near the discharge point (at a profile depth of 0.92 m) contained very little NO_3-N. Samples from the 1.53 m depth contained an average 28.6 mg NO_3-N/l, indicating N compounds discharged from septic systems readily convert to NO_3^-. It was also evident that the rate of conversion did not decrease significantly during the winter months.

Deep profile samples were obtained in areas that had been reshaped to establish orchards. It was evident from this phase of the study that NO_3^- is released as a result of reshaping, but the quantity of NO_3-N released generally is not a problem unless heavy fill is used.

RECOMMENDATIONS

Several management practices should be encouraged to minimize nitrate contamination from agricultural sources.

Because NO_3-N does leach from the effective root zones (1.83 m) of orchards on the Peninsula during the winter, the practice of fall fertilization should be discontinued. Nitrogen fertilizers should be applied in the spring at rates of 56 to 112 kg N/ha (165 to 329 kg NH_4NO_3/ha) to ensure minimal contamination.

In reshaping surfaces to establish orchards, heavy fill (i.e. top soil) should not be used in excessive amounts (depths greater than 1.22 m). Preferably, it should be used in the final stage of reshaping.

Following reshaping, the area should be seeded to a fast growing cover crop to utilize the NO_3^- released. The cover crop should be maintained until the orchard is well established.

Residential subdivisions pose special problems. At present, it is not economically feasible to implement the known methods of controlling NO_3^- contamination from septic systems. Instead, monitoring the quality of incoming household water on a regular basis may be necessary. This would be especially true in homes with small children.

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APPENDIX A

Table A-1. *Nitrate* content of Soils at Site A, Treatment 1*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NO_3-N/kg							
0- 15	2.29	7.56	12.33	7.33	4.02	5.12	1.54	0.86
15- 30	0.78	6.54	7.53	4.47	4.18	3.37	1.04	0.70
30- 45	0.97	6.05	8.40	6.40	4.43	3.47	0.87	0.84
45- 60	0.51	3.77	5.63	4.76	5.85	2.86	1.50	0.67
60- 75	0.52	2.72	3.98	5.22	5.39	2.39	1.27	0.73
75- 90	0.45	2.22	3.33	3.55	4.89	2.66	1.38	0.68
90-105	0.42	1.65	2.91	1.95	3.87	3.78	1.47	0.65
105-120	0.38	1.49	1.92	1.65	2.91	2.65	1.82	0.55
120-135	0.43	1.18	3.25	1.77	3.33	3.36	1.41	0.54
135-150	0.40	1.18	2.19	1.39	2.82	2.39	2.05	0.60
150-165	0.47	1.08	2.50	-	-	-	-	0.54
165-180	0.50	1.16	2.67	-	-	-	-	0.62

*Treatment 1 received 112 kg N/ha as ammonium nitrate. Each value is a mean of two replications.

Table A-2. Nitrate content of Soils at Site A, Treatment 2*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NO_3-N/kg							
0– 15	22.1	7.89	12.5	15.4	12.1	4.15	5.22	1.16
15– 30	3.55	7.05	8.41	8.74	11.7	3.10	6.53	0.70
30– 45	4.79	9.18	9.99	15.5	9.34	4.09	2.90	0.57
45– 60	1.06	6.56	7.91	8.71	14.2	4.97	3.39	0.56
60– 75	2.29	3.97	5.12	14.3	8.85	3.88	3.16	0.51
75– 90	0.81	2.50	3.95	7.99	7.73	3.23	4.03	0.53
90–105	1.37	1.69	3.30	7.39	6.12	4.36	3.78	0.53
105–120	0.79	1.42	2.14	4.28	3.40	2.77	2.90	0.43
120–135	1.00	1.14	2.61	2.95	3.72	3.16	3.50	0.47
135–150	0.76	1.53	2.00	2.78	2.81	2.58	4.12	0.49
150–165	1.21	1.14	2.77	-	-	-	-	0.46
165–180	0.74	0.92	2.01	-	-	-	-	0.78

* Treatment 2 received 56 kg N/ha as ammonium nitrate from our application and an additional 72.8 kg from the grower. Total = 129 kg N/ha. Each value is a mean of four replications.

Table A-3. Nitrate content of Soils at Site A, Treatment 3*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NO_3-N/kg							
0- 15	25.53	13.5	16.3	16.4	7.59	26.34	1.25	1.38
15- 30	3.52	18.3	12.6	16.6	9.4	10.4	1.10	0.71
30- 45	5.12	15.6	11.8	16.5	10.3	10.4	1.15	0.48
45- 60	0.75	6.99	9.7	10.0	13.4	16.8	1.35	0.45
60- 75	2.23	3.48	8.10	13.6	12.4	6.57	1.68	0.39
75- 90	0.78	4.17	4.67	4.25	9.4	5.17	2.96	0.47
90-105	0.93	1.81	3.87	4.18	5.67	7.14	3.28	0.56
105-120	0.73	2.85	2.69	2.44	5.08	4.48	4.38	0.45
120-135	0.66	2.14	3.10	2.23	7.52	8.96	4.54	0.44
135-150	0.65	1.59	1.76	2.49	5.17	4.52	7.24	0.55
150-165	1.22	1.46	2.21	-	-	-	-	0.52
165-180	0.93	1.44	1.49	-	-	-	-	0.57

*Treatment 3 received 112 kg N/ha as ammonium nitrate from our application and an additional 72.8 kg from the grower. Total = 185 kg N/ha. Each value is a mean of two replications.

Table A-4. Nitrate content of Soils at Site A, Treatment 4*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NO_3-N/kg							
0- 15	2.74	11.6	13.9	19.2	6.62	5.99	1.43	3.61
15- 30	1.14	7.43	10.4	21.0	6.56	4.76	1.66	0.83
30- 45	1.13	8.57	17.4	23.1	8.53	5.76	2.60	0.72
45- 60	0.57	8.34	11.0	21.9	7.69	6.71	4.33	0.63
60- 75	1.51	5.21	9.24	20.9	7.03	5.77	6.50	0.49
75- 90	0.56	3.14	7.18	11.03	11.1	6.49	9.17	0.54
90-105	0.50	2.21	4.02	7.19	11.8	6.86	6.87	0.66
105-120	0.43	1.17	4.07	5.10	5.91	6.19	7.84	0.49
120-135	0.43	1.27	5.28	4.74	5.83	6.91	6.52	0.45
135-150	0.53	1.56	4.32	5.06	4.89	6.13	5.85	0.49
150-165	0.48	1.08	4.01	-	-	-	-	0.54
165-180	0.52	0.96	2.91	-	-	-	-	0.80

*Treatment 4 received 224 kg N/ha as ammonium nitrate. Each value is a mean of two replications.

Table A-5. Nitrate content of Soils at Site A, Treatment 5*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NO_3-N/kg							
0- 15	25.2	22.0	20.5	16.5	13.5	13.3	3.33	0.87
15- 30	3.42	16.4	23.0	17.3	12.5	8.21	7.22	0.75
30- 45	4.12	13.7	20.6	19.1	16.7	8.45	7.80	0.65
45- 60	0.89	11.8	15.7	17.2	17.1	7.27	9.57	0.53
60- 75	1.79	7.02	8.33	22.0	13.3	15.6	14.1	0.45
75- 90	0.77	4.32	5.94	6.94	12.2	7.52	8.68	0.44
90-105	1.12	2.52	3.13	7.28	6.65	9.78	7.47	0.61
105-120	0.62	2.02	3.23	2.83	5.79	7.63	9.48	0.62
120-135	1.48	1.84	3.88	3.07	6.49	11.0	6.84	0.65
135-150	0.79	1.89	3.68	1.88	4.72	6.70	6.88	0.57
150-165	1.24	1.53	3.02	-	-	-	-	0.59
165-180	0.75	2.00	5.57	-	-	-	-	0.75

*Treatment 5 received 224 kg N/ha as ammonium nitrate from our application and an additional 72.8 kg from the grower. Total = 297 kg N/ha. Each value is a mean of two replications.

Table A-6. Ammonium content of Soils at Site A, Treatment 1*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NH_4-N/kg							
0- 15	0.25	2.94	3.13	1.33	1.46	1.34	1.62	1.50
15- 30	0.29	0.56	0.91	0.66	1.53	1.15	0.67	1.00
30- 45	0.24	0.56	1.74	1.89	1.33	0.91	0.67	1.04
45- 60	0.28	0.86	0.86	0.84	3.22	1.34	0.90	0.97
60- 75	0.31	0.39	0.98	1.68	2.04	0.89	0.73	0.95
75- 90	0.12	0.63	0.86	1.19	1.76	0.66	1.02	1.00
90-105	1.46	0.36	1.22	0.86	2.04	1.57	1.50	1.01
105-120	0.16	0.51	1.70	0.79	1.52	1.12	0.73	0.92
120-135	0.16	0.36	0.96	1.19	2.12	1.10	1.50	0.99
135-150	0.20	0.63	0.93	1.12	2.16	1.09	0.48	1.60
150-165	0.39	0.67	1.04	-	-	-	-	0.87
165-180	0.20	0.94	0.86	-	-	-	-	0.99

*Treatment 1 received 112 kg N/ha as ammonium nitrate. Each value is a mean of two replications.

Table A-7. Ammonium content of Soils at Site A, Treatment 2*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NH_4-N/kg							
0- 15	0.27	2.38	2.42	3.85	4.49	1.30	0.98	2.14
15- 30	0.55	0.55	1.05	1.08	3.08	0.99	0.93	1.24
30- 45	0.43	0.62	1.35	4.04	1.74	1.18	0.55	1.01
45- 60	0.16	0.80	0.78	1.80	4.59	2.82	0.77	1.26
60- 75	0.38	0.47	0.71	7.90	2.01	1.31	0.58	0.79
75- 90	0.71	0.46	0.74	5.17	2.05	0.88	0.46	1.58
90-105	0.47	0.61	0.77	5.69	2.38	1.78	0.58	1.57
105-120	0.31	1.64	0.61	2.15	1.61	1.05	0.97	1.05
120-135	0.14	0.73	1.42	1.25	1.45	1.74	0.87	0.74
135-150	0.34	0.75	0.75	1.24	1.52	1.36	0.79	1.11
150-165	0.30	0.74	0.73	-	-	-	-	1.00
165-180	0.20	0.44	1.96	-	-	-	-	1.19

*Treatment 2 received 56 kg N/ha as ammonium nitrate from our application and an additional 72.8 kg from the grower. Total = 129 kg N/ha. Each value is a mean of four replications.

Table A-8. Ammonium content of Soils at Site A, Treatment 3*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NH_4-N/kg							
0- 15	0.26	8.23	8.92	3.10	3.12	5.66	0.93	2.60
15- 30	0.13	1.58	1.27	1.72	1.56	1.70	0.73	1.40
30- 45	0.53	0.80	1.22	2.83	1.82	1.35	1.30	0.84
45- 60	0.48	1.15	0.87	0.97	4.58	3.06	0.59	1.56
60- 75	0.16	0.59	1.62	2.68	2.06	0.87	0.71	0.69
75- 90	0.16	0.94	0.75	1.04	1.86	0.76	0.30	0.98
90-105	0.55	0.70	1.03	1.05	1.71	2.55	0.74	1.66
105-120	0.44	0.67	0.55	0.84	1.41	1.67	0.45	1.04
120-135	0.16	0.28	0.81	0.79	2.15	2.42	1.35	1.07
135-150	0.12	0.75	0.44	0.95	2.37	1.32	0.75	1.65
150-165	0.48	0.67	0.90	-	-	-	-	1.81
165-180	0.56	0.40	1.22	-	-	-	-	0.83

*Treatment 3 received 112 kg N/ha as ammonium nitrate from our application and an additional 72.8 kg from the grower. Total = 185 kg N/ha. Each value is a mean of two replications.

Table A-9. Ammonium content of Soils at Site A, Treatment 4*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NH_4-N/kg							
0- 15	0.86	5.80	6.44	11.9	7.62	1.78	0.81	1.83
15- 30	0.65	0.99	1.48	1.56	3.04	8.43	0.68	1.08
30- 45	0.22	2.02	3.10	11.5	2.74	1.13	0.71	0.90
45- 60	0.16	3.30	3.91	7.05	6.71	2.04	1.00	0.85
60- 75	0.48	0.83	1.70	11.2	4.10	1.35	0.71	1.10
75- 90	0.12	0.63	1.22	2.19	2.39	1.17	0.71	1.17
90-105	0.08	1.06	0.90	1.17	5.64	1.20	0.68	1.38
105-120	0.16	0.48	0.74	0.76	1.87	1.30	0.58	3.03
120-135	0.36	0.32	0.99	0.92	3.16	1.23	0.71	1.02
135-150	0.16	0.95	1.67	1.71	2.32	1.67	0.82	1.10
150-165	0.44	0.75	0.84	-	-	-	-	1.20
165-180	0.69	0.55	2.20	-	-	-	-	0.78

*Treatment 4 received 224 kg N/ha as ammonium nitrate. Each value is a mean of two replications.

Table A-10. Ammonium content of Soils at Site A, Treatment 5*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NH_4-N/kg							
0- 15	0.25	9.36	9.87	4.38	12.0	4.74	2.83	2.87
15- 30	0.21	2.38	4.08	1.83	2.88	1.48	1.17	2.30
30- 45	0.16	0.56	2.22	2.73	2.99	1.47	1.30	1.39
45- 60	0.52	1.27	7.79	1.35	6.98	1.40	1.69	0.97
60- 75	0.40	0.75	1.42	3.27	1.91	6.74	1.03	0.75
75- 90	0.28	0.59	1.02	1.10	2.88	1.49	1.34	1.25
90-105	0.28	0.82	0.83	1.33	2.69	3.57	1.91	1.37
105-120	0.16	1.17	0.91	1.13	1.69	1.61	1.23	0.83
120-135	0.28	0.58	1.07	1.52	2.99	3.47	1.55	1.02
135-150	0.28	0.51	1.20	1.09	1.92	1.51	1.18	1.00
150-165	0.24	0.31	1.39	-	-	-	-	1.05
165-180	0.16	0.31	2.61	-	-	-	-	0.91

*Treatment 5 received 224 kg N/ha as ammonium nitrate from our application and an additional 72.8 kg from the grower. Total = 297 kg N/ha. Each value is a mean of two replications.

APPENDIX B

Table B-1. Nitrate content of Soils at Site B, Treatment 1*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	kg NO_3-N/kg							
0- 15	3.33	6.83	8.23	5.70	2.32	1.66	1.58	1.60
15- 30	2.42	7.63	7.66	5.98	2.12	1.74	1.19	1.19
30- 45	1.64	5.37	7.62	5.50	1.83	1.22	0.81	0.92
45- 60	1.27	4.43	4.09	2.23	1.95	1.26	1.06	0.84
60- 75	1.16	3.31	5.31	3.97	1.70	0.95	1.08	0.79
75- 90	0.92	1.94	1.74	1.43	1.57	1.05	1.24	0.79
90-105	0.80	2.74	2.53	2.22	2.00	1.02	1.42	1.14
105-120	0.70	1.67	1.06	1.20	1.75	0.98	1.09	0.88
120-135	0.61	1.15	1.06	2.14	1.56	1.21	1.00	1.12
135-150	0.66	1.51	1.29	0.75	0.85	0.86	1.58	1.24
150-165	0.91	0.90	0.70	-	-	-	-	1.25
165-180	0.79	0.83	0.65	-	-	-	-	1.51

*Treatment 1 received 56 kg N/ha as ammonium nitrate. Each value is a mean of four replications.

Table B-2. Nitrate content of Soils at Site B, Treatment 2*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NO_3-N/kg							
0- 15	2.14	11.4	11.6	7.8	3.39	2.48	1.86	2.31
15- 30	1.85	9.2	11.9	12.0	4.37	3.61	1.28	1.32
30- 45	1.35	6.97	10.3	8.7	3.68	3.09	1.00	1.03
45- 60	1.07	6.51	5.61	4.44	3.73	3.05	2.08	0.84
60- 75	1.06	4.21	8.33	4.31	5.53	3.71	4.48	0.84
75- 90	1.18	3.22	4.15	2.33	4.16	4.73	4.64	0.95
90-105	1.51	2.94	4.64	4.05	2.41	3.17	3.68	0.99
105-120	0.88	1.51	1.86	1.62	2.17	2.55	3.60	1.17
120-135	0.84	1.99	1.05	3.80	1.64	2.55	7.31	1.81
135-150	0.80	1.69	3.16	1.79	1.27	1.49	7.94	1.17
150-165	0.78	2.01	1.27	-	-	-	-	1.68
165-180	1.25	3.12	1.00	-	-	-	-	1.35

*Treatment 2 received 112 kg N/ha as ammonium nitrate. Each value is a mean of four replications.

Table B-3. Nitrate content of Soils at Site B, Treatment 3*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NO_3-N/kg							
0- 15	4.14	36.8	16.0	27.9	5.31	2.94	1.90	2.32
15- 30	3.29	22.4	24,1	22.3	16.1	4.45	1.68	1.28
30- 45	2.05	19.7	16.5	14.4	11.9	5.43	2.53	1.11
45- 60	1.47	14.6	12.1	6.51	11.4	4.92	2.99	0.95
60- 75	1.28	10.9	12.8	9.5	13.3	6.08	4.77	0.83
75- 90	0.92	7.6	5.65	4.89	10.1	8.44	6.31	0.88
90-105	1.09	8.3	5.90	7.14	5.86	6.63	5.60	1.07
105-120	0.95	5.26	3.08	2.63	3.84	8.42	7.01	1.08
120-135	0.97	2.39	2.32	5.40	2.85	6.73	6.08	2.07
135-150	1.03	6.06	4.99	1.95	2.23	2.92	7.20	1.92
150-165	1.02	1.97	2.12	-	-	-	-	1.93
165-180	1.19	2.64	1.38	-	-	-	-	1.98

*Treatment 3 received 224 kg N/ha as ammonium nitrate. Each value is a mean of four replications.

Table B-4. Ammonium content of Soils at Site B, Treatment 1*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NH_4-N/ha							
0- 15	0.52	1.19	2.66	1.03	1.05	0.92	1.06	2.06
15- 30	0.34	5.08	1.72	1.65	0.98	0.61	0.76	1.37
30- 45	0.35	3.89	1.33	1.14	0.94	0.78	0.51	1.46
45- 60	0.29	3.62	1.20	0.63	1.07	0.89	1.09	1.27
60- 75	0.23	8.02	3.60	0.88	0.92	0.66	1.10	0.89
75- 90	0.39	1.32	0.89	0.54	0.72	0.65	0.89	1.15
90-105	0.28	0.98	1.21	0.90	1.28	0.80	0.93	1.57
105-120	0.30	3.04	1.01	0.62	1.02	0.69	0.71	1.08
120-135	0.34	0.50	1.29	1.00	1.42	0.60	1.12	1.99
135-150	0.30	0.54	2.08	0.33	0.80	0.53	0.89	1.43
150-165	0.26	0.21	1.08	-	-	-	-	1.12
165-180	0.30	0.18	1.10	-	-	-	-	1.37

*Treatment 1 received 56 kg N/ha as ammonium nitrate. Each value is a mean of four replications.

Table B-5. Ammonium content of Soils at Site B, Treatment 2*.

	Month							
Depth	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NH_4-N/kg							
0- 15	0.55	1.61	3.93	0.79	1.06	0.98	0.93	2.04
15- 30	0.41	1.72	2.92	1.06	1.05	0.80	0.72	1.21
30- 45	0.27	1.34	2.95	1.23	0.83	0.89	1.42	1.20
45- 60	0.44	1.58	4.75	0.59	1.19	1.42	1.17	1.39
60- 75	0.39	0.83	5.95	0.72	0.81	1.02	1.26	1.01
75- 90	0.45	0.39	3.13	0.47	0.81	1.28	0.63	1.28
90-105	0.36	0.54	3.07	0.86	1.17	1.27	1.74	1.39
105-120	0.40	0.50	1.85	0.54	0.74	0.63	1.81	1.03
120-135	0.32	0.30	1.93	0.84	0.90	1.05	2.37	1.45
135-150	0.28	0.17	1.17	0.89	1.15	0.72	1.68	1.35
150-165	0.26	0.54	1.64	-	-	-	-	1.34
165-180	0.31	0.40	2.43	-	-	-	-	1.24

*Treatment 2 received 112 kg N/ha as ammonium nitrate. Each value is a mean of four replications.

Table B-6. Ammonium content of Soils at Site B, Treatment 3*.

Depth	Month							
	April 81	May 81	June 81	July 81	August 81	Sept. 81	October 81	April 82
cm	mg NH_4-N/kg							
0- 15	0.28	4.17	2.01	1.81	0.98	1.09	0.77	1.81
15- 30	0.32	2.63	4.56	2.70	0.95	0.95	0.58	1.37
30- 45	0.33	3.58	2.57	1.25	1.05	0.71	1.54	1.46
45- 60	0.47	2.59	3.48	0.50	1.24	0.93	0.68	1.39
60- 75	0.31	2.08	2.96	1.06	0.88	0.97	1.25	1.92
75- 90	0.35	2.39	1.78	0.43	0.79	0.93	0.56	0.93
90-105	0.23	2.26	1.80	0.82	0.81	3.30	0.46	1.43
105-120	0.19	1.36	1.98	0.73	0.81	1.33	0.79	1.15
120-135	0.28	0.41	1.26	0.81	1.46	1.23	0.76	1.17
135-150	0.17	0.86	2.40	0.50	0.96	1.52	1.02	2.30
150-165	0.24	0.67	3.60	-	-	-	-	1.75
165-180	0.24	0.53	6.48	-	-	-	-	1.50

*Treatment 3 received 224 kg N/ha as ammonium nitrate. Each value is a mean of four replications.

APPENDIX C

Table D-1. Nitrate content of soil and soil water at Location 1, Site A--light fill area.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Dark sandy loam	1.40	7.00
0.31- 0.62	Dark sandy loam	7.09	35.4
0.62- 0.92	Dark sandy loam	9.67	48.3
0.92- 1.22	Dark brown loam	5.52	24.8
1.22- 1.53	Dark brown sandy loam	3.82	19.1
1.53- 1.83	Light brown loam	1.92	8.64
1.83- 2.14	Light brown clay loam	1.84	7.26
2.14- 2.44	Light brown clay loam	1.12	4.48
2.44- 2.75	Light brown clay loam	1.04	4.16
2.75- 3.05	Light brown sandy loam	0.79	3.95
3.05- 3.36	Light brown clay loam	0.68	2.72
3.36- 3.66	Light brown clay loam	0.80	3.20
3.66- 3.97	Dark clay	1.08	3.89
3.97- 4.27	Dark clay	1.45	5.22
4.27- 4.58	Clay	1.24	4.46
4.58- 4.88	Clay	1.27	4.57
4.88- 5.19	Clay	1.58	5.69
5.19- 5.49	Light brown sandy gravel	1.58	9.88
5.49- 5.80	Light brown sandy gravel	1.19	7.44
5.80- 6.10	Light sand	1.01	6.31
6.10- 6.41	Light sand	1.01	6.31
6.41- 6.71	Light sand	0.90	5.63
6.71- 7.02	Light sand	1.05	6.56
7.02- 7.32	Light sand	0.74	4.63
7.32- 7.63	Light sand	1.05	6.56
7.63- 7.93	Light sand	1.52	9.50
7.93- 8.24	Light sand	1.16	7.25
8.24- 8.54	Light sand	0.85	5.31
8.54- 8.85	Light sand	0.64	4.00
8.85- 9.15	Light sand	1.05	6.56
9.15- 9.46	Light sand	1.05	6.56
9.46- 9.76	Light sand	1.22	7.63
9.76-10.1	Light sand	0.90	5.63
10.1 -10.4	Light sand	1.16	7.25
10.4 -10.7	Light sand	1.10	6.88

(continued)

Table D-1. (Continued)

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg--------	
10.7 -11.0	Light sand	0.96	6.00
11.0 -11.3	Light sand	0.79	4.94
11.3 -11.6	Light gravelly sand	0.53	3.31
11.6 -11.9	Light sand	0.43	2.69
11.9 -12.2	Light sand	0.33	2.06
12.2 -12.5	Light sand	0.33	2.06
12.5 -12.8	Light sand	1.11	6.94
12.8 -13.1	Light sand	0.95	5.94
13.1.-13.4	Light sand	1.16	7.22
13.4 -13.7	Light sand	1.06	6.63
13.7 -14.0	Light sand	0.97	6.06
14.0 -14.3	Light sand	1.49	9.31

Table D-2. Nitrate content of soil and soil water at Location 1, Site B--cut area near site A.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Light sand	0.64	4.00
0.31- 0.61	Light sand	0.85	5.31
0.61- 0.92	Light sand	0.81	5.06
0.92- 1.22	Light sand	0.33	2.06
1.22- 1.53	Light sand	0.28	1.75
1.53- 1.83	Light sand	0.44	2.75
1.83- 2.14	Light sand	0.64	4.00
2.14- 2.44	Light sand	0.65	4.06
2.44- 2.75	Light sand	0.60	3.75
2.75- 3.05	Light sand	0.65	4.06
3.05- 3.36	Light sand	0.56	3.50
3.36- 3.66	Light gravelly sand	0.56	3.50
3.66- 3.97	Light sand	0.69	4.31
3.97- 4.27	Light sand	0.61	3.81
4.27- 4.58	Light sand	0.55	3.44
4.58- 4.88	Light sand	0.66	4.13
4.88- 5.19	Light sand	0.65	4.06
5.19- 5.49	Light sand	0.64	4.00
5.80- 6.10	Light sand	0.65	4.06
6.10- 6.41	Light sand	0.70	4.38
6.41- 6.71	Light sand	0.74	4.63
6.71- 7.02	Light sand	0.65	4.06
7.02- 7.32	Light sand	0.63	3.94
7.32- 7.63	Light sand	0.69	4.31
7.63- 7.93	Light sand	0.74	4.63
7.93- 8.24	Light sand	0.68	4.25
8.24- 8.54	Light sand	0.48	3.00
8.54- 8.85	Light sand	0.53	3.31
8.85- 9.15	Light sand	0.64	4.00
9.15- 9.46	Light sand	0.58	3.63
9.46- 9.76	Light sand	0.53	3.31
9.76-10.1	Light sand	0.53	3.31
10.1 -10.4	Light sand	0.68	4.25
10.4 -10.7	Light sand	0.56	3.50
10.7 -11.0	Light sand	0.53	3.31

(continued)

Table D-2. (Continued)

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
11.0 -11.3	Light sand	2.46	15.4
11.3 -11.6	Light sand	0.53	3.31
11.6 -11.9	Light sand	0.43	2.69
11.9 -12.2	Light sand	0.38	2.38
12.2 -12.5	Light sand	0.32	2.00
12.5 -12.8	Light sand	0.32	2.00
12.8 -13.1	Light sand	0.33	2.06
13.1 -13.4	Light sand	0.27	1.69
13.4 -13.7	Light sandy gravel	0.28	1.75
13.7 -14.0	Light sand	0.43	2.69
14.0 -14.3	Light sand	0.75	4.69
14.3 -14.6	Light sand	0.78	4.88
14.6 -15.0	Light sand	0.58	3.63

Table D-3. Nitrate content of soil and soil water at Location 2, Site C-- heavy fill area.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Dark brown sand	2.48	15.5
0.31- 0.61	Dark brown sand	2.14	13.4
0.61- 0.92	Brown sand	4.65	29.1
0.92- 1.22	Dark brown sand	4.26	26.6
1.22- 1.53	Dark brown sand	3.80	23.8
1.53- 1.83	Dark brown sand	2.00	12.5
1.83- 2.14	Dark brown sand	3.63	22.7
2.14- 2.44	High organic matter sand	3.72	18.6
2.44- 2.75	High organic matter sand	3.93	19.6
2.75- 3.05	Darker brown sand	2.47	15.4
3.05- 3.36	Darker brown sand	3.45	21.6
3.36- 3.66*			
3.66- 3.97	Sandy gravel	1.91	11.9
3.97- 4.27	Dark brown sand	2.25	14.1
4.27- 4.58	Dark brown sand	3.13	19.6
4.58- 4.88	Dark brown sand	2.82	17.6
4.88- 5.19	Dark brown sand	2.35	14.7
5.19- 5.49	Brown sand	1.89	11.8
5.49- 5.80	Lighter brown sand	2.37	14.8
5.80- 6.10*			
6.10- 6.41	Coarse gravel	1.51	9.44
6.41- 6.71*			
6.71- 7.02	Coarse gravel	1.04	6.50
7.02- 7.32	Gravelly sand	1.10	6.88
7.32- 7.63	Gravelly sand	0.57	3.56
7.63- 7.93	Gravelly sand	0.78	4.88
7.93- 8.24	Coarse sand	0.89	5.56
8.24- 8.54	Gravelly sand	0.63	3.94
8.54- 8.85	Gravelly sand	0.68	4.25
8.85- 9.15	Gravelly sand	0.58	3.63
9.15- 9.46	Gravelly sand	0.79	4.94
9.46- 9.76	Brown sand	0.53	3.31
9.76-10.1	Brown sand	0.74	4.63
10.1 -10.4	Gravelly sand	0.58	3.63
10.4 -10.7	Gravelly sand	0.63	3.94

(continued)

*Missing samples were because of stones which prevented a complete sample from being obtained.

Table D-3. (Continued)

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
10.7 -11.0	Light brown sand	0.78	4.88
11.0 -11.3	Light brown sand	0.68	4.25
11.3 -11.6	Light brown sand	0.89	5.56
11.6 -11.9	Light brown sand	0.73	4.56
11.9 -12.2	Light brown sand	0.94	5.88
12.2 -12.5	Light brown sand	1.76	11.0
12.5 -12.8	Light brown sand	0.88	5.50
12.8 -13.1	Light brown sand	0.78	4.88
13.1 -13.4	Light brown sand	0.67	4.19
13.4 -13.7	Light brown sand	0.52	3.25
13.7 -14.0	Light brown sand	0.42	2.63
14.0 -14.3	Light brown sand	0.47	2.94

Table D-4. Nitrate content of soil and soil water at Location 2, Site D--cut area near site C.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Dark brown sand	7.18	44.9
0.31- 0.61	Dark brown sand	3.00	18.8
0.61- 0.92	Brown gravelly sand	1.83	11.4
0.92- 1.22	Brown gravelly sand	1.75	10.9
1.22- 1.53	Brown gravelly sand	1.45	9.06
1.53- 1.83	Coarse gravel	1.34	8.38
1.83- 2.14	Coarse gravel	0.69	4.31
2.14- 2.44	Coarse gravel	0.38	2.38
2.44- 2.75	Coarse gravel	0.43	2.69
2.75- 3.05	Coarse gravel	0.38	2.38
3.05- 3.36	Coarse gravel	0.32	2.00
3.16- 3.66*			
3.66- 3.97	Coarse gravel	0.43	2.69
3.97- 4.27	Coarse gravel	0.58	3.63
4.27- 4.58	Light brown gravelly sand	0.73	4.56
4.58- 4.88	Light brown sand	0.88	5.50
4.88- 5.19	Light brown sand	0.94	5.88
5.19- 5.49	Light brown sand	0.99	6.19
5.49- 5.80	Light brown sand	1.04	6.50
5.80- 6.10	Darker brown sand	0.78	4.88
6.10- 6.41	Brown sand	0.79	4.94
6.41- 6.71	Light brown sand	0.89	5.56
6.71- 7.02	Dark brown sand	1.10	6.88
7.02- 7.32	Brown gravelly sand	1.05	6.56
7.32- 7.63	Brown gravelly sand	1.31	8.19
7.63- 7.93	Brown gravelly sand	1.30	8.13
7.93- 8.24	Brown gravelly sand	1.10	6.88
8.24- 8.54	Brown gravelly sand	1.15	7.19
8.54- 8.85	Brown gravelly sand	1.20	7.50
8.85- 9.15	Brown sand	1.53	8.38
9.15- 9.46	Brown sand	1.34	8.38
9.46- 9.76	Brown sand	0.91	5.69
9.76-10.1	Brown sand	0.75	4.69
10.1 -10.4	Brown sand	0.64	4.00
10.4 -10.7	Brown sand	0.64	4.00

(continued)

*Missing samples were because of stones which prevented a complete sample from being obtained.

Table D-4. (Continued)

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
10.7 -11.0	Brown sand	0.64	4.00
11.0 -11.3	Brown sand	0.64	4.00
11.3 -11.6	Brown sand	0.69	4.31
11.6 -11.9	Brown sand	0.79	4.94
11.9 -12.2	Brown sand	0.84	5.25
12.2 -12.5	Brown sand	0.89	5.56
12.5 -12.8	Brown sand	0.90	5.63
12.8 -13.1	Brown sand	1.10	6.88
13.1 -13.4	Clay layer then gravel	1.28	6.30
13.4 -13.7	Very coarse gravel	1.17	7.31
13.7 -14.0	Very coarse gravel	1.01	6.31
14.0 -14.3	Very coarse gravel	1.33	8.31
14.3 -14.6	Gravel then sand	1.47	9.19
14.6 -15.0	Brown sand	1.68	10.5

Table D-5. Nitrate content of soil and soil water at Location 3, Site E--medium fill area.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Dark brown loam	3.74	16.8
0.31- 0.61	Dark brown loam	1.98	8.91
0.61- 0.92	Dark organic sand	0.80	4.00
0.92- 1.22	Light brown sand then dark organic sand	1.15	5.75
1.22- 1.53	Brown sand	0.47	2.94
1.53- 1.83	Brown sand	0.70	4.38
1.83- 2.14	Light brown sand	0.44	2.75
2.14- 2.44	Light brown sand	0.44	2.75
2.44- 2.75	Light brown sand	0.58	3.63
2.75- 3.05	Light brown sand	0.71	4.44
3.05- 3.36	Sandy loam	2.07	10.4
3.36- 3.66	Light brown sand 1" clay layer	2.24	14.0
3.66- 3.97	Sand with clay bands	1.80	11.2
3.97- 4.27	Sand with clay bands	1.81	11.3
4.27- 4.58	Light brown sand	1.47	9.19
4.58- 4.88	Light brown sand with clay	1.26	5.04
4.88- 5.19	Clay	1.31	4.72
5.19- 5.49	Clay	1.04	3.74
5.49- 5.80	Gravelly clay	0.86	3.44
5.80- 6.10	Gravelly clay	0.84	3.36
6.10- 6.41	Sandy loam	0.56	2.80
6.41- 6.71	Silty clay	0.52	2.08

Table D-6. Nitrate content of soil and soil water at Location 3, Site F--cut area near site E.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Dark brown loam	3.63	16.3
0.31- 0.61	Brownish-red sand	2.44	15.2
0.61- 0.92	Brownish-red sand	0.67	4.19
0.92- 1.22	Heavy clay	0.93	3.35
1.22- 1.53	Heavy clay	0.92	3.31
1.53- 1.83	Heavy clay	1.04	3.74
1.83- 2.14	Heavy clay	1.01	3.64
2.14- 2.44	Heavy clay	0.94	3.38
2.44- 2.75	Heavy clay	0.70	2.52
2.75- 3.05	Heavy clay	0.76	2.74
3.05- 3.36	Sandy clay	0.60	2.40
3.36- 3.66	Sandy clay	0.69	2.76
3.66- 3.97	Sandy clay	0.74	2.96
3.97- 4.27	Sandy clay	0.69	2.76
4.27- 4.58	Sandy clay	0.69	2.76
4.58- 4.88	Sandy clay	0.64	2.56
4.88- 5.19	Sandy clay	0.69	2.76
5.19- 5.49	Clay	0.64	2.56
5.49- 5.80	Clay	0.64	2.56

Table D-7. Nitrate content of soil and soil water at Location 4, Site N--light fill area.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	High organic sand	0.50	3.13
0.31- 0.61	Brown sand	0.49	3.06
0.61- 0.92	Red-brown loam	1.42	6.39
0.92- 1.22	Red-brown loam	1.43	6.44
1.22- 1.53	Red-brown loam	1.17	5.27
1.53- 1.83	Reddish sand	1.92	12.0
1.83- 2.14	Reddish sand	1.62	10.1
2.14- 2.44	Red-brown sand	1.68	10.5
2.44- 2.75	Red-brown sandy gravel	1.31	8.19
2.75- 3.05	Light sandy gravel	1.12	7.00
3.05- 3.36	Light sandy gravel	0.92	5.75
3.36- 3.66	Light yellow-brown sand	1.31	8.19
3.66- 3.97	Light yellow-brown sand	1.58	9.88
3.97- 4.27	Light yellow-brown sandy loam	0.38	1.90
4.27- 4.58	Light brown sandy loam	0.09	0.45
4.58- 4.88	Light brown sandy clay loam	0.12	0.48
4.88- 5.19	Light brown sandy clay loam	0.12	0.48
5.19- 5.49	Light brown sandy clay loam	0.08	0.32
5.49- 5.80	Light brown sandy clay loam	0.11	0.44
5.80- 6.10	Light brown sand	0.07	0.44
6.10- 6.41	Sand(6"), Brown clay(6")	0.09	0.56
6.41- 6.71	Brown clay, sand layer	0.05	0.18
6.71- 7.02	Brown sandy clay	0.20	0.80
7.02- 7.32	Brown sandy clay	0.16	0.64
7.32- 7.63	Brown sandy clay	1.01	4.05
7.63- 7.93	Brown sandy clay	1.14	4.56
7.93- 8.24	Brown sandy clay	0.94	3.76
8.24- 8.54	Brown sandy clay	1.11	4.44
8.54- 8.85	Brown sandy clay	1.18	4.72
8.85- 9.15	Brown sandy clay	0.93	3.72
9.15- 9.46	Light sand	0.54	3.38

Table D-8. Nitrate content of soil and soil water at Location 4, Site M--cut area near site N.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Dark loamy sand	0.94	5.88
0.31- 0.61	Light brown sandy loam	0.61	3.05
0.61- 0.92	Light yellow sand	0.49	3.06
0.92- 1.22	Light yellow sand	0.43	2.69
1.22- 1.53	Light yellow sand	0.49	3.06
1.53- 1.83	Light yellow-brown sand	0.43	2.69
1.83- 2.14	Light yellow-brown sand	0.38	2.38
2.14- 2.44	Light yellow sand	0.33	2.06
2.44- 2.75	Mixed light yellow & brown sandy loam	0.46	2.30
2.75- 3.05	Mixed light yellow & brown sandy loam	0.33	1.65
3.05- 3.36	Light brown clay	0.85	3.09
3.36- 3.66	Light yellow-brown sandy loam	0.44	2.20
3.66- 3.97	Light yellow sand	0.49	3.06
3.97- 4.27	Light yellow-brown sand	0.44	2.75
4.27- 4.58	Light brown sand	0.32	2.00
4.58- 4.88	Light brown sand	0.33	2.06
4.88- 5.19	Light brown sand	0.33	2.06
5.19- 5.49	Light brown sand (clay lens)	0.34	2.13
5.49- 5.80	Light brown clay	0.59	2.14
5.80- 6.10	Light brown sandy clay	0.34	1.20
6.10- 6.41	Light brown sand	0.33	2.06
6.41- 6.71	Light brown sand	0.34	2.13
6.71- 7.02	Light brown sand	0.36	2.25
7.02- 7.32	Light brown sand	0.35	2.19
7.32- 7.63	Light brown sand	0.38	2.38
7.63- 7.93	Light brown sand	0.44	2.75
7.93- 8.24	Brown sandy clay	0.60	2.40
8.24- 8.54	Brown sandy clay	0.61	2.44
8.54- 8.85	Brown sandy clay	0.55	2.20
8.85- 9.15	Brown sandy clay	0.55	2.20
9.15- 9.46	Brown sandy clay	0.61	2.44

Table D-9. Nitrate content of soil and soil water at Location 5, Site P--light fill area.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Dark sand	0.95	5.94
0.31- 0.61	Dark sand	0.74	4.63
0.61- 0.92	Brown sand	0.81	5.06
0.92- 1.22	Light brown sand	0.99	6.19
1.22- 1.53	Light brown sand	0.94	5.88
1.53- 1.83	Red-brown loamy sand	1.74	10.9
1.83- 2.14	Brown sand	2.14	13.4
2.14- 2.44	Brown clay	1.89	6.86
2.44- 2.75	Brown clay	2.41	8.75
2.75- 3.05	Brown clay (sand lens)	1.52	5.52
3.05- 3.36	Gray clay	0.61	2.21
3.36- 3.66	Gray clay (sand lens)	0.70	2.54
3.66- 3.97	Gray clay (saturated)	0.70	2.54
3.97- 4.27	Gray clay (saturated)	0.71	2.58
4.27- 4.58	Gray clay (saturated)	0.84	3.05
4.58- 4.88	Gray clay (saturated)	0.80	2.90
4.88- 5.19	Gray clay (saturated)	0.76	2.76
5.19- 5.49	Gray clay (saturated)	0.90	3.27
5.49- 5.80	Gray clay (sand lens)	0.85	3.09
5.80- 6.10	Gray clay (saturated)	0.84	3.05

Table D-10. Nitrate content of soil and soil water at Location 5, Site O--cut area near site P.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Light red-brown sand	0.48	3.00
0.31- 0.61	Light red-brown sand	0.50	3.13
0.61- 0.92	Red-brown sand	0.55	3.44
0.92- 1.22	Red-brown sand	0.64	4.00
1.22- 1.53	Red-brown sand	0.74	4.63
1.53- 1.83	Light brown sand	0.67	4.19
1.83- 2.14	Light brown sand	0.74	4.63
2.14- 2.44	Light brown sand (stones)	0.63	3.94
2.44- 2.75	Light sand (stones)	0.61	3.81
2.75- 3.05	Light sand	0.58	3.63
3.05- 3.36	Light sand	0.52	3.25
3.36- 3.66	Light brown sand	0.55	3.44
3.66- 3.97	Brown sand	0.55	3.44
3.97- 4.27	Brown sand	0.61	3.81
4.27- 4.58	Brown sand	0.56	3.50
4.58- 4.88	Brown sand	0.65	4.06
4.88- 5.19	Yellow-brown sand	0.80	5.00
5.19- 5.49	Yellow sand	0.56	3.50
5.49- 5.80	Yellow sand	0.53	3.31
5.80- 6.10	Yellow sand	0.51	3.19
6.10- 6.41	Yellow sand	0.56	3.50
6.41- 6.71	Yellow sand	0.53	3.31
6.71- 7.02	Bright yellow sand	0.71	4.44
7.02- 7.32	Bright yellow sand	0.58	3.63
7.32- 7.63	Bright yellow sand	0.88	5.50
7.63- 7.93	Light brown sand	0.64	3.81
7.93- 8.24	Light brown sand	0.68	4.25
8.24- 8.54	Light brown sand	0.69	4.31
8.54- 8.85	Light brown sand	0.81	5.06
8.85- 9.15	Light brown sand (saturated)	0.90	3.00
9.15- 9.46	Light brown sand (saturated)	1.39	4.63

Table H-11. Nitrate content of soil and soil water at Location 6, Site H--medium fill area.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Dark sand	7.53	47.1
0.31- 0.61	Dark sand	4.81	30.1
0.61- 0.92	Yellow sand	3.02	18.9
0.92- 1.22	Yellow sand	1.15	7.19
1.22- 1.53	Yellow sand	1.37	8.56
1.53- 1.83	Yellow sand	1.63	10.2
1.83- 2.14	Yellow sand	2.10	13.1
2.14- 2.44	Yellow sand	2.19	13.7
2.44- 2.75	Yellow sand	2.57	16.1
2.75- 3.05	Yellow sand	3.04	19.0
3.05- 3.36	Yellow sand	2.14	13.4
3.36- 3.66	Yellow sand	2.16	13.5
3.66- 3.97	Yellow sand	2.52	15.8
3.97- 4.27	Yellow sand	2.19	13.7
4.27- 4.58	Yellow sand	3.53	22.1

Table H-12. Nitrate content of soil and soil water at Location 6, Site G--cut area near site H.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Yellow sand	0.64	4.00
0.31- 0.61	Yellow sand	0.79	4.94
0.61- 0.92	Yellow sand	1.94	12.1
0.92- 1.22	Yellow sand	2.07	12.9
1.22- 1.53	Yellow sand	0.81	5.06
1.53- 1.83	Yellow sand	0.94	5.88
1.83- 2.14	Yellow sand	1.16	7.25
2.14- 2.44	Yellow sand	1.35	8.44
2.44- 2.75	Yellow sand	1.55	9.69
2.75- 3.05	Yellow sand	1.36	8.50
3.05- 3.36	Yellow sand	1.08	6.75

Table H-13. Nitrate content of soil and soil water at Location 7, Site J--medium fill area.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Dark loamy sand	1.77	11.1
0.31- 0.61	Dark loamy sand	4.85	30.4
0.61- 0.92	Yellow sand	3.96	24.8
0.92- 1.22	Yellow sand	1.90	11.9
1.22- 1.53	Yellow sand	2.57	16.1
1.53- 1.83	Yellow sand	2.90	18.1
1.83- 2.14	Yellow sand	1.66	10.4
2.14- 2.44	Yellow sand	1.29	8.1

Table H-14. Nitrate content of soil and soil water at Location 7, Site K--very light fill area near site J.

Sample Depth	Description	NO_3-N in Soil	Estimated NO_3-N in Water
meters		----------mg/kg----------	
0.00- 0.31	Dark loamy sand	0.84	5.25
0.31- 0.61	Dark loamy sand	1.30	8.13
0.61- 0.92	Brown sand	0.91	5.69
0.92- 1.22	Yellow sand	0.50	3.13
1.22- 1.53	Yellow sand	0.47	2.94
1.53- 1.83	Yellow sand	0.78	4.88
1.83- 2.14	Clay	2.26	8.20
2.14- 2.44	Clay	1.77	6.48