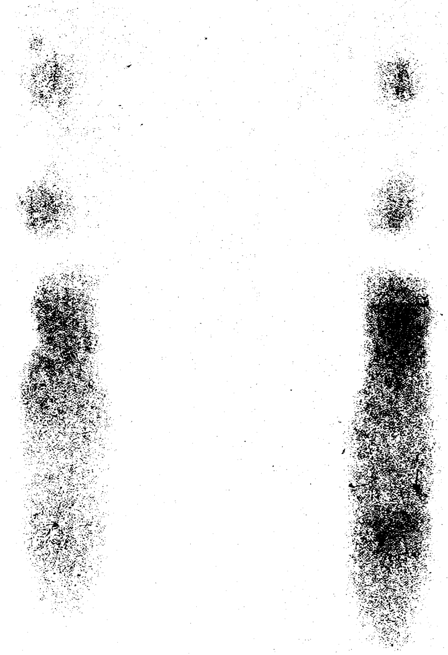

THE UNIVERSITY OF MICHIGAN
Biological Station

NON-POINT POLLUTION DETERMINATION IN NORTHERN MICHIGAN:

A GROUND WATER MONITORING APPROACH IN EVALUATING ON-SITE WASTEWATER DISPOSAL SYSTEMS

TECHNICAL REPORT NO. 9

BY

PROJECT CLEAR 1978

Moira Croghan
Sam Ehlers
Diedre Feeney
Kevin Hughes
Mark Hummel
Brian Marshall
Richard Murray
Joan Schumaker
Michael Tilchin*
Mark Torf

*Student Project Director

Douglas Lake

NON-POINT POLLUTION ASSESSMENT IN NORTHERN MICHIGAN
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PROJECT CLEAR 1978

(Community Lake-Environment Awareness and Research)

Moira Croghan
Sam Ehlers
Diedre Feeney
Kevin Hughes
Mark Hummel
Brian Marshall
Richard Murray
Joan Schumaker
Michael Tilchin*
Mark Torf

Dr. James Boyle, Faculty Advisor

A Report Prepared for the National Science Foundation and the Elizabeth Kennedy Foundation

FROM

THE UNIVERSITY OF MICHIGAN BIOLOGICAL STATION

PELLSTON, MICHIGAN 49769

FALL 1979

*Student Project Director

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Dedicated to the Lakeshore Residents of Burt Lake

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ABSTRACT

A group of nine investigators at the University of Michigan Biological Station conducted a study integrating research on on-site wastewater disposal with an environmental management program. The objectives of the study were to:

1. assess the ability of several groundwater sampling techniques to monitor on-site wastewater disposal systems.
2. identify soil factors and septic system characteristics that influence nutrient loading to the groundwater.
3. educate lakeshore communities on lake protection and management.

The physical and chemical limitation of porous ceramic cup (PCC) lysimeters, sand point wells, silicon carbide lysimeters, and polyvinyl chloride (PVC) membrane lysimeters were assessed on four test plots from a range of soil texture and moisture conditions. Problems with the assembly and installation of silicon carbide and PVC membrane lysimeters rendered them unsuitable for field use. Sand point wells functioned in a severely restricted range of texture and moisture conditions. PCC lysimeters demonstrated substantial variablity among samples in several water quality tests, but were the best available method for monitoring groundwater in the subsequent septic system study.

Quality of groundwater adjacent to nine lakeside septic systems was monitored. Concentrations of ammonia, nitrate, phosphorus, and chloride were measured from groundwater samples collected from an array of PCC lysimeters between the septic system drainfield and the lake shore. Excessive nitrogen (greater than 10 mg/l Tot-N) and phosphorus (greater than 1 mg/l TDP) levels were detected at two sites. At a third site, high nitrogen concentrations but no phosphorus loading were found.

Results indicate that septic systems built in undistrubed soils affected groundwater less than those systems constructed in fill materials. Application of large effluent loads (greater than 600 gpd) resulted in measurable deterioration of groundwater quality.

Presentations and workshops on wastewater management, septic system monitoring, and wetland ecology were given to lake associations, county commissioners and public health officials. Innovative programs for septic system maintenance and water quality monitoring were implemented.

Introduction

About 10,000 years ago, the Wisconsin Glaciers left northern lower Michigan with a wealth of inland lakes and streams. The water resources of the area have made it a popular vacation land for much of the last century. During the past decade, the appeal which historically attracted tourists has now begun to stimulate a dramatic migration of summer and year-round residents to the area from the heavily populated southern part of the state. The population increase during the 1970-1974 period in the northern counties averaged 24 percent, (see Fig. 1), and much of that growth occurred around the inland lakes and rivers (Marans 1977).

What impact will increasing numbers of people have on the quality of the inland lakes? Water pollution, resulting from rapid and unplanned shoreline development, threatens the same environmental features that make northern lower Michigan so attractive today. If, however, development is directed through sound land use planning, the impacts of growth on the natural features of the area can be minimized.

Water pollution in northern lower Michigan is caused primarily by nutrient enrichment (Gold and Nagel 1978, Richardson 1978). Nutrients (nitrogen and phosphorus) act as fertilizer for algae and other aquatic plants. With proper land use planning, the amount of nutrients coming into the lakes and streams can be minimized; water quality can thereby be maintained at a high level.

Figure 1A

Population Increase in Michigan Counties: 1970-1974

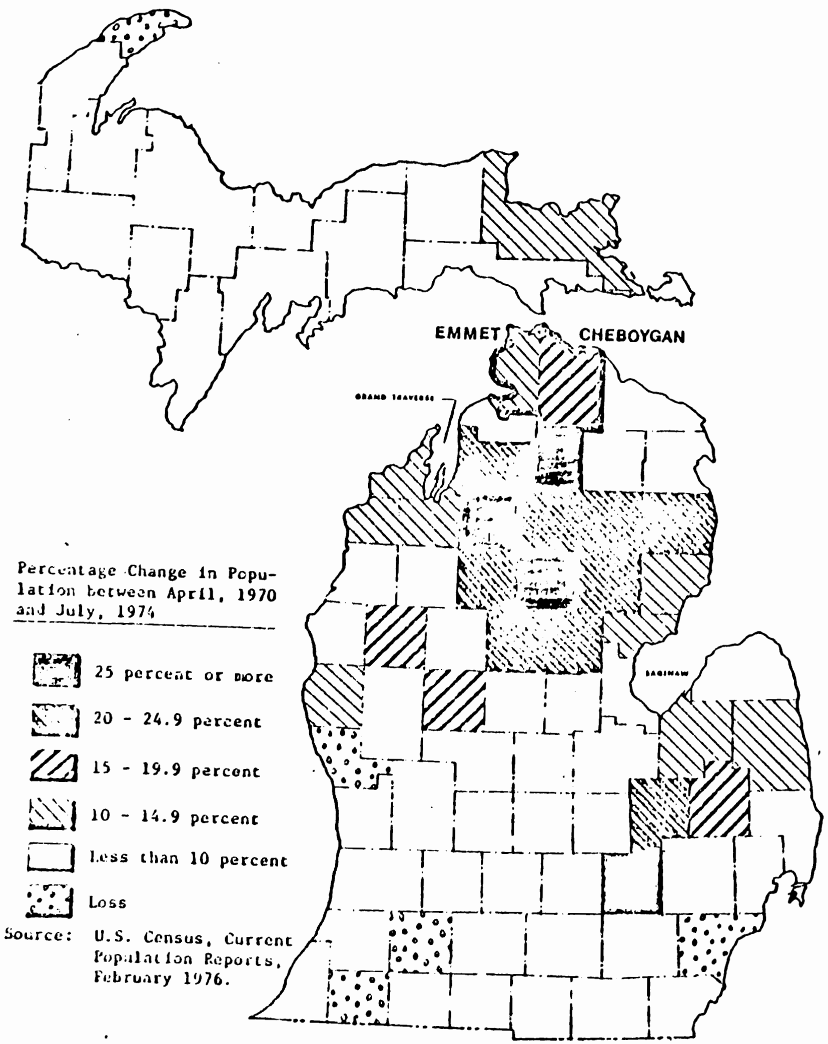
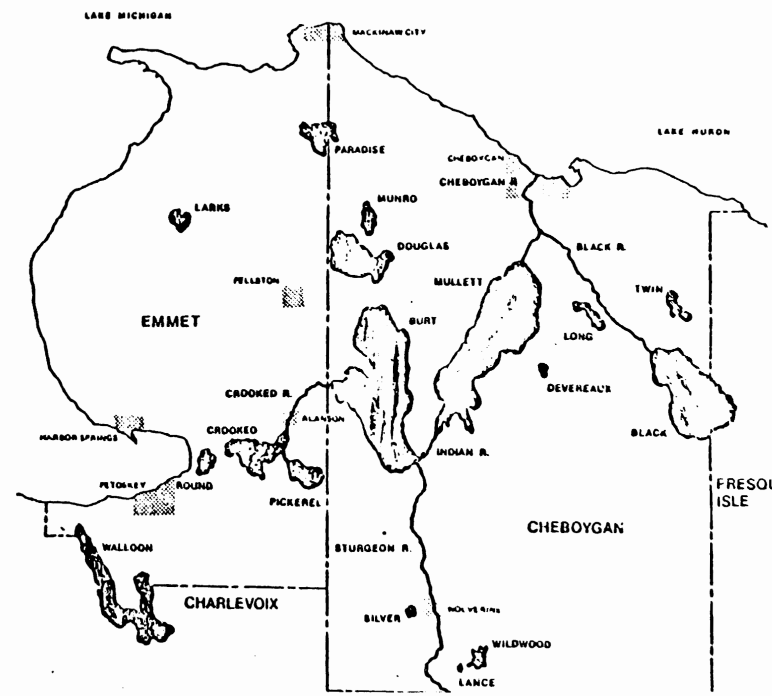


Figure 1B

Populated Lakes and Rivers and Incorporated Cities and Villages - Cheboygan and Emmet Counties



(Reprinted from Marans, 1977)

Septic tanks in shoreline areas are a potentially significant contributor of nutrients to a lake (Ellis and Childs 1973). A review of several domestic wastewater studies concluded that 45 mg/ℓ Total-N and 25 mg/ℓ Total-P are estimates of "typical" nutrient concentrations in septic tank effluent (Dudley and Stephenson 1973). All of the homes surrounding the study area, Burt Lake, and 72% of the households in the region are currently served by septic systems (NEMCOG, 1978). These on-site systems depend on the soil to absorb and treat septic system effluent. A properly performing septic system should be able to adequately protect nearby surface waters from nutrient contamination.

When a septic system fails to absorb effluent, ponding of untreated water on the soil surface creates an obvious nuisance and public health hazard. A septic tank that absorbs effluent quite well but fails to treat it adequately is more difficult to detect; polluted groundwater flows from the system to the lake unnoticed. Identifying this type of failing system requires sampling and analyses of shallow groundwater beneath and surrounding the disposal field. Health departments and other agencies responsible for wastewater disposal have expressed great interest in monitoring the effects of septic systems on groundwater quality in this way.

Several methods of obtaining groundwater for nutrient analysis are available to health departments interested in monitoring septic systems; one objective of this study was to assess the strengths and limitations of several of these methods. A second objective of this study was to investigate relationships between the nutrient removal performance of septic systems and soil properties, septic system design, and wastewater loading. A better understanding of these relationships based on quantitative data will assist in water quality protection planning efforts in the future.

Water quality preservation efforts in northern lower Michigan must receive public support if they are to be successful. A third objective of this study was therefore to set up a comprehensive environmental communications program coordinated with the Clean Water Management Planning Agencies of the region to improve the "water quality awareness" of those who live on or use the lakes.

Literature Review

As the population shifts from urban centers to rural areas, pressures mount on rural environments. In order to manage and protect the resources of these areas, we must understand the physical, chemical and biological processes and the sensitivities of ecosystems supporting increasing populations. In rapidly growing rural areas that rely on the soil to treat wastes, the potential for contamination of water resources has stimulated research designed to determine the treatment performance of on-site waste-water disposal systems.

Although new methods of waste disposal for use in unsewered areas have become available in recent years (aerobic and chemical toilets, grey water recycling systems, etc.), soil absorption comprised of a septic tank and drainfield remains the dominant method of waste treatment. The performance of these systems has traditionally been judged on the following criteria: Is the rate of infiltration into the soil sufficient to prevent surfacing of effluent? Is the soil effectively removing fecal indicators and pathogens from the effluent before it reaches the groundwater? The concept of treatment has broadened because of the growing concern over the potential for accelerated eutrophication of lakes and rivers caused by nutrient enrichment from septic seepage. The high concentration levels of nitrogen and phosphorus in wastewater must be reduced before percolating effluent reenters the water cycle. These nutrients (most commonly phosphorus) are limiting factors for algal growth in lakes, and additional inputs from septic systems must be checked if deterioration of water quality is to be avoided.

Nitrogen and Phosphorus in Soils:

Nitrogen and phosphorus occur in the soil environment in a variety of organic and inorganic compounds. The more complex of these compounds are generally quite insoluble and are largely unavailable for plant uptake. Simpler compounds are more readily used, and are active agents in nutrient cycling (Brady, 1974).

The amount of nitrogen in soils of humid regions typically range from 0.02 to 0.05% by weight (Brady, 1974). Sources of nitrogen include plant residues and animal wastes, precipitation, and fixation of atmospheric nitrogen by specialized plants and microorganisms. The bulk of the nitrogen is tied up in organic compounds and cannot be taken up by plants. Phosphorus is supplied to the soil from organic materials and inorganic sources through the weathering of phosphorus-bearing minerals, such as apatite.

Nitrogen exists in the soil in three forms:

1. Organic-N in soil humus.
2. Clay-fixed nonexchangeable ammonium ion (NH_4).
3. Soluble ammonia and nitrate (NO_3) compounds (Brady, 1974).

Through the biochemical process of mineralization, organic-N is transformed into ammonium salts. Ammonium will either be used by vegetation, fixed into the lattice structure of clays, or be transformed to nitrate compounds by a process called nitrification. The reactions and responsible agents are outlined below:

$$\text{Organic-N} \xrightarrow{1} NH_4 \xrightarrow{2} NO_2 \xrightarrow{3} NO_3$$

where step 1 occurs via non-specialized organisms, step 2 via *nitrosomonas*, and step 3 via *nitrobacter*. Step 1 is termed mineralization, and steps 2 and 3 are termed nitrification (Black, 1957).

Nitrification occurs to a more complete degree if aerobic conditions exist in the soil. Nitrate compounds are highly soluble and move easily through the soil. In a reducing environment, nitrates may be transformed to gaseous nitrogen through the process of denitrification.

The amount of phosphorus in humid region soils typically range from 0.01 to 0.20% by weight. As stated, phosphorus is supplied to the soil from both organic and inorganic sources. The ionic character of phosphorus (as ortho-phosphate) is determined by the pH of the soil solution.

$H_2PO_4^-$	HPO_4^{-2}	PO_4^{-3}
strongly acidic	mildly acidic	alkaline

Although the H_2PO_4 is readily available for plant uptake, it vigorously complexes with other soil ions and minerals that render it unusable (Brady, 1974). In acidic conditions, the phosphate ion combines with Fe and Al cations and/or participates in an anion exchange with Fe and Al hydrous-oxides (gibbsite, goethite, boehmite) to form insoluble hydroxy-phosphates (Brady, 1974). Under mildly acidic conditions, the concentration of Fe and Al ions drops, but phosphate ion readily reacts with silicate clays to form similar hydroxy-phosphates.

In soils that have developed from limestone-bearing parent material, phosphate ions react with available Ca ions and with $CaCO_3$. As these calcium phosphates form, continued reaction with Ca ions in solution results in the formation of increasingly insoluble apatite minerals.

Soils of different mineralogies and textures and with soil solutions over a range of pH values demonstrate a tremendous ability to absorb phosphorus. Only in coarse non-calcareous sands and in soils with high organic matter/mineral ratios would phosphorus movement be anticipated under natural field conditions (Craddock, 1977; Dudley and Stephenson, 1973). Laboratory determined phosphorus absorption capacities of Michigan soils range from 231 lbs./per acre-3ft. (Dune Sand) to 2915 lbs./acre-3ft. (Warsaw Loam)(Ellis and Erickson, 1969). In a phosphorus loading study on some Arizona soils (Lance, 1977), phosphate absorption continued to be extremely effective after 60,000 kg-P had been applied to an hectare of calcareous sand over a seven year period.

Nutrient Movement from Septic Systems

A basic principle inherent in septic system treatment of wastewater is that a relatively small volume of soil receives tremendous quantity of water and waste to absorb and treat. Wastewater entering the soil from drainfields acts as a concentrated source of nutrient supply to the soil/soil-water system. Gannon and Paddock (1974) estimate that the average per person contribution of N and P in wastewater is 5.4 kg-N and 0.45 kg-P annually (P value excludes input from phosphate detergents which add an additional 1 kg/person-year). These nutrients either accumulate over time in the soil surrounding the drainfield or they move away from the drainfield through the soil (Hook et al., 1978).

As effluent leaves the zone of saturation around the drainfield, ammonia is converted to nitrate provided that the groundwater level is sufficiently deep. The soil has no capacity to absorb nitrate, so the soluble anion will percolate freely through the soil down to the water table if not taken up by vegetation. If nitrate moves into a new zone of saturation (such as a perched water table) before reaching the normal groundwater level, denitrification may result and nitrogen will be lost to the atmosphere (Miller, 1974). Otherwise, nitrate moves freely with the flowpath of the groundwater, and mechanisms for lowering nitrate concentration are limited to dispersion and dilution in the surrounding waters (Hook et al., 1978).

Nitrate is the most frequently observed contaminant moving from the septic system into the groundwater. Studies have documented nitrate concentration in excess of drinking water standards (greater than 10 ppm NO_3-N) in groundwater at considerable distances from the septic system drainfield. Polkowski and Boyle (1970) found nitrate concentrations as high as 21 ppm at 15 feet from the drainfield. Concentrations remained above 10 ppm NO_3-N within 100 feet in some cases. Ellis and Childs (1973) followed the horizontal and vertical path of nitrate migration from drainfields at homesites on Houghton

Lake, Michigan. On a septic system located on a well-drained sandy soil that had been used by a family of six for 15 years, nitrate concentrations of 15.6 ppm and 8.0 ppm were found at distances of 100 feet (10 feet below the water table) and 330 feet (16 feet below the water table) respectively, from the drainfield.

Adsorption and precipitation reactions between phosphorus and several soil constituents greatly restrict the movement of P from soil absorption systems (Jones, Lee, 1977). Soil characteristics that determine the P-adsorption capacity of soils include the presence of clay minerals, Fe and Al oxides, availability of a calcium source, and pH of the soil solution. Models of phosphate retention have allowed for estimates of field P-adsorption capacities for specific soils (Craddock, 1977; Sawhney, 1977; Ellis and Erickson, 1969).

Gannon and Paddock (1974) and Ellis and Childs (1973) assume that once the P-adsorption capacity of the soil has been saturated, phosphorus will travel through the soil and into groundwater and nearby surface waters. In a subsequent study, however, Childs (1974) states that phosphorus retention mechanisms continue to operate after phosphorus has moved into the soil below the water table. Further tests (Beek, 1977; Sawhney, 1977; Lance, 1977) have shown that long-term retention of phosphorus often greatly exceeds calculated adsorption capacities, and in some soils can be considered to be almost limitless under normal loading conditions (Lance, 1977).

Review of Research

Bouma et al. (1972) monitored five septic systems in Wisconsin of different ages and in varying soil types. Six to 17 wells per site were placed adjacent to and at distances from the drainfield to trace the movement of nutrients and fecal indicators. Results of their investigations led to several conclusions about the fate of nitrogen and phosphorus entering the soil from drainfields:

- Crusting occurs on the bottom of seepage beds after a few years of use and inhibits infiltration. Provided that the groundwater level is greater than 3 feet below the drainfield, an unsaturated zone is created, fostering quite complete nitrification of ammonia in the effluent to nitrate.

- Phosphorus was effectively removed from effluent in each system. Four of five systems failed to reduce nitrogen concentrations to non-contaminating levels. Concentrations of 30 mg/l-NO_3 were found at depths of 12 feet in the water table below the drainfield of one system.

Reneau (1977) monitored nitrogen movement from a septic system in a sandy loam with a fluctuating water table. Average reduction of NH_4 with distance was from 23 mg/l to 4 mg/l at 1.5m and 12m, respectively. Nitrate concentrations rose from 0.03 mg/l in the drainfield to 2.92 mg/l at a distance of 3.05 m. Under similar water table condidtions, Preul (1966) noted a similar ammonia decrease (60ppm to 4 ppm NH_4-N) and nitrate increase (0 to 40 ppm) from the drainfield to a test well 6 m away. Decreases of total-N can be attributed to the fixation of NH_4 on soil particles (high NH_4 concentrations were found in the fine fraction of the soil) and to denitrification as the soil solution moved from aerobic to anaerobic zones.

Phosphorus loading studies by Lance (1977) and Sawhney (1977) established firm evidence that a soil's ability to retain phosphorus exceeds calculated adsorption capacities. Lance suggests that there is a strong correlation between loading rate and P removal efficiency. After an initial period in which phosphorus adsorption is independent of loading rate and retention time, slower absorption and precipitation reactions that continue to pull phosphorus out of solution are time-dependent. For a 200 day period, P-removal was 90-95% effective regardless of the rate of phosphorus loading. P-adsorption with continued loading dropped from 73% to 58% as the infiltration rate increased from 18.2 to 22.3 cm/day. The phosphorus concentration could be raised or lowered by speeding or slowing the infiltration rate.

Evidence of the regeneration of P-adsorption sites when the soil columns were allowed to dry was indicated by concentration minimums that occurred after the initiation of loading after columns were allowed to dry five days (Lance, 1977). In a series of laboratory tests, 100% of the original P-adsorption capacity of sixteen Michigan soils was recovered three months after initial P-saturation (Ellis and Erickson, 1969). The regeneration is thought to occur as new Ca ions (in alkaline soils) or Fe and Al ions (in acidic soils) are released by weathering of parent materials. Lance (1977) noted that minimum concentrations of phosphorus in effluent coincided with peak Ca cation concentrations.

Sawhney (1977) also concluded that P-adsorption occurs in two stages. Initial rapid adsorption on mineral surfaces is followed by slower uptake and precipitation as Al and Fe phosphates. Adsorption capacities determined through short term loading experiments fail to account for the slower retention mechanisms, and therefore underestimate the soils' ability to adsorb phosphorus.

Loading columns of a fine sandy loam and a silt loam at rates of 8.5 ml/hr and 5 ml/hr, respectively (2×10^{-4}M P), Sawhney (1977) noted that "phosphorus breakthrough" occurred at 300 hrs (fsl) and 1000 hrs (sil), after which the P-concentration in column effluent increased with continued loading. Though effluent P-concentrations never equalled influent concentrations, Sawhney acknowledged the potential for shallow groundwater contamination after prolonged septic system use in soils with low P-adsorption capacities.

From studies of phosphate movement through soils on a sewage farm after 50 years of sewage disposal, Beek et al. (1977) found that phosphate adsorption was still 96% effective. Accumulation of phosphorus in the soil was limited to the upper 75 cm of the soil profile, and predominantly in the upper 50 cm. Although a number of precipitation and adsorption reactions contributed to P-adsorption, chemical analysis of the soil revealed that Al-bonding reactions leading to the formation of Al-phosphates was the dominant retention mechanism.

A four year study of migration of nutrients, ions (Cl^-,Na^+, Ca^{+2}, Mg^{+2}), and other water quality parameters from a septic system installed in a sandy Wisconsin soil asserted that phosphorus mirgration was so limited that it presented no threat to groundwater and surface water quality (Jones and Lee, 1977). Concentrations of conservative chemical tracers in monitoring wells showed that effluent did reach the groundwater and move downgradient from the septic system, but at no time did phosphate concentrations in any of the samples collected from the 15 sample stations rise significantly. Nitrate concentrations began to rise in some of the wells after one year, but the rise was inconsistent with respect to time. The investigators felt that increased aquatic growth from nitrogen contamination from septic systems might occur in nitrogen-limited lakes.

Other studies have reached different conclusions about the movement of phosphorus from the drainfield to the groundwater. Dudley and Stephenson (1973) encountered significant levels of phosphorus (greater than 1 mg/l Tot-P) in groundwater at four of the eleven sites they sampled. Phosphorus concentrations as high as 12.2 mg/l Tot-P occurred fifteen feet from one disposal field. Phosphorus concentrations in groundwater above background levels extended over 100 feet at several septic system sites investigated by Ellis and Childs (1973). On a soil characterized by poor drainage and slow permeability, phosphorus concentrations of 11.6 ppm-P and 8.8 ppm-P occurred 75 feet and 120 feet from the drainfield. The depth of maximum phosphorus concentration ranged from two to six feet.

Four soils in Northern California used to treat spray effluent at a National Park were studied by Craddock (1977). Calculating P-adsorption isotherms in four strata (to a depth of 65 cm) in two of the spray field areas, Craddock estimated the time until P-saturation would occur to be 90 years and 380 years (for a soil 160 cm deep). The soils were moderately acidic, and contained significant amounts of

Fe and Al-oxides. These estimates were considered to be conservative because of the nature of the P-adsorption tests.

Nitrate levels in runoff near one of the irrigation sites had risen by a factor of 3 over baseline values, and indicated that 1/3 of the nitrogen added by the spray effluent was reaching the drainage streams.

Craddock (1977) highlighted the role that ammonium ion might play in P-adsorption and precipitation reactions by maintaining acidic conditions in the soil as nitrification occurred. The soils at one site are coarse and shallow, and have little potential for long-term nitrogen removal. Deeper soils with greater storage capacity, more vegetation, and an argillic horizon (capable of fixing NH_4^+) released nitrates at a much lower level.

The studies reveiwed are in general agreement with regard to retention and mobility predictions of nutrients in soils. The investigators' conclusions about potential contamination problems (nutrient enrichment) from septic seepage are not entirely consistent. Leaching of nitrates into groundwater was recognized as a pollution hazard in each study. The degree to which nitrogen addition threatens water quality raises a question about the conditions under which nitrogen is the limiting nutrient for aquatic plant growth in lakes. When the nitrogen/phosphorus ratio is less than 7:1, nitrogen may then be the limiting factor. Typically, the concentration of nitrogen is an order of magnitude or more than the concentration of phosphorus (Wetzel, 1975).

Evidence of a soil's long-term ability to remove phosphorus under intermittent loading conditions and/or reduced loading rates (Lance, 1977; Sawhney, 1977) suggest that the use of dual drainfields and dosing pumps would facilitate extended effective P-adsorption. Seasonal populations where the septic system gets "rested" each year should increase the time to P-saturation.

Engineering and hydraulic modifications of disposal systems can be designed to maximize nutrient removal. Introduction of calcareous materials to boost precipitation of phosphorus and construction of a clay barrier to adsorb both phosphates and ammonium and promote denitrification are feasible measures that deserve attention. Mound installations using these materials might prove to be very effective treatment systems. Legal measures, such as minimum setback requirements and zoning ordinances that limit or prohibit disposal in sensitive areas with poorly suited soils, can be effective if properly enforced.

Through a greater understanding of the soil's ability to treat wastes, on-site wastewater disposal methods can become increasingly more effective. Innovations in design and materials can be tailored to meet expected loading demands on a particular soil. The next phase in rural wastewater research should focus on applying the principles and processes that govern nutrient movement in soils towards developing improved soil absorption systems.

Section I

Groundwater Sampling Techniques

Materials and Methods

Section I

Groundwater Sampling Techniques

Material and Methods

No standard collection method has been proposed for groundwater quality research. Several collection instruments have been used in investigations into the effects of on-site wastewater disposal on groundwater, and concern over the reliability of collection methods has been expressed in some of these studies (Hansen and Harris, 1975, Childs, 1974).

Four groundwater sampling instruments were tested to assess their potential for use in septic system monitoring studies. These were:

Galvanized steel, #60 mesh sandpoint wells

Porous ceramic cup (PCC) tension lysimeters (Parizek, Lane, 1970)

PVC membrane filter tension lysimeters (Appendix I)

Silicon carbide tension lysimeter (Post, 1976)

The instruments were evaluated on the following criteria:

- chemical variability in groundwater samples attributable to the collection method
- range of soil texture and soil moisture conditions over which the collection method functions
- cost
- time and energy requirements for installation of the instrument and sample collection

The performance of the instruments was tested on four soil plots and in the laboratory. Plots were selected to represent a range of conditions in soil texture, soil moisture and groundwater nutrient concentration. It was assumed that the plots approached internal homogeneity in their groundwater distribution and groundwater chemistry.

Test Plot Descriptions

Site 1

Nine PCC's and 3 well points were placed in a 12 m^2 plot in an Eastport sand (sandy, mixed, frigid Spodic Udipsamment). PCC's were placed at depths of 0.5 m and 1.0 m to compare collection ability under saturated and unsaturated conditions. Wellpoints were driven to depths of 1.5-2.0 m. Permeability of the soil is rapid and water holding capacity is low.

Site 2

Twelve PCC's and 3 wellpoints were placed in a 9 m^2 plot adjacent to the University of Michigan Biological Station septic system drain-field. Wastewater from 200 Biological Station summer residents is absorbed in the field area from June through August. PCC's were placed at depths of 60 cm and 1 m. Well points were driven to various depths down to 5 m. The soil is a Rubicon sand (sandy, mixed, frigid Entic Haplorthod). Though permeability is rapid and water-holding capacity is low, innundation from septic tank effluent keeps the soil saturated during the summer months.

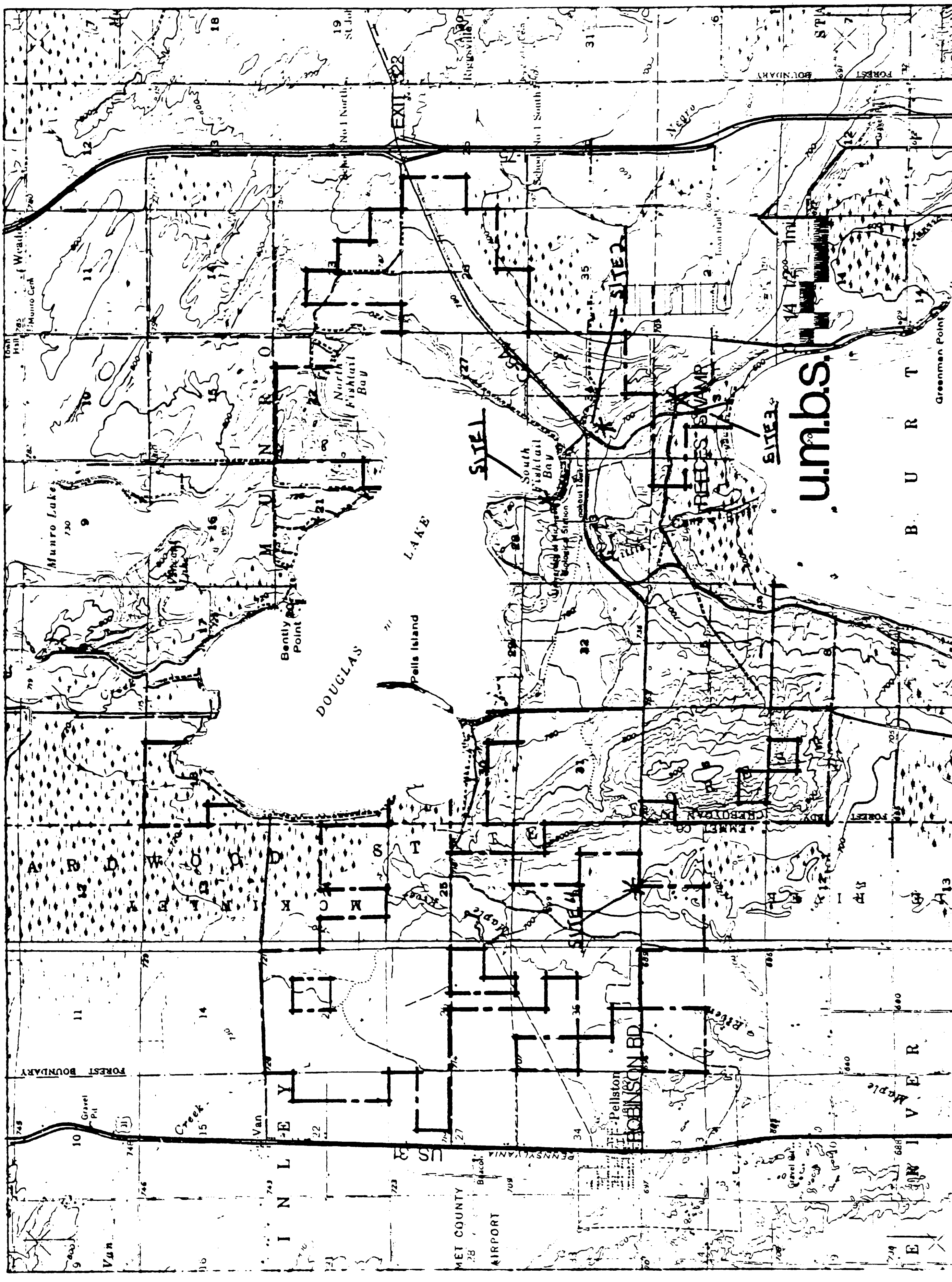
Site 3

Six PCC's, 3 wellpoints, and 3 PVC membrane lysimeters were installed in a 12 m^2 plot in a Tawas muck (sandy, mixed, euic Terric Borosaprist). The soil is characterized by a 30 cm organic surface horizon over a sandy subsoil. Groundwater is at the soil surface throughout most of the summer.

Site 4

Eight PCC's and two wellpoints were placed in a 12 m^2 plot in a

Figure 2: Location of Test Sites



Nester loam (fine, mixed, Typic Eutroboralf). The soil series is characterized by a well developed argillic horizon from 20 to 60 cm with 80% clay in the B horizon. The groundwater table was 1.5 m deep in early June. Permeability of the soil is moderately slow and its water holding capacity is high (SCS, 1973).

Field Methods

Problems with the assembly and installation of silicon carbide lysimeters made them unsuitable for field use. The PVC membrane lysimeters (Appendix I) was also eliminated from further study because of repeated clogging problems. As a result, all groundwater samples tested in this study were obtained from PCC lysimeters and sand point wells.

The lysimeters used in the study were constructed of 18 inch, 1.5 inch I.D. PVC pipe. At one end was attached a porous ceramic cup (1 μm pore size). At the opposite end was attached a #10, 2-hole rubber stopper. Three-sixteenth inch O.D. polyethylene tubing was inserted through the holes. One piece extended to the bottom of the lysimeter (inside the ceramic cup, almost touching the bottom). The other piece of tubing ended just below the rubber stopper. Both polyethylene tubes extended outside the lysimeter a distance sufficient to reach the surface after the lysimeter was inserted into the ground. To the outside ends of both polyethylene tubes were attached short lengths of flexible plastic tubing (Tygon, I.D. 3/16 inch). Each piece of Tygon tubing was fitted with a screw-type pinch clamp, used to occlude the inside of the lysimeter from the atmosphere when pumping a vacuum and when drawing a sample. All connections were sealed with epoxy cement.

Ceramic cup lysimeters were placed in the ground by first augering a 2 inch diameter hole at an angle of 20 to 30 degrees from the vertical and then inserting the lysimeter. The purpose of this was to ensure that the ceramic cup -- the intake portion of the lysimeter -- was beneath an undisturbed soil profile. The holes were backfilled to prevent the augered bore from acting as a channel for infiltrating water. A string was tied to the top of the PVC pipe and supported with duct tape. The string extended to the top of the polyethylene tubing and was used to aid in the removal of the lysimeter once sampling had been completed. A wire mesh was placed over each lysimeter to prevent animals from chewing on the exposed tubing.

Once the lysimeters were in the ground, a water sample was collected by pumping a vacuum into the lysimeter and then allowing the initial pressure gradient to reach equilibrium with the outside soil moisture tension. First the flexible plastic tubing connected to the shorter length of polyethylene tubing was closed off by means of its attached pinch clamp. The longer polyethylene tube was then connected to a two-way hand pump with tension gauge. To minimize the variability between ceramic cups due to screening and sorption of phosphorus, the lysimeters were activated with a consistent vacuum of 70 cm Hg. The vacuum drew groundwater into the lysimeter through the porous cup until the vacuum inside the lysimeter had diminished to the point that it equalled the surrounding soil moisture tension plus the atmospheric pressure (approximately 0 psig).

The water was removed from the lysimeter for analysis by attaching the exit valve of the two-way pump to the shorter polyethylene tube. When a pressure was exerted with the pump, the sample was pushed up the longer tube and collected in test tubes.

Sandpoint wells were constructed of galvanized steel, 1.25 inch I.D., length 24 inches, 18 inches of which consisted of #60 screen mesh. They were pounded into the ground with a two-handled insertion hammer. Additional lengths of 1.25 I.D. pipe were added to the top of the sandpoint well so that it could be driven further into the ground to reach saturated soil. Unlike the ceramic cup lysimeter, a sand-point well is only capable of drawing a groundwater sample if the soil is saturated and its permeablility is rapid.

A sample was taken from a sandpoint well by attaching a screw-on pitcher pump to the top of the uppermost pipe. The pump was primed and water was drawn out until it flowed continuously.

All samples were collected in 20X200 mm, acid-washed test tubes and then covered with Parafilm to prevent contamination or spillage. Samples were immediately placed on ice to preserve them until they reached the lab, at which point they were refrigerated at 4 C.

All ceramic cup lysimeters were washed with acid to remove loose ions that may have been adsorbed to the lysimeter surfaces. The ceramic cups contain Ca^{2+} and Mg^{2+}, which are able to complex with PO_4^{3-}, leading to an underestimated total phosphorous concentration (Hansen and Harris, 1975). Acid washing also removes phosphate ions which this study found to be present in new ceramic cups (Appendix 2). The cleaning procedure involved soaking all segments of the partially assembled lysimeter (except for the polyethylene tubing) in 10% HCl for three hours. They were then soaked in deionized water twice for one hour each, followed by an additional five minute rinse.

Evidence from Phase I of this study indicated that chloride had been retained by the lysimeter (most likely in the ceramic cups) after cleaning, giving elevated chloride readings, especially in the first samples taken. To abate this error, the instruments were cleaned prior to Phase II just as they were before Phase I, except 10% sulfuric acid was utilized in place of hydrochloric acid.

The polyethylene tubing used in the lysimeters was washed by drawing 1 liter of 10% H_2SO_4 through 50 foot lengths. This was followed by drawing three liters of deionized water through each length of tubing.

All glassware was washed in 10% H_2SO_4 followed by three rinses in deionized water to remove any phosphate adsorbed to the surfaces. Autoanalyzer polystyrene disposable sample cups were also cleaned with acid to prevent interference from dissolved ions. Because the sample cups have small openings, they were especially difficult to rinse properly. To ensure cleanliness, the sample cups were rinsed four times instead of the normal three. In order to further prevent possible contamination, the chloride determinations used only cups washed with sulfuric acid. Likewise, the two nitrogen tests (nitrate and ammonia) utilized only cups washed in hydrochloric acid, because sulfuric acid is known to contain nitrogen as a contaminant (Technicon).

Samples obtained from the sandpoint wells were filtered through glass filter paper to eliminate interference from turbidity within the sample. Filter paper was soaked in four deionized water baths for one hour each to remove any contaminants that may have been present. However, the ceramic cups used in this study had pore sizes of 1 micron, which thus acted as a built-in filter. Consequently, it was unnecessary to filter samples obtained with the lysimeters.

Laboratory Methods

Groundwater samples were analyzed for four constituents: nitrate-nitrogen, ammonia-nitrogen, total soluble phosphorus, and chloride. Water samples were analyzed for nitrate and ammonia forms of nitrogen, the two types primarily used by algae and other aquatic plants. In addition, these two forms are present at high concentrations in septic outflow, making them easily detectable.

Most nitrogen in human wastes is initially in organic form (primarily urea, but also nucleic acids, amino acids, polypeptides, proteins and synthetic organic materials). However, for several reasons, tests for organic nitrogen were not performed. First, the procedure generally used, the kjelkahl method, determines nitrogen only in the trinegative oxidation state. It includes inorganic ammonia-nitrogen, but does not encompass any of the following nitrogen forms: azide, azine, azo, hydrazone, nitrate, nitrite, nitrile, nitro, nitroso, oxime, and semi-carbazone. This method also requires elaborate digestion procedures not necessary when analyzing only inorganic forms of nitrogen. Furthermore, most organic nitrogen in wastewater is converted into ammonia fairly rapidly by the hydrolysis of urea and the deamination of amino acids such that septic effluent contains nitrogen largely in the form of ammonia.

Plants utilize phosphorus in the form of orthophosphate. However, the other common forms of phosphorus -- metaphosphates, polyphosphates, and organically bound phosphates -- are easily interconvertible into orthophosphate and thus they are all potential sources of plant-labile phosphorus. For this reason samples have been analyzed for total soluble phosphorus, which includes all nonparticulate-bound ortho-,meta-,poly-, and organic phosphates.

Chloride is present in human waste at high levels, and remains in soil solution without significant removal through precipitation or adsorption, thus serves as a good tracer species for nutrients discharged from septic systems. It also has the advantage over the measurement of nutrients directly, in that chloride is stable in aqueous solution indefinitely.

The concentrations of these four constituents in water samples were determined using a Technicon Autoanalyzer II. All determinations were made using standard methods (APHA, 1976; EPA, 1976, Technicon). Every fifth sample was analyzed in duplicate and every twentieth sample was tested in triplicate in order to evaluate errors that may have occurred due to equipment and technique.

Nitrate-nitrogen concentrations were determined using the automated cadmium reduction method. Nitrate is first reduced to nitrite followed by a colorimetric determination of the nitrite present. Thus the procedure used actually measures the sum of both nitrate and nitrite present in the sample. However, nitrite is usually present only at very low levels even in wastewater treatment plant effluent (Sawyer and McCarthy, 1978), and therefore virtually all nitrogen measured by this method is due to the nitrate present.

Ammonia concentrations were measured with the automated colorimetric phenate method. Intake air was scrubbed with 5% H_2SO_4 to remove any ammonia which may have been present.

To convert meta-, poly- and organic phosphates into measurable orthophosphate the samples were digested with 5% potassium persulfate solution. Six ml of persulfate solution was added to 8 ml of each sample. These were then heated for a minimum of 45 minutes at 15 psig in a steam autoclave. Then the total amount of soluble phosphorus (in the form of orthophosphate) was determined using the automated ascorbic acid method.

The analysis of chloride utilized the automated mercuric thicyanate method. Instead of ferric nitrate, ferric ammonium sulfate was employed in the creation of the colored ferric thiocyaniate complex formed during this procedure.

Results and Discussion

A major limitation posed by both wellpoints and porous cups is the limited range of soil texture and soil moisture conditions under which the two instruments are effective. Although heavy loading from wastewater saturated the soil surface at Site 2, no samples could be pumped from wellpoints driven to a depth of 4.5 m. Site 4 was situated on a low alluvial terrace with the groundwater table less than 1.5 m below the soil surface. The clayey subsoil, however, severely restricted water movement and wellpoints yielded no samples. A partial sample set was collected from porous cups on Site 4 (not recorded). Subsequent 1 day, 4 day, and 10 day sampling periods failed to yield sufficient sample volumes for analysis. Clogging of cup pores by clay particles and capillary tension in the soil surrounding the porous cup that were greater than the pull of the lysimeters are possible explanations.

Wellpoints require considerable effort to drive into the ground and are difficult to remove. Soils must be coarse textured and saturated for the wellpoint to function satisfactorily. When the proper conditions exist, wellpoints provide representative samples with less instrument-related variability than pourous cups. An individual wellpoint (24 inches long, I.D. 1.25 inches) costs approximately $25.00, to which the cost of a pump and lengths of pipe must be added.

Porous cups are relatively easy to use, but considerable time is required to assemble and acid-wash the instruments before use in the field. Porous cups do not work well when soil moisture conditions are well below field capacity or in clayey soils (even when saturated). The potential for instrument bias of samples make them best suited for water quality investigations where trends are more important than precise measurements and when large numbers of samples can be collected. Vacuum leaks around pinch clamps present a problem with the porous cup tension lysimeters and an improved design is suggest below. The cost of materials for each instrument is about $5.00. A two-way hand pump with tension gauge costs about $24.00.

The means and variances of wellpoint and porous cup samples were compared. The variance of porous cup samples was greater than well-point samples in each group (NO_3-N, NH_4-N,TDP,Cl: Sites 1 and 3). An F-test for equality of two variances showed that in one of the eight comparisons (NO_3-N, Site 1), the difference was statistically significant and the hypothesis of equal variance was rejected at $\alpha=.05$. The seven remaining groups were compared, and a T-test for the equality of means showed that the hypothesis of equal means was accepted at $\alpha=.05$ for all other groups at the two sites. It was therefore concluded that wellpoints and porous cup samples were similar in their water quality. See Table 1.

Although porous cups provide clear cost and feasibility advantages over wellpoints, large variability in porous cup samples raise questions concerning their use:

1. How much of the chemical variability is the result of changes in the groundwater, and how much reflects bias of samples from the PCC lysimeter?

Table 1

Mean, Standard Deviation for Sandpoint Well (SPW)

and Porous Ceramic Cup (PCC) Samples from Test Plots*

Site 1	TDP pbb		NH_4-N pbb		NO_3-N pbb		Cl ppm	
SPW	44,6	n=3	88,31	n=3	11,9	n=3	4.5,0.5	n=3
PCC	92,36	n=9	105,94	n=9	297,572	n=9	5.9,1.7	n=9

Site 2	TDP pbb		NH_4-N pbb		NO_3-N pbb		Cl ppm	
SPW			no samples					
PCC	7788,3554	n=12	23089,8809	n=12	13752,17088	n=12	56.3,3.7	n=12

Site 3	TDP pbb		NH_4-N pbb		NO_3-N pbb		Cl ppm	
SPW	79,6	n=3	117,11	n=3	58,9	n=3	2.7,0.5	n=3
PCC	105,48	n=6	166,97	n=6	61,47	n=6	2.6,0.7	n=6

n= number of samples

* Site 4 failed to yield sufficient samples for analysis

2. What are the sources of sample bias?

3. How can sample bias be minimized?

Nutrient concentrations in shallow groundwater are continually changing, and significant variability is expected in groundwater samples taken over time (Hansen and Harris, 1975). If wellpoint samples are assumed to more accurately represent groundwater conditions, variability from PCC lysimeter sample bias is quite large. While the sample bias makes the analysis of data more complicated, interpretation of results is still feasible, as noted above.

Hansen and Harris (1975) noted the following major sources of variability and bias in PCC lysimeter samples: adsorption of P on ceramic cup walls, sampler intake rate, plugging of pores, sample depth, length of sample period, and type of vacuum system. Based on their laboratory and field tests, it was suspected that the ceramic cup portion of the lysimeter would remove phosphorus from solution. Instead of finding significant losses from adsorption, ceramic cups were found to contain extractable phosphorus, contributing it to solution (See Appendix 2).

Laboratory experiments to determine sample bias effects from evacuation tubes in the PCC lysimeter showed that positive interference of phosphorus readings from copper tubing led to measurements indicating phosphorus at levels higher than actually present (See Appendix 2). Polyethylene tubing was tested as an alternative to copper tubing. The polyethylene did not adsorb phosphorus significantly or detectably affect the measurement of phosphorus (See Appendix 2), and was used to replace copper tubing in old PCC lysimeters and in all new lysimeter construction.

Hansen and Harris (1975) recommend the following procedure for reducing the variability of PCC lysimeters:

Group sampler by intake rate, use samplers of uniform length, use short sampling intervals, and create constant intial vacuum for all samplers. Acid washing of ceramic cups with 1N HCl was recommended by Grover and Lamborn (1970) to reduce phosphorus adsorption. Phosphorus contributions rather than phosphorus adsorption from ceramic cups was discovered, and acid washing with 10% HCl reduced but did not eliminate extractable phosphorus contained in the cup (See Appendix 2).

The advantages and disadvantages of wellpoints and PCC lysimeters were weighed in choosing a sampling method for a septic system monitoring study. The purpose of the study was to identify and roughly quantify septic system pollution of ground water. Precise representation in samples of groundwater nutrient concentrations was desirable but not essential. In light of this fact and the favorable cost and ease of use considerations, the PCC lysimeter was selected as the sampling instrument for the study.

Suggested Design Modifications for PCC Lysimeters

Porous Ceramic Cup, PVC pipe, and stopper assembly are as described in Materials and Methods. The tube assembly is adjusted as follows: Attach 10 cm pieces of 1/4 inch polyethylene tube inside the two flexible plastic tubes (Tygon, I.D. 3/16 inch). Cut short (2.5 cm) pieces of Tygon tubing, heat one side above a candle or another suitable heat source, and seal it off by squeezing with a needle-nose pliers. These Tygon "caps" provide an effective vacuum seal and are very economical.

Section II

Nutrient Movement from Septic Systems

Section II

Nutrient Movement from Septic Systems

Introduction

Nutrient movement from septic system wastewater is thought to be influenced by the texture of the soil around the drainfield, volume of wastewater loading, age of the septic system, and the seasonal or year round use of the septic system. A properly functioning septic system absorbs and treats wastewater, preventing surfacing of effluent and protecting groundwater from contamination. Soil texture is critical to both processes. While sands and similar coarse textured soils are able to rapidly absorb and transport large volumes of water, silt and clay particles in the soil body increases the soil's capacity to remove nutrients (Ellis and Childs, 1969).

Over time, nutrients from wastewater are added to the soil around the drainfield, filling exchange sites for ammonia and phosphorus adsorption. Long term wastewater loading may result in phosphorus migration through the soil (Dudley and Stephenson, 1973).

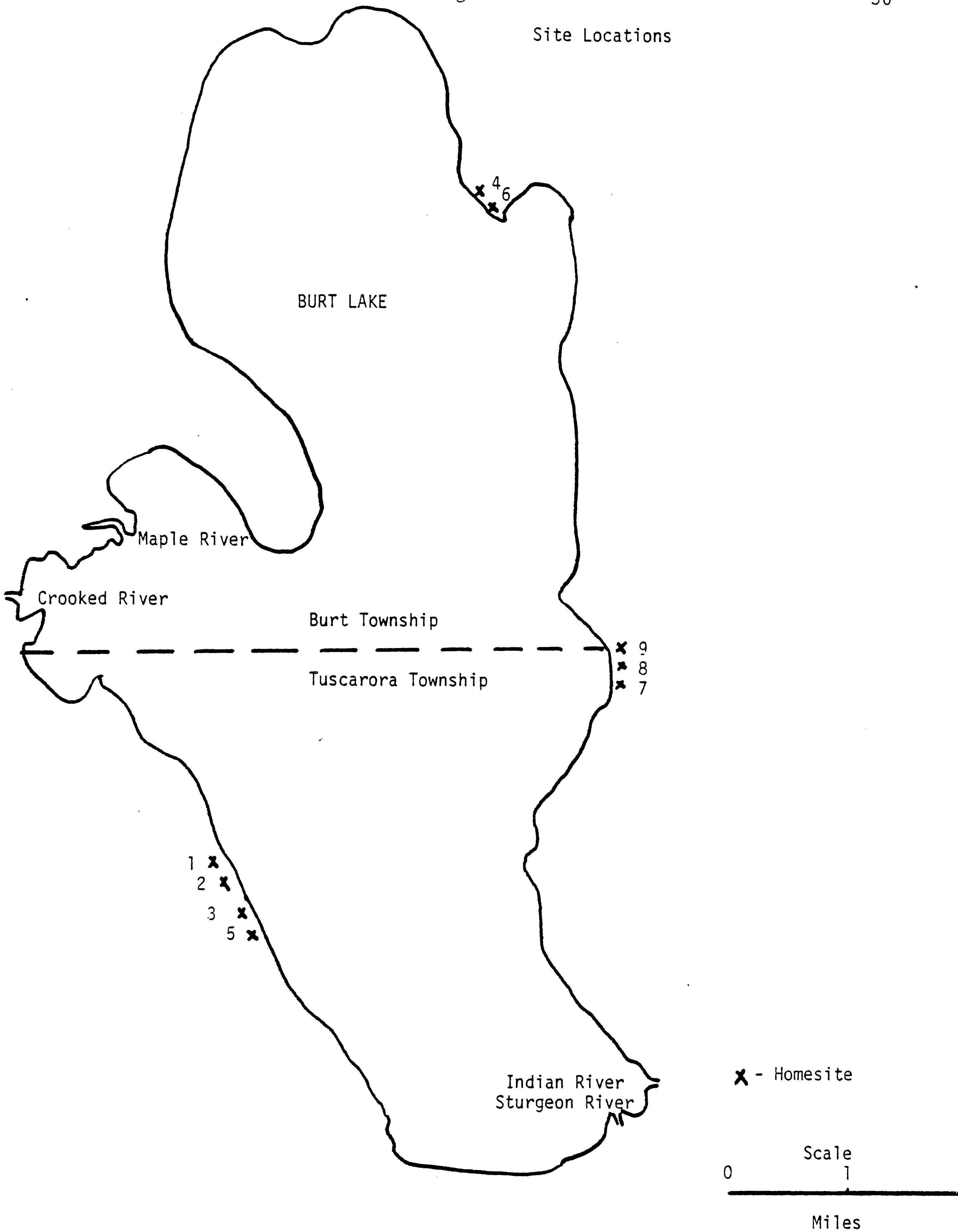
Seasonal occupancy provides for periodic resting of the drainfield. If the drainfield can dry out during periods of non-use, aerobic decomposition of the organic crust will inhibit drainfield clogging (Warshall, 1976), and regeneration of P-adsorption sites can occur (Ellis and Erickson, 1969).

Site Selection

Seven conventional septic systems and two mound systems were studied. All sites were located on the shore of Burt Lake, Cheboygan County, Michigan (Fig. 3). Three factors were considered in the site

Figure 3

Site Locations



selection process: soil texture, age of septic system, and occupancy (year round or seasonal). A shallow (less than 1.5 m) groundwater table was present at each site.

Materials and Methods

Soil texture was determined from composite auger samples collected at each site. Sites with sand and/or loamy sand soil surface and subsurface horizons were compared to sites with finer textured horizons. (It is worthwhile to note that the bottom of the drainfield is typically .75 to 1.0 m below the soil surface in conventional septic systems. Soil above this depth may not influence effluent treatment.) Texture was determined by the hydrometer method (Bouyoucos, 1936) followed by sieve analysis of the sand fraction (Table 2). Ages of septic systems were obtained from health department files or from the residents. Residents stated whether the home was occupied year round or seasonally.

Many factors important to septic system performance were not considered in the site selection process. These factors include: installation and maintenance of the system, houshold water use, lawn fertilization and watering, size and design of the drainfield, and others. Information on these factors was gathered through site inspection and household survey.

At each site the location of the drainfield was determined. Two porous ceramic cup (PCC) lysimeters were installed in the soil up gradient from the drainfield to obtain ambient nutrient concentrations in the groundwater. Lysimeters were installed in holes augered with a standard soil auger down to the zone of saturation. Prior to

Table 2

Textural Analysis

Site	Depth(m)	%Sand	%Silt	%Clay	Remarks
1	0.5	60	28	12	
1	1.0	90	6	4	
2	0.5	52	36	12	
2	1.0	94	4	2	
3	0.5	98	0	2	
3	1.0	97	0	3	
4	0.5	95	0	5	gravelly
4	1.0	--	-	-	organic
5	0.5	58	10	32	
5	1.0	17	27	56	
6	0.5	--	--	--	not analyzed
6	1.0	--	--	--	not analyzed
7	0.5	94	4	2	
7	1.0	--	--	--	organic
8	0.5	--	--	--	same as site 7
8	1.0	--	--	--	same as site 7
9	0.5	--	--	--	same as site 7
9	1.0	--	--	--	same as site 7

installation, lysimeters were acid washed and rinsed as described in Section I.

Groundwater under the drainfield was assumed to flow towards the lake. An arc of 4 to 9 lysimeters was placed between the drainfield and the lake within 3 meters of the approximate perimeter of the drainfield. Large volume and high nutrient concentrations in lysimeter samples were used to better estimate the direction of flow and the path of nutrient migration from the drainfield. A second arc of lysimeters was subsequently placed in the estimated direction of flow within five meters of the lake. Samples were taken at twenty four hour intervals. Six sets of samples were obtained from sites 1-6. Four sets of samples were obtained from sites 7-9.

Results and Discussion

Groundwater data from the nine homesites are presented in Table 3 and Figure 4. Information on the age of the septic system, seasonal or permanent occupancy, soil texture, water use, and number of occupants is given for each site. Daily water use and the average number of residents were estimated from information contained in a survey filled out by the residents during the sampling period. Water use was estimated to be 50 gallons per person per day (gppd) for homes with no washing machine. Where a washing machine was in use less than once a day, water use was estimated to 60 gppd, and 75 gppd where the washing machine was used more than once a day.

Mean values of TDP, NO_3-N, NH_4-N, and Cl for each sampler on each site are given at the bottom of the columns in Table 3 and shown graphically in Figure 4, along with the placement of the samplers.

On sites 1,2,3,7,8 and 9, samplers could be grouped according to their positions with respect to the septic system drainfield (on sites 4,5, and 6, the placement of the samplers did not lend themselves to such groupings). A Control group included samplers up gradient from the septic system drainfield and was used as an indicator of background groundwater conditions. A Near group within 3 m of the drainfield indicated groundwater conditions in the zone of maximum influence from wastewater loading. A Far group of samplers within 5 m of the shoreline served as a measure of nutrient and chloride concentrations in the groundwater as it entered Burt Lake.

The means and standard deviations of Control, Near and Far

Table 3 Burt Lake Data

Site No.	Age	Occupancy	Texture	Estimated water use (gpd)	Avg. No. residents
1	9	seasonal	0.5 m sandy loam 1.0 m sand	675	9

TDP_{ppb}

Lysimeter No.	1	2	3	4	5	6	7	8	9
Sample No. 1	30	*	*	35	40	*	**	**	**
2	20	*	*	70	70	*	**	**	**
3	*	*	*	160	*	*	137	77.5	72
4	68	*	*	752	*	*	216	—	95
5	*	*	187	—	*	*	147	—	64
6	30	140	315	250	*	70	80	90	**
7	30	1960	2640	3280	1040	960	—	920	**
Mean	35.60	1050	1047.3	757	383.3	515	145.0	362.5	77.0

NO_3-N_{ppb}

Lysimeter No.	1	2	3	4	5	6	7	8	9
Sample No. 1	212	*	*	3200	14000	*	**	**	**
2	124	*	*	9300	15500	*	**	**	**
3	*	*	8900	18800	22000	*	10800	0	704
4	10	*	*	10500	11000	*	500	—	200
5	*	*	15000	—	16500	*	2480	80	1480
6	60	8200	9200	15000	13000	100	4700	12000	**
7	55	775	5400	80	—	950	—	85	**
Mean	86.83	4487.5	9675	9480	15,333	525	4620	4833	794

* Insufficient volume for analyses
** No sample attempted
_ Sample lost

Table 3 Con't.

Site No. 1 con't

NH_3-N_{ppb}

Lysimeter No.		1	2	3	4	5	6	7	8	9
Sample No.	1	—	*	*	800	7200	*	**	**	**
	2	0	*	*	2200	293	*	**	**	**
	3	*	*	—	1000	2000	*	2730	6250	2904
	4	120	*	*	270	2500	*	2500	—	2500
	5	*	*	103	—	350	*	1760	9500	4250
	6	15	200	37	10000	105	60	110	—	**
	7	70	90	215	11000	215	493	—	6000	**
Mean		51.25	145	118	4420	1809	276	1775	7250	3218

CL_{ppm}

Lysimeter No.		1	2	3	4	5	6	7	8	9
Sample No.	1	10.5	*	*	10.7	40	*	**	**	**
	2	13	*	*	26	33	*	**	**	**
	3	*	*	—	44.6	—	*	38.0	158.2	120
	4	39	*	*	22.5	—	*	56.5	—	39.5
	5	*	*	39.0	—	—	*	39.5	38.7	33.5
	6	12	17	25	30	24	25	24	—	**
	7	16	13	18	23	20	30	—	28	**
Mean		18.10	15	27.33	26.13	29.25	27	39.5	63.2	64.33

Table 3 Con't.

Site No.	Age	Occupancy	Texture	Estimated water use (gpd)	Avg. No. residents
2	20	seasonal	0.5 m loam 1.0 m sand	75	3

TDP_{ppb}

Lysimeter No.		1	2	3	4	5	6
Sample No.	1	20	18	**	**	**	**
	2	30	30	70	*	155	30
	3	44	55	69	80	79	73
	4	—	107	60	60	135	126
	5	134	32	35	37	35	*
	6	25	26	105	*	50	30
	7	**	**	40	—	70	*
Mean		41.6	44.7	63.16	63.78	87.3	64.75

$NO_3\text{-}N_{ppb}$

Lysimeter No.		1	2	3	4	5	6
Sample No.	1	25	55	**	**	**	**
	2	10	60	30	*	175	125
	3	20	98	0	0	200	255
	4	—	105	0	10	190	270
	5	44	105	5	19	69	—
	6	30	50	—	*	220	315
	7	**	**	10	—	140	—
Mean		24.8	78.8	9.7	9.7	165.6	218.0

Site No. 2 con't

NH_3-N_{ppb}

Lysimeter No.	1	2	3	4	5	6
Sample No. 1	195	167	**	**	**	**
2	175	170	133	*	200	73
3	175	215	140	310	75	75
4	—	110	105	280	40	75
5	185	91	92	306	48	*
6	80	60	120	*	150	60
7	**	**	150	—	165	*
Mean	162	132.2	123.3	298.67	113	70.75

CL_{ppm}

Lysimeter No.	1	2	3	4	5	6
Sample No. 1	—	—	**	**	**	**
2	1.0	5.6	8.2	*	5.4	8.6
3	5.2	5.3	4.6	—	8.8	7.0
4	—	5.1	16.5	19.5	6.2	6.7
5	5.4	4.9	3.9	5.9	6.7	*
6	4.2	4.2	3.0	—	4.5	5.4
7	**	**	—	—	4.6	*
Mean	3.95	5.02	6.63	12.7	6.03	6.92

Site No.	Age	Occupancy	Texture	Estimated water used	Avg. No. residents
3	20	seasonal	0.5 m sand 1.0 m sand	120 gpd	2

TDP_{ppb}

Lysimeter No.	1	2	3	4	5	6	7	8	9	10	11
Sample No. 1	20	19	120	40	—	—	**	70	**	**	**
2	25	45	100	60	505	—	**	50	**	**	**
3	104	122	*	177	190	112	**	142	**	**	**
4	26	54	**	**	**	33	57	48	60	14	—
5	65	95	**	**	**	90	65	65	80	50	65
6	—	45	**	**	**	60	—	90	30	—	145
Mean	45.5	64.6	110	92.3	347.5	73.75	61	77.5	56.6	32	105

$NO_3\text{-}N_{ppb}$

Lysimeter No.	1	2	3	4	5	6	7	8	9	10	11
Sample No. 1	32	24	3	0	—	—	**	**	**	**	**
2	8	6	84	0	8	0	**	150	**	**	**
3	5	5	*	10	0	0	**	550	**	**	**
4	24	0	**	**	**	33	3	900	8	530	—
5	15	10	**	**	**	90	0	150	0	135	0
6	—	18	**	**	**	60	—	950	5	—	5
Mean	19.5	14.0	43	3.3	4	37.5	1.5	540	4.3	332.5	2.5

Table 3 Con't.

Site No. 3 con't

NH_3-N_{ppb}

Lysimeter No.		1	2	3	4	5	6	7	8	9	10	11
Sample No.	1	248	128	69	75	—	—	**	98	**	**	**
	2	78	75	84	50	1600	—	**	224	**	**	**
	3	75	70	—	30	55	525	**	125	**	**	**
	4	10	6	**	**	**	2300	2370	124	51	93	—
	5	40	60	**	**	**	90	170	55	—	52	270
	6	—	100	**	**	**	1400	—	70	325	—	220
Mean		90.2	55.3	76	52	825	1078.7	1270	116	188	72.5	245

CL_{ppm}

Lysimeter No.		1	2	3	4	5	6	7	8	9	10	11
Sample No.	1	6.3	6.3	—	12.5	—	—	**	8.7	**	**	**
	2	7.9	10.6	—	9.0	30	—	**	10.4	**	**	**
	3	30.5	7.4	*	10.5	11.0	51.0	**	4.4	**	**	**
	4	26.	8.5	**	**	**	111.8	6.6	3.7	7.5	46.5	—
	5	5.0	6.6	**	**	**	8.6	3.6	3.4	5.0	6.0	14.4
	6	—	4.6	**	**	**	6.9	—	2.5	4.0	—	6.7
Mean		15.5	6.5		10.6	20.5	44.6	5.1	5.5	5.5	26.2	10.5

Table 3 Con't.

Site No.	Age	Occupancy	Texture	Estimated water use (gpd)	Avg. No. residents
4	1	year round	0.5 m gravelly sand 1.0 m woody peat	225	3

TDP_{ppb}

Lysimeter No.		1	2	3	4	5	6	7	8	9	10
Sample No.	1	30	80	35	95	70	85	**	**	**	**
	2	100	146	94	116		105	**	**	**	**
	3	15	230	103	—	128	99	**	**	**	**
	4	50	290	—	130	115	190	40	80	**	**
	5	40	320	130	80	65	95	65	45	**	**
	6	**	**	**	**	72	**	**	100	80	135
	7	**	**	**	**	70	**	**	110	90	240
Mean		47	213.2	90.5	105.2	86.7	114.8	52.5	83.8	85	187.5

$NO_3\text{-}N_{ppb}$

Lysimeter No.		1	2	3	4	5	6	7	8	9	10
Sample No.	1	0	4	56	—	202	73	**	**	**	**
	2	0	83	120	60	*	1500	**	**	**	**
	3	0	2	183	2	3900	1925	**	**	**	**
	4	0	0	—	30	490	160	50	25	**	**
	5	0	0	1500	—	3800	1350	65	200	**	**
	6	0				260	**	**	70	22	110
	7	**	**	**	**	45	**	**	108	25	295
Mean		0	17.8	452	30.7	1449.5	1001	57.5	100.8	23.5	202.5

Site No. 4 con't

$NH_3\text{-}N_{ppb}$

Lysimeter No.	1	2	3	4	5	6	7	8	9	10
Sample No. 1	86	70	103	—	160	7	**	**	**	**
2	186	192	666	450	*	55	**	**	**	**
3	126	167	—	8	2000	572	**	**	**	**
4	130	150	—	15	70	170	175	60	**	**
5	140	170	490	25	118	60	170	650	**	**
6	**	**	**	**	600	**	**	327	55	4
7	**	**	**	**	1500	**	**	240	190	135
Mean	133.6	149.8	419.6	124.5	741.3	172.8	172.5	348	122.5	69.5

CL_{ppm}

Lysimeter No.	1	2	3	4	5	6	7	8	9	10
Sample No. 1	6.4	6.3	35	—	80	—	**	**	**	**
2	4.9	4.9	46.0	11.0	*	36	**	**	**	**
3	4.7	4.8	27.5	9.9	63.0	50.5	**	**	**	**
4	4.0	4.1	—	9.2	50	31	11.6	25	**	**
5	3.5	11.1	14	6.7	49	36	4.2	9.3	**	**
6	**	**	**	**	3.9	**	**	2.5	6.0	8.6
7	**	**	**	**	38	**	**	2.6	5.7	4.3
Mean	4.7	17.6	20.1	9.2	47.3	38.4	7.9	9.8	5.85	6.4

Site No.	Age	Occupancy	Texture	Estimated water use (gpd)	Avg. No. residents
5	5	seasonal	0.5 m sandy clay loam 1.0 m clay	60	1

TDP_{ppb}

Lysimeter No.	1	2	3	4	5	6	7
Sample No. 1	*	*	*	75	**	**	**
2	265	—	160	*	166.5	**	**
3	*	142	90	173	45	54	**
4	160	7	14	85	272	112	**
5	100	85	*	85	100	—	**
6	115	**	—	75	140	80	115
7	**	**	40	65	**	30	165
8	**	**	110	**	**	100	200
Mean	160	78	82.8	93	144.7	75.2	160

$NO_3\text{-}N_{ppb}$

Lysimeter No.	1	2	3	4	5	6	7
Sample No. 1	*	32	—	38	**	**	**
2	0	1500	200	*	200	**	**
3	*	2560	0	3500	620	0	**
4	12	2550	750	4030	530	150	**
5	15	3400	*	3500	500	—	**
6	30	**	1850	3700	520	33	3700
7	**	**	1650	4100	**	900	850
8	**	**	1900	**	**	800	310
Mean	19.0	2008.4	1058	3144.6	474	376.6	1620

Table 3 Con't.

Site No. 5 con't

NH_3-N_{ppb}

Lysimeter No.	1	2	3	4	5	6	7
Sample No. 1	*	400	—	400	**	**	**
2	295	160	245	*	140	**	**
3	*	120	0	400	90	0	**
4	140	70	131	186	60	78	**
5	920	100	*	250	35	—	**
6	1650	**	140	1750	42	70	380
7	**	**	1.5	62	**	1	50
8	**	**	15	**	**	0	100
Mean	751	170	66.5	508	73.4	29.8	176.6

CL_{ppm}

Lysimeter No.	1	2	3	4	5	6	7
Sample No. 1	*	28	34	138	**	**	**
2	112	18.8	107.5	*	285	**	**
3	*	—	107.5	133.5	112.8	435	**
4	107	31.0	160.0	288	49.0	97.0	**
5	81	22.0	*	132	12	—	**
6	70	**	—	112	13	34	23
7	**	**	600	128	**	4	9.5
8	**	**	575	**	**	2.2	18
Mean	92.5	24.9	247.3	155.2	94.36	114.4	16.8

Site No.	Age	Occupancy	Texture	Estimated water use (gpd)	Avg. No. residents
6	20	seasonal	0.5 m sandy loam 1.0 m woody peat	200	4

TDP_{ppb}

Lysimeter No.		1	2	3	4	5	6
Sample No.	1	35	70	95	95	45	45
	2	58	78	*	116	90	90
	3	36	43	155	58	59	59
	4	55	50	**	75	90	40
	5	70	55	**	120	205	80
Mean		50.8	59.2	125	88	97.4	62.8

$NO_3\text{-}N_{ppb}$

Lysimeter No.		1	2	3	4	5	6
Sample No.	1	700	533	75	10	6	2
	2	600	90	*	35	5	5
	3	920	530	25	63	32	8
	4	60	500	**	1800	40	12
	5	2050	360	**	50	30	20
Mean		866	402.6	50	391.6	22.6	9.4

Table 3 Con't.

Site No. 6 con't

NH_3-N_{ppb}

Lysimeter No.	1	2	3	4	5	6
Sample No. 1	106	13	353	205	169	76
2	35	10	*	165	190	150
3	21	50	380	125	145	73
4	50	50	**	35	130	190
5	85	80	**	78	210	130
Mean	59.4	40.6	366.5	121.6	168.8	123.8

CL_{ppm}

Lysimeter No.	1	2	3	4	5	6
Sample No. 1	10.0	7.0	71	33	58	4.2
2	4.9	5.4	*	50.5	27.4	5.5
3	4.8	5.4	—	61.5	31.5	2.8
4	33	4.8	**	14.2	11.6	3.6
5	3.0	4.1	**	11.8	10.3	2.5
Mean	11.1	5.3	71	34.2	27.7	3.6

Site No.	Age	Occupancy	Texture	Estimated water use (gpd)	Avg. No. residents
7	9	year round	0.5 m sand(fill) 1.0 m woody peat	100	2

TDP_{ppb}

Lysimeter No.	1	2	3	4	5	6	7	8	9	10	11
Sample No. 1	135	130	1520	–	1000	–	3120	340	2280	**	**
2	250	1250	1080	1280	1344	14720	3000	720	2200	**	**
3	70	**	880	800	–	11840	1720	560	2160	**	**
4	120	**	**	1040	325	9920	1000	800	**	640	1200
5	–	**	**	2000	1080	9280	1240	840	**	760	1280
Mean	143.75	690	1160	1280	937.25	11440	2016	652	2213.3	700	1240

$NO_3\text{-}N_{ppb}$

Lysimeter No.	1	2	3	4	5	6	7	8	9	10	11
Sample No. 1	–	0	0	–	0	0	0	5	0	**	**
2	115	0	0	–	10	10	0	0	0	**	**
3	12	**	5	1900	–	3	1	1	1	**	**
4	12	**	**	270	8	4	4	2	*	3	6
5	–	**	**	11	3	2	1	0	*	4	0
Mean	46.3	0	1.6	727	7	4.75	2	1.8	.3	3.5	3

Site No. 7 con't

NH_3-N_{ppb}

Lysimeter No.	1	2	3	4	5	6	7	8	9	10	11
Sample No. 1	—	7500	6250	19000	15750	—	—	16750	11250	**	**
2	450	1320	2530	5500	9790	38500	26400	26400	8800	**	**
3	390	**	2400	2750	—	26500	21900	11350	7600	**	**
4	435	**	**	3900	4350	39600	35200	12300	**	6900	7350
5	—	**	**	4050	3950	22750	19800	10350	**	4550	7000
Mean	425	4410	3726.7	7040	8460	31837	25825	15430	9216	5725	7175

CL_{ppm}

Lysimeter No.	1	2	3	4	5	6	7	8	9	10	11
Sample No. 1	17.5	12.0	14.0	40	46	82	30	15	8	**	**
2	8.4	20	11.4	40	34	65	27	14.8	5.9	**	**
3	11	**	12	33	—	66	22.5	16.0	25	**	**
4	45	**	**	26	42.5	109	46.0	70	**	38	18
5	—	**	**	30	42.5	60	22.0	14.8	**	38	18
Mean	20.5	16.0	12.5	33.8	41.25	76.4	29.5	26.1	13.0	38	18

Site No.	Age	Occupancy	Texture	Estimated water use (gpd)	Avg. No. residents
8	2	year round	0.5 m sand (fill) 1.0 m woody peat	150	2

TDP_{ppb}

Lysimeter No.	1	2	3	4	5	6	7	8
Sample No. 1	—	135	2400	4080	**	**	**	**
2	45	150	3840	435	**	**	**	**
3	—	**	—	—	**	**	**	**
4	60	**	—	3840	375	2320	880	1920
5	55	**	—	3680	400	2680	310	1640
Mean	53.3	142.5	3013.3	3008.7	387.5	2500	595	1780

$NO_3\text{-}N_{ppb}$

Lysimeter No.	1	2	3	4	5	6	7	8
Sample No. 1	—	65	10	5	**	**	**	**
2	2	220	50	5	**	**	**	**
3	—	**	—	—	**	**	**	**
4	5	**	—	3	60	32	2	7
5	25	**	—	0	22	—	—	30
Mean	10.6	142.5	30	3.25	41.0	32	2	18.5

Site No. 8 con't

NH_3-N_{ppb}

Lysimeter No.		1	2	3	4	5	6	7	8
Sample No.	1	—	5000	21000	8750	**	**	**	**
	2	232	350	11440	7260	**	**	**	**
	3	—	**	—	—	**	**	**	**
	4	72	**	—	6900	1150	3600	6000	21750
	5	10	**	11000	5815	900	3100	550	6850
Mean		104.6	2675	14480	7181	1025	3350	3275	14300

CL_{ppm}

Lysimeter No.		1	2	3	4	5	6	7	8
Sample No.	1	—	13	13.5	46	**	**	**	**
	2	31	4.5	14.8	37	**	**	**	**
	3	8.9	**	13.0	70	**	**	**	**
	4	65	**	—	39	6.8	8.5	17.0	25
	5	77.5	**	15.4	40	7.1	9.85	7.3	17.0
Mean		45.6	6.01	14.1	46.4	7.0	9.2	12.2	21

Table 3 Con't.

Site No.	Age	Occupancy	Texture	Estimated water use (gpd)	Avg. No. residents
9	9	seasonal	0.5 m sand (fill) 1.0 m woody peat	180	3

TDP_{ppb}

Lysimeter No.	1	2	3	4	5	6
Sample No. 1	240	**	135	320	**	**
2	150	145	350	350	**	**
3	135	880	70	455	260	—
4	105	920	65	—	250	—
Mean	157.5	648.3	155	375	255	

$NO_3\text{-}N_{ppb}$

Lysimeter No.	1	2	3	4	5	6
Sample No. 1	50	**	75	10	**	**
2	80	4	70	5	**	**
3	2	140	71.5	2	155	—
4	378	3220	100	—	155	—
Mean	127.5	1121.3	79.1	5.7	155	

Site No. 9 con't

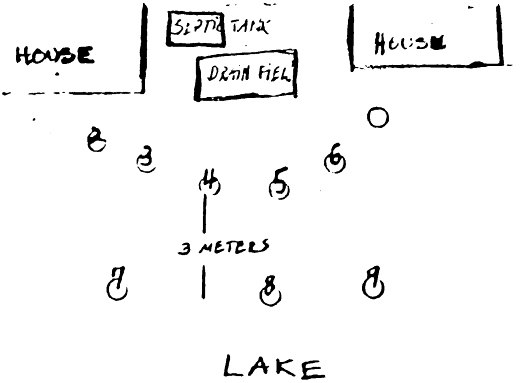
NH_3-N_{ppb}

Lysimeter No.		1	2	3	4	5	6
Sample No.	1	770	**	60	1900	**	**
	2	515	4070	75	1800	**	**
	3	440	–	72.5	–	372	20
	4	397	450	56	1900	103	–
Mean		530.5	2260	65.9	1866.7	237.5	20

CL_{ppm}

Lysimeter No.		1	2	3	4	5	6
Sample No.	1	4.4	**	16.6	18.0	**	**
	2	5.25	9.1	15.2	17.0	**	**
	3	7.0	9.9	16.2	31	34	18
	4	8.2	9.6	19	–	22	–
Mean		6.2	9.5	16.75	22	28	18

Figure 4: Mean Nutrient Concentrations for Samplers on Homesites



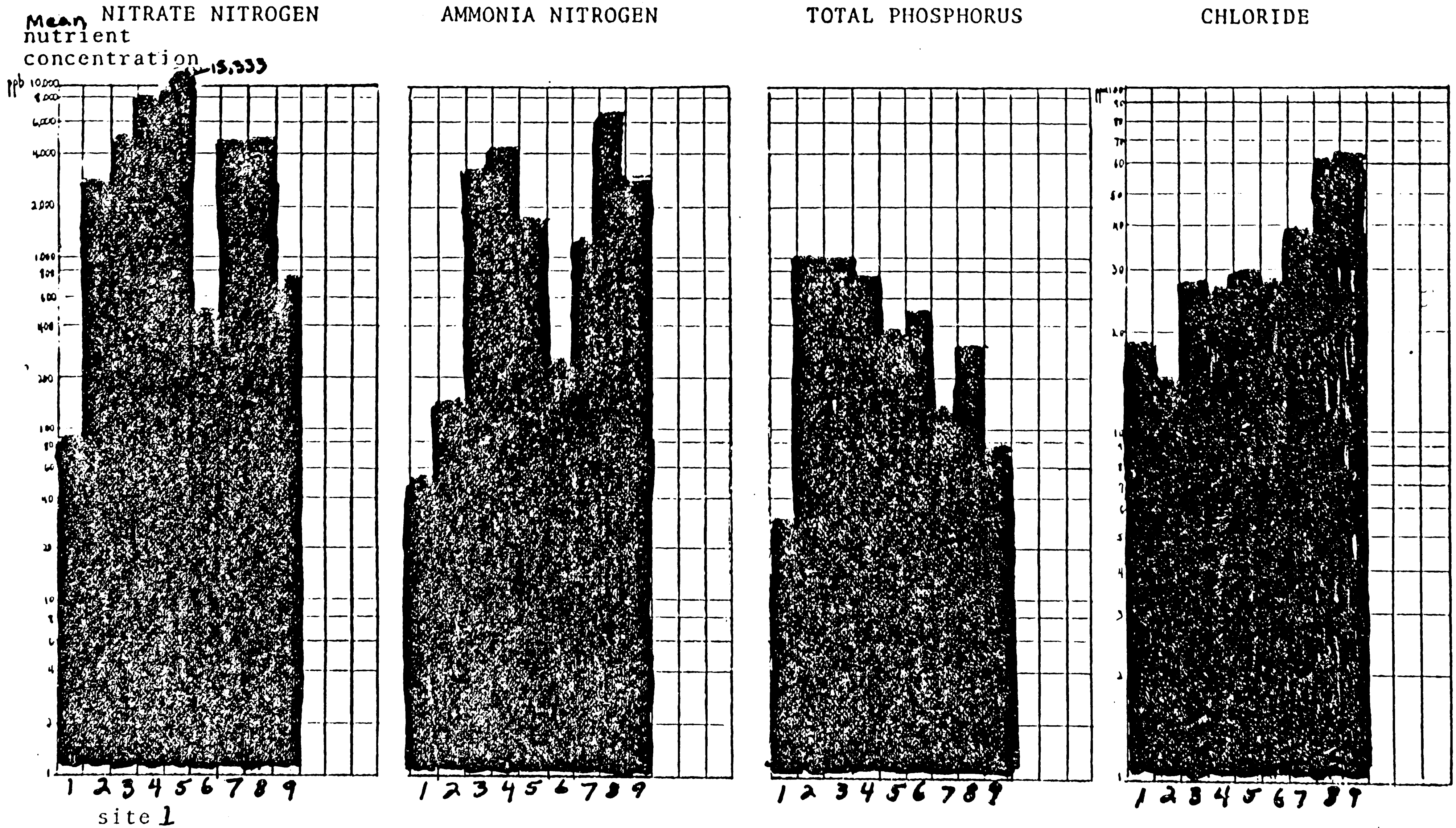
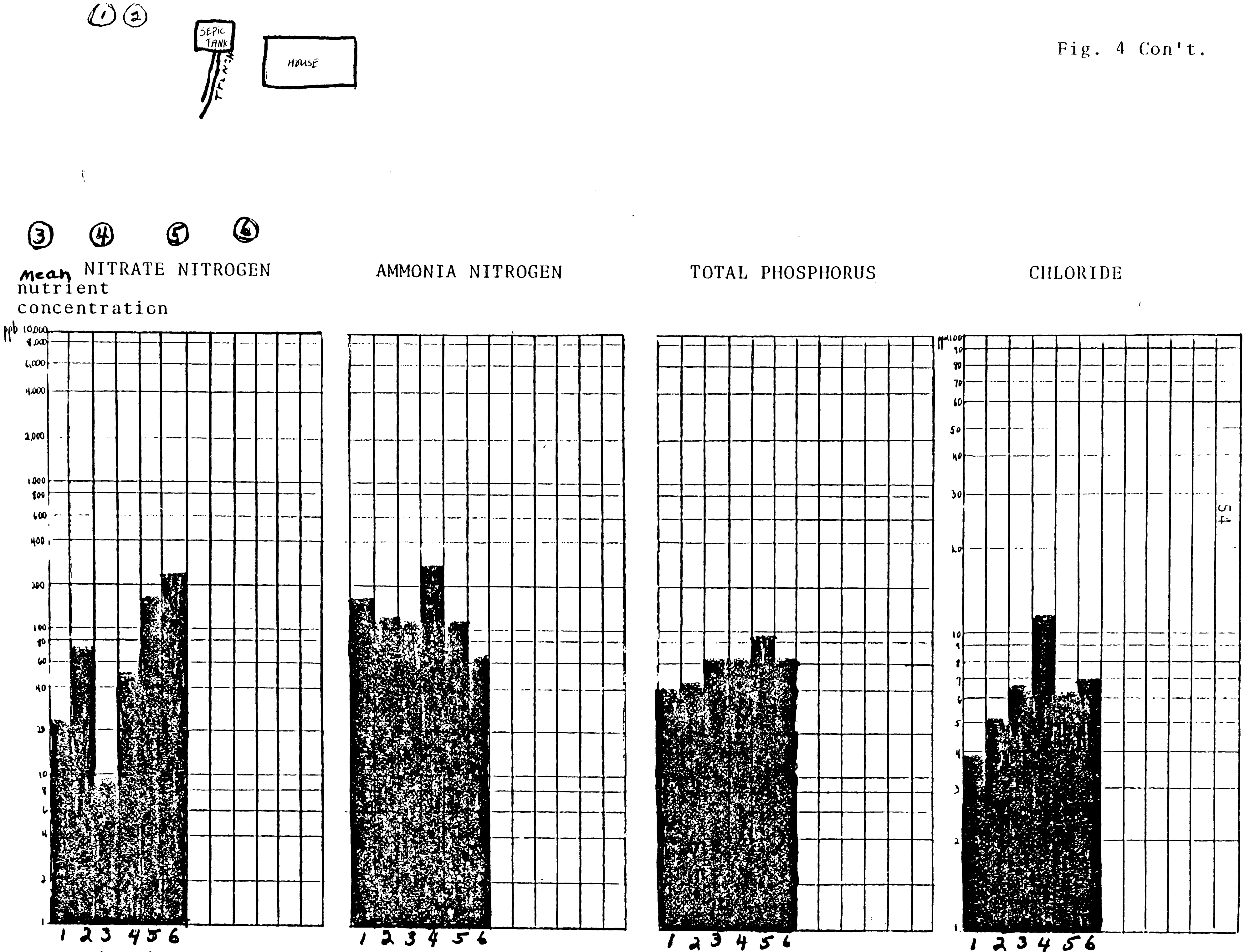


Fig. 4 Con't.



1
2
SEPIC TANK
HOUSE
3
4
5
6
Mean nutrient concentration
ppb
NITRATE NITROGEN
AMMONIA NITROGEN
TOTAL PHOSPHORUS
CHLORIDE
1 2 3 4 5 6

Fig. 4 Con't.

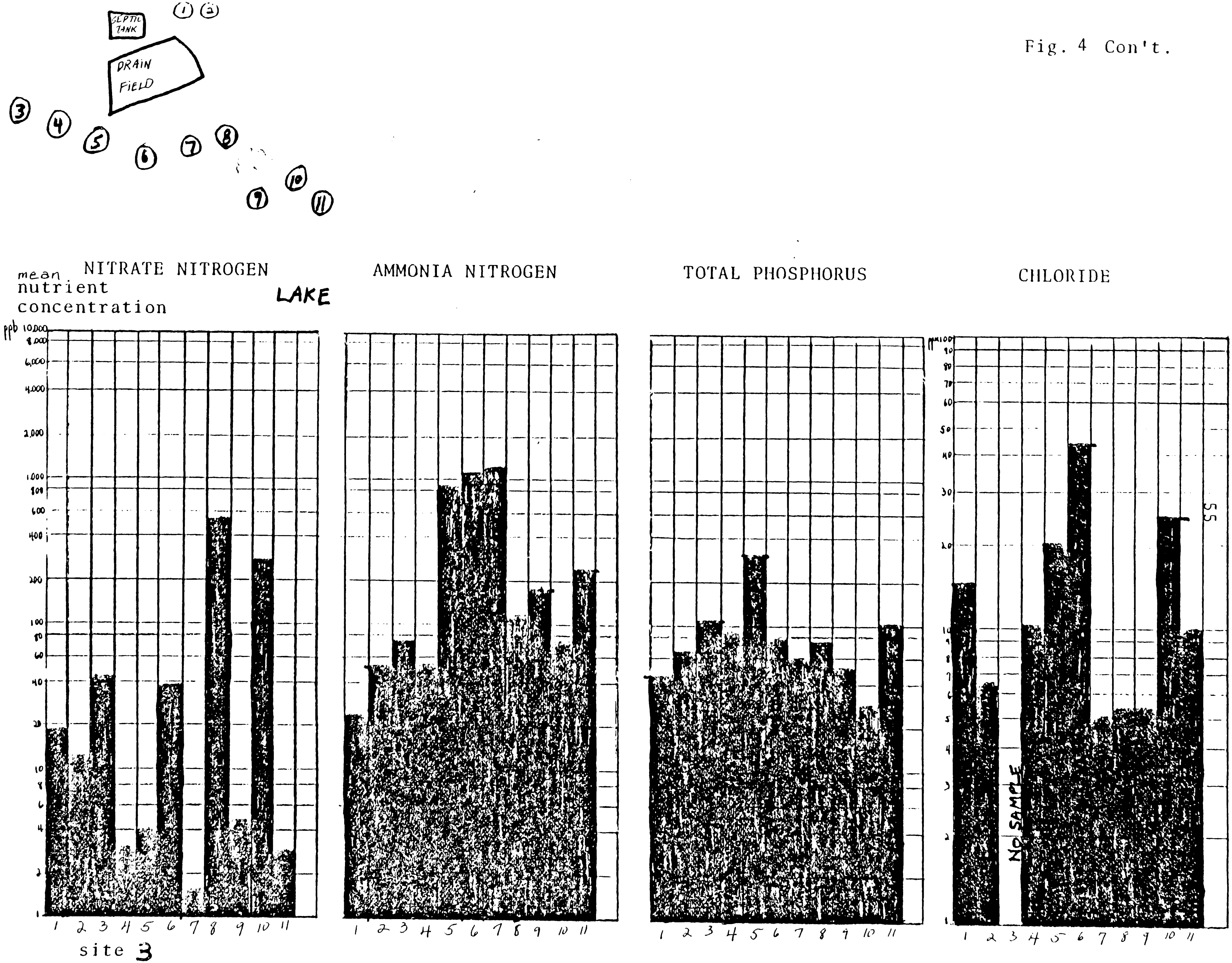
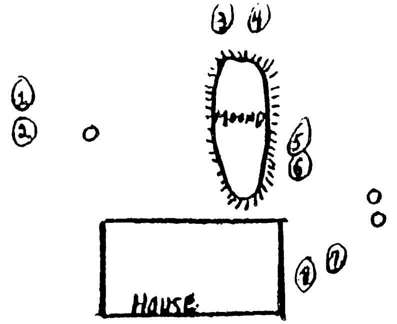

SEPTIC TANK
DRAIN FIELD
LAKE
NITRATE NITROGEN
AMMONIA NITROGEN
TOTAL PHOSPHORUS
CHLORIDE
mean nutrient concentration
ppb
ppm
NO SAMPLE
site 3

Fig. 4 Con't.


HOUSE
LAKE

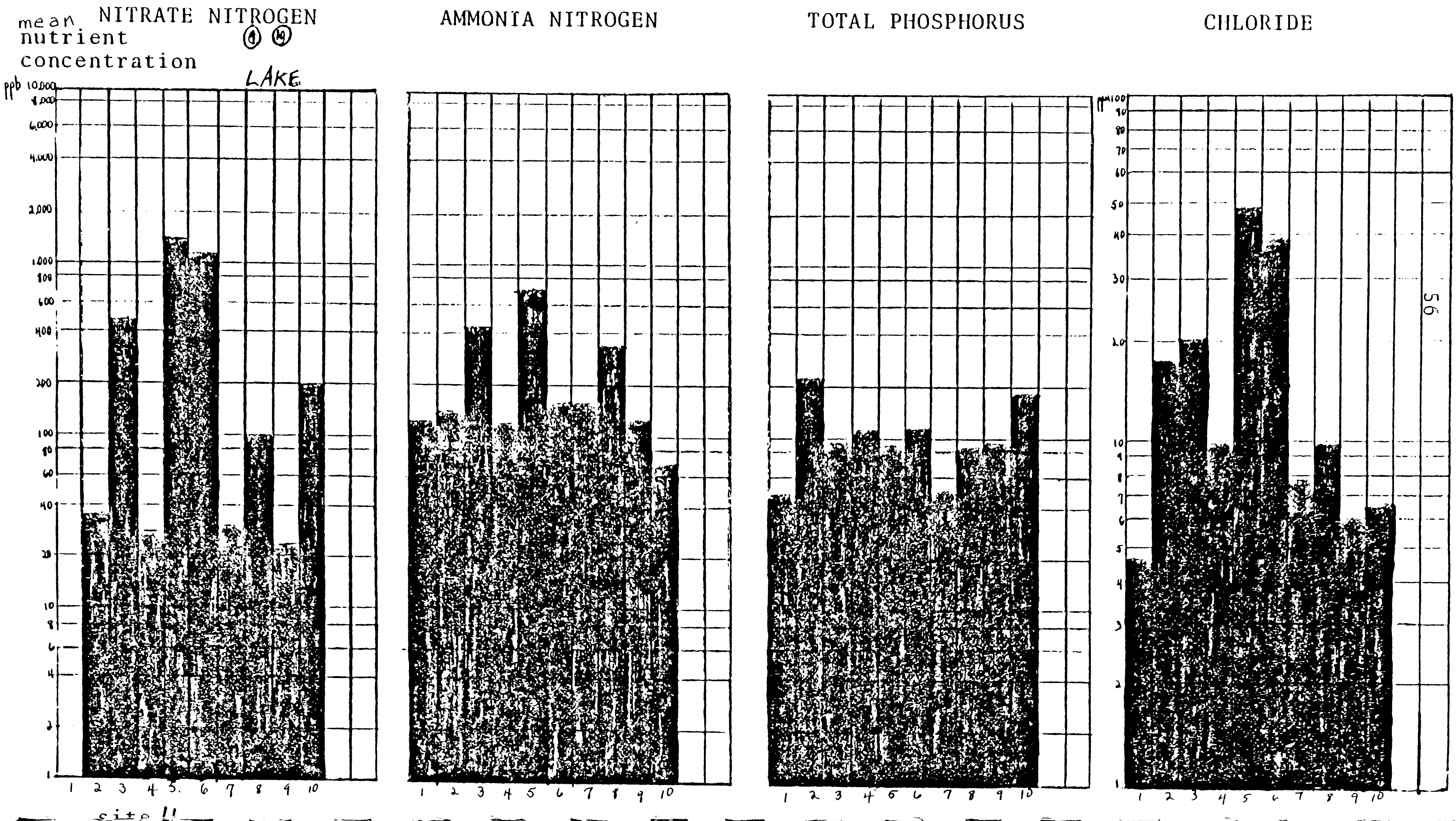

mean nutrient concentration
ppb
NITRATE NITROGEN
AMMONIA NITROGEN
TOTAL PHOSPHORUS
CHLORIDE
site

Fig.4 Con't.

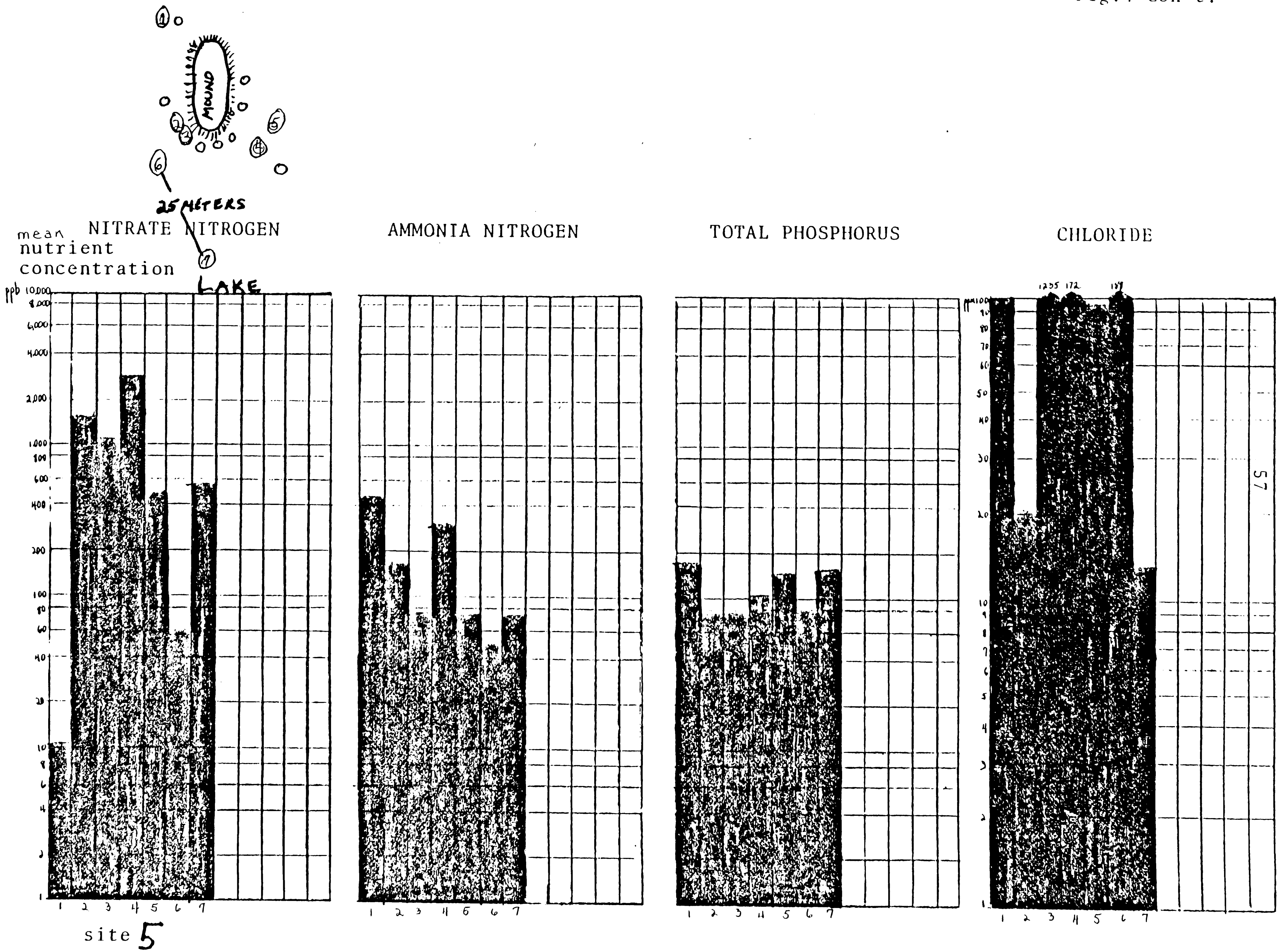
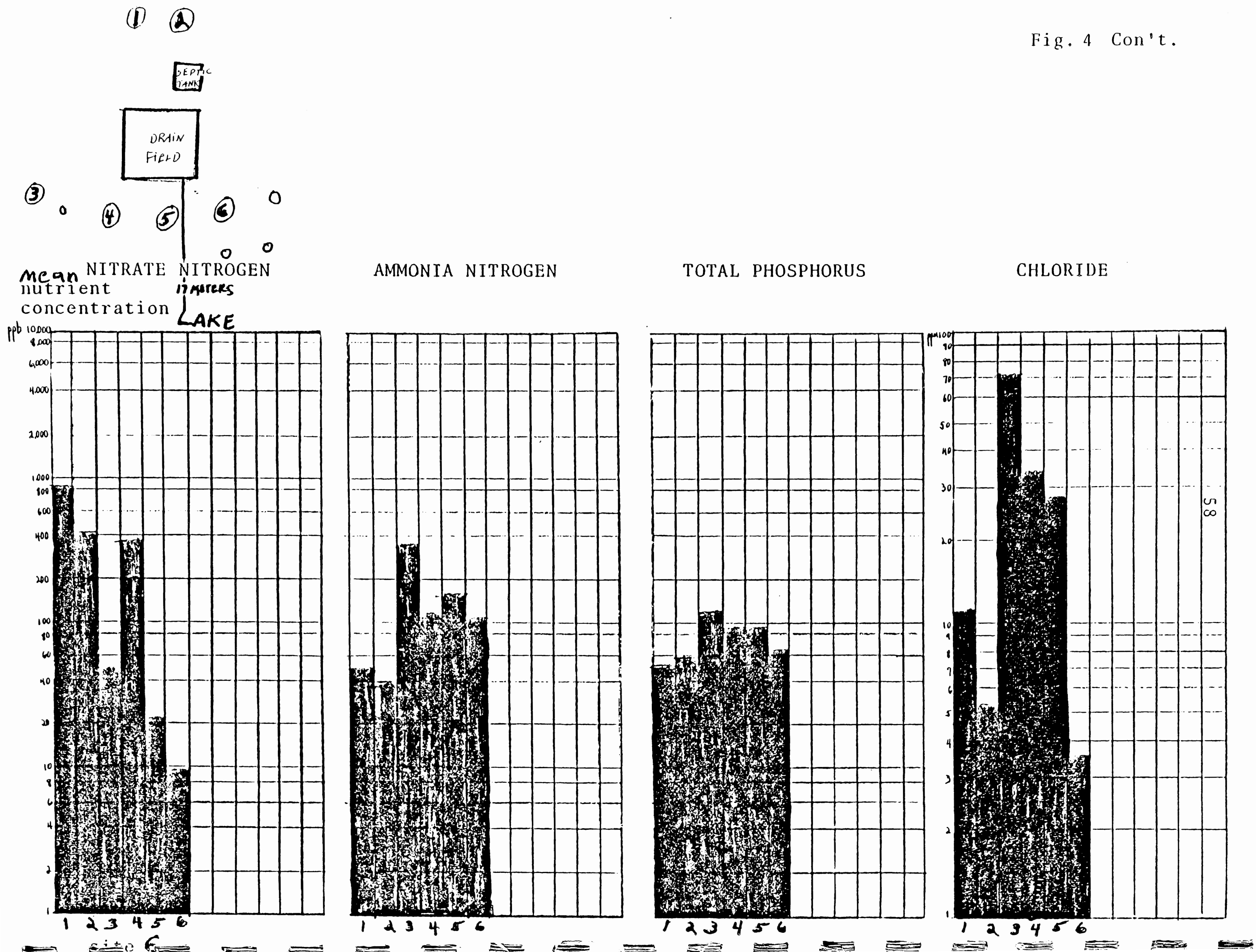

MOUND
25 METERS
LAKE
mean nutrient concentration
NITRATE NITROGEN
AMMONIA NITROGEN
TOTAL PHOSPHORUS
CHLORIDE
ppb
ppm
1255
172
159
site 5

Fig. 4 Con't.



1
2
SEPTIC TANK
DRAIN FIELD
3
4
5
6
17 METERS
LAKE
Mean nutrient concentration
NITRATE NITROGEN
AMMONIA NITROGEN
TOTAL PHOSPHORUS
CHLORIDE
ppb
10,000
8,000
6,000
4,000
2,000
1,000
800
600
400
200
100
80
60
40
20
10
8
6
4
2
1
ppm 100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
1 2 3 4 5 6
site

Fig. 4 Con't.

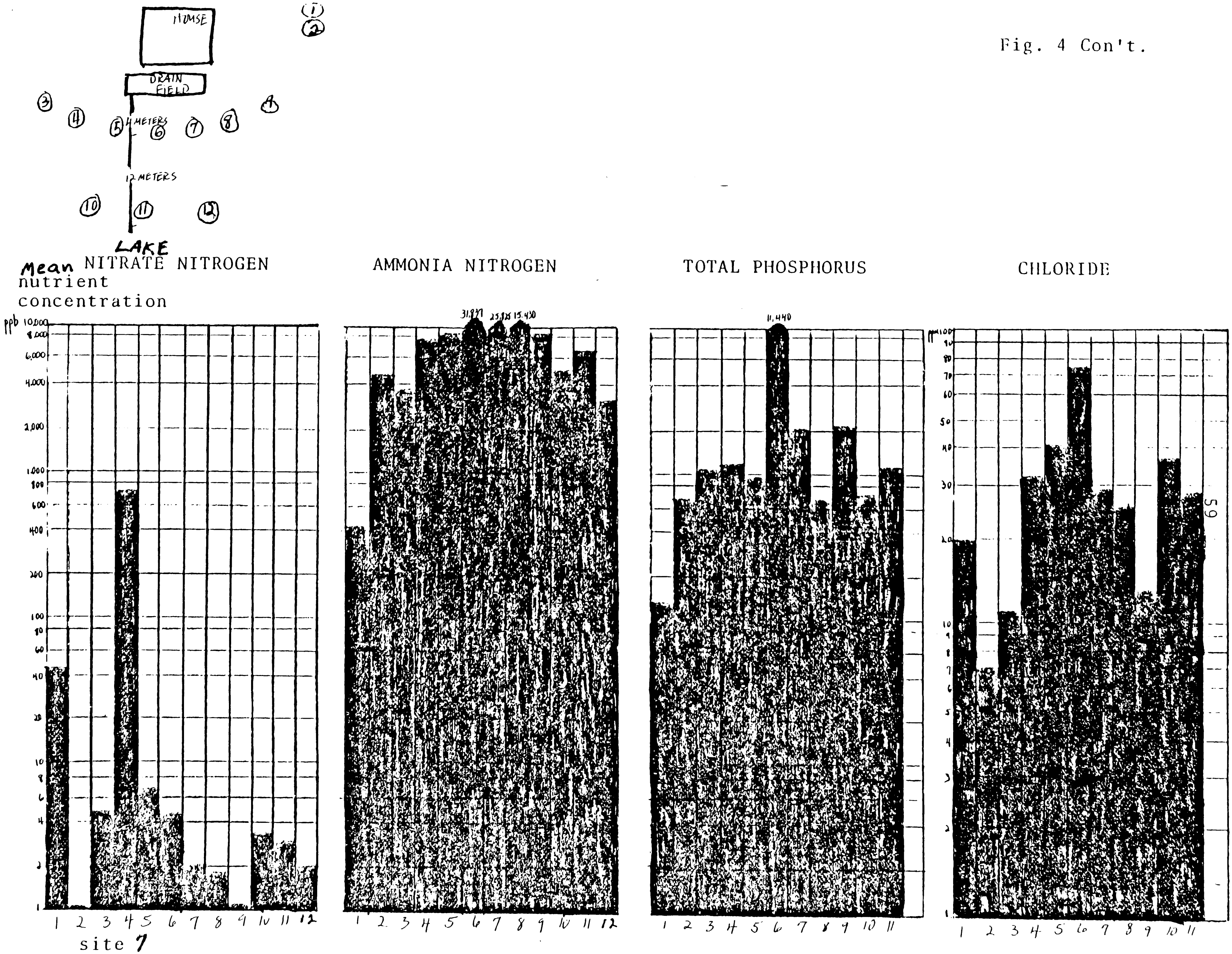
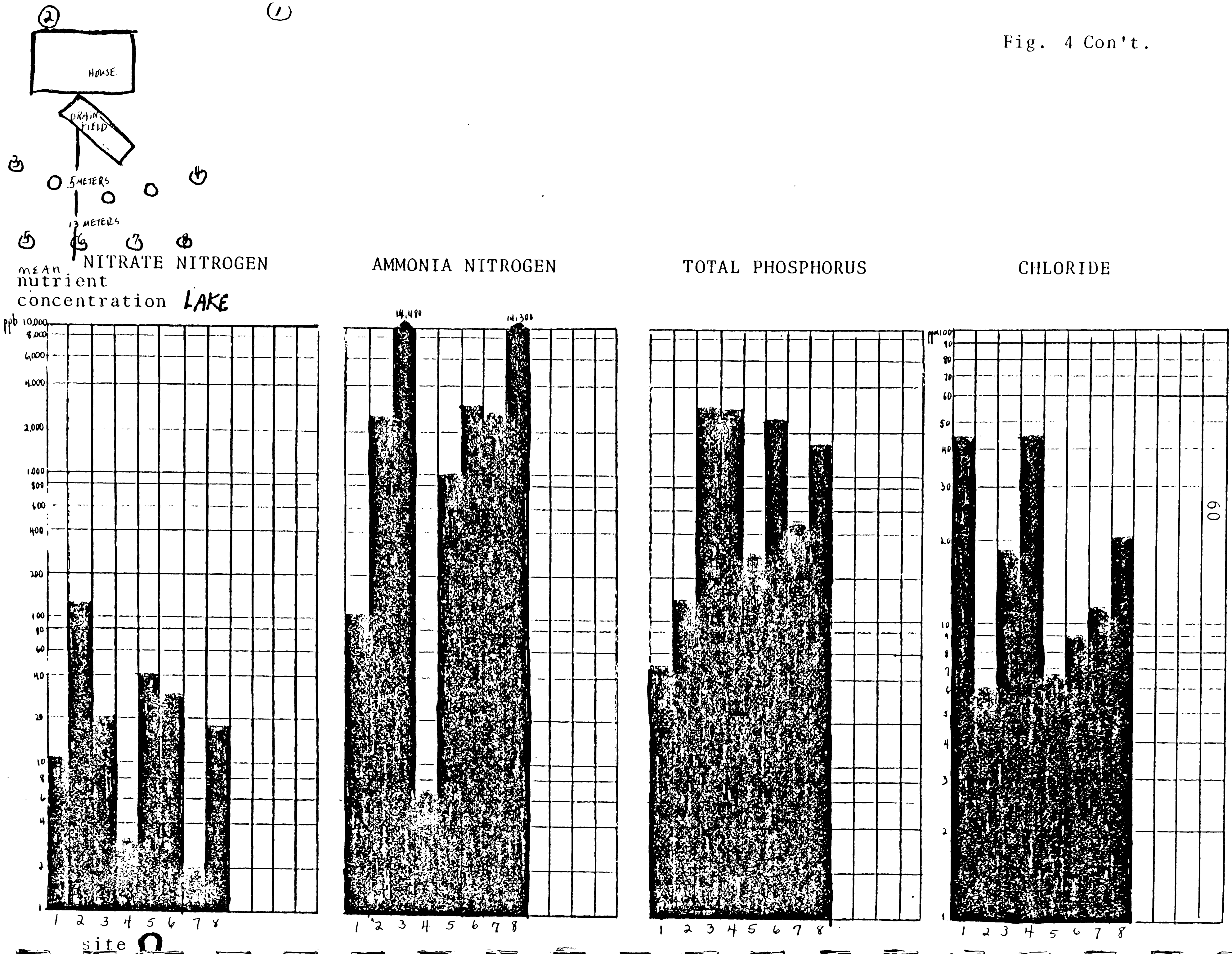
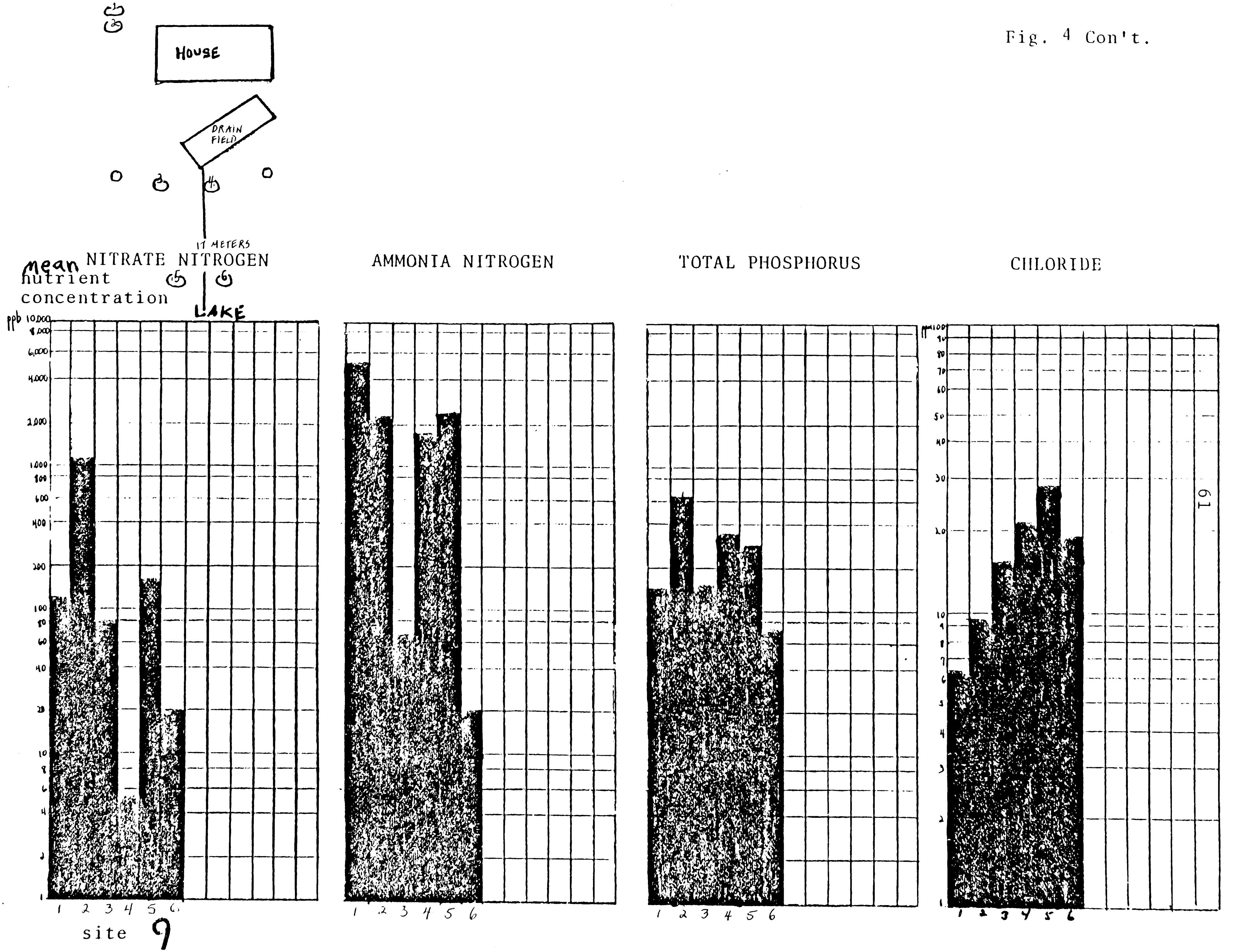

HOUSE
DRAIN FIELD
LAKE
4 METERS
12 METERS
Mean nutrient concentration
ppb
NITRATE NITROGEN
AMMONIA NITROGEN
31,877
25,828
15,430
TOTAL PHOSPHORUS
11,440
CHLORIDE
site 7

Fig. 4 Con't.



HOUSE
DRAIN FIELD
5 METERS
13 METERS
LAKE
MEAN nutrient concentration
NITRATE NITROGEN
AMMONIA NITROGEN
TOTAL PHOSPHORUS
CHLORIDE
ppb
ppm
14,480
14,300
site

Fig. 4 Con't.


HOUSE
DRAIN FIELD
17 METERS
LAKE
Mean nutrient concentration
NITRATE NITROGEN
AMMONIA NITROGEN
TOTAL PHOSPHORUS
CHLORIDE
ppb
10,000
8,000
6,000
4,000
2,000
1,000
800
600
400
200
100
80
60
40
20
10
8
6
4
2
1
1 2 3 4 5 6
site 9

groups on the six sites are given in Table 4. An F-test for the equality of variances between both Control v. Far and Near v. Far groups showed that in 23 of 40 comparisons, the hypothesis of equal variance was rejected at $\alpha=.05$. The large difference in within group variances indicated that a standard T-test would not be an appropriate test for the equality of means between groups. The Behrens-Fisher test, which does not rely on the assumption of equal variance, showed that in 24 Control v. Far comparisons the difference in the means between background and lakeside groundwater conditions was statistically significant in only five cases (Table 4).

The data, with such large between group and within group variances, does not lend itself to statistical interpretation (Several sources of the sample variance are discussed in Section 1). Several trends in groundwater conditions at the sites are evident, however, and are discussed below:

Site 1:

The septic system is constructed in well drained sandy loam soils and is underlain by sand. Two seasonal homes contribute an estimated 675 gpd of effluent to the drainfield during the summer, the largest volume of water use of all sites tested. Concentrations of ammonia and nitrate in the groundwater increase by two orders of magnitude from background to lakeside levels. The unexpected increase in ammonia concentrations from Near to Far samples indicate that Near and Far samplers intercept different groundwater tables in the solum. Far samplers were located on a steep sideslope a meter below Near samplers, and may be influenced by other sources of ammonia than the drainfield.

Phosphorus concentrations rise much less than ammonia and nitrate but the increase is considerable. An isolated zone of algal growth on the rocks along the shore may be a response to nutrient loading from the septic system.

Site 2:

The soil, slope, and groundwater conditions on site 2 are very similar to those on site 1. The significant difference between the septic systems is the wastewater load. Water use at this site is limited to 75 gpd. The septic system here has no significant influence on groundwater conditions.

Site 3:

Water use at this site is estimated at 130 gpd. The soil is sandy and somewhat poorly drained. No significant nutrient loading is apparent.

Site 4:

This is a permanently occupied home with a mound system built in gravelly sand fill material over an organic soil. Water use is estimated at 225 gpd. Drainage ways on three sides of the mound and construction on the site make it difficult to determine the direction of groundwater flow. Sampler 9 and 10 near the lake indicate that nutrient loading is minor.

Site 5:

This is a second mound system serving a permanently occupied home. This is the only site in the study where clay soils are present. Water use was estimated at 60 gpd, the least of all sites. High chloride values may reflect inputs from a water softener. Nutrient loading is apparently insignificant, but it should be noted that with only one

Table 4

MEANS ± STANDARD DEVIATIONS OF CONTROL, NEAR, AND FAR GROUPS ON HOMESITES 1-3, 7-9**

Site No.	Group	Samplers	TDP ppb	NO_3-N ppb	NH_4-N ppb	Cl ppm
1	Control	1	35.6± 18.6	92.2± 78.3	51± 54.8	18.1± 11.8
	Near	2-6	748± 1015	9870± 6514	1956±-3353	25.9± 9.4
	Far	7-9	190± 260	3002± 4389	3850± 2720	57.6± 44.7
	*signif.				X	X
2	Control	1-2	47.1± 38.1	54.7± 34.3	147.5± 52.3	4.5± 1.4
	Near					
	Far	3-6	70.4± 36.7	112± 109	144± 79.7	7.3± 4.3
	signif.					X
3	Control	1-2	56.3± 36.1	13.4± 10.0	80.9± 65.9	10.9± 8.8
	Near	3-8	109± 105	157.4± 299	500.7± 785	17.3± 27.1
	Far	9-11	63.4± 42	97.6± 196.9	168.5±118.7	12.8± 15.2
	signif.					
7	Control	1-2	326± 457	28± 49	2019± 3088	18.9± 13.4
	Near	3-9	2789± 3754	80± 360	14845±11211	32.9± 23.5
	Far	10-11	970± 317	3.25± 2.5	6450± 1281	28± 11.5
	signif.					
8	Control	1-2	89± 49	63± 91	1133± 2166	33± 31
	Near	3-4	3045±1142	12± 19	10309±5157	32± 20
	Far	5-8	1315± 946	26± 21	5488± 6970	12± 6.6
	signif.		X			
9	Control	1-2	368± 366	553± 1183	1107±1458	7.6± 2.2
	Near	3-4	249± 156	48± 41	838± 963	19± 5.4
	Far	5-6	255± 7	155± 0	19± 5.4	24.7± 8.3
	signif.					

*: "X" indicates significant difference in Control and Far means determined by Behrens-Fisher test, α = .05

**distribution of samplers on homesites 4-6 unsuited for Control, Near, and Far groupings sampler by the lake (7), statements about groundwater condition near the lake bear a large measure of uncertainty.

Site 6:

This system is constructed in somewhat poorly drained soils high in organic matter with 0.5 m of sandy loam on the surface. No samples were collected near the lakeshore, but samples collected around the drainfield indicated that nutrient movement through the orgainic-rich soil is limited. This system is likely to experience soil absorption problems when used during wet seasons.

Site 7:

This system has been constructed in poorly drained organic soil with 0.5 m of sandy fill material on the surface. The house is occupied year-round. Control samples indicate that background nitrogen (as ammonia) and phosphorus levels are high (2019 ppb NH_4-N, 326 ppb TDP). These levels rise considerably around the drainfield (14,845 ppb NH_4-N, 2789 ppb TDP). Low nitrate levels for all groups indicate that the soil is saturated throughout, inhibiting nitrification. Ammonia (6450) and phosphorus (970ppb) concentrations remain high enough to indicate substantial nutrient loading to Burt Lake.

Site 8:

Soil conditions, occupancy, and water use(150 gpd) are similar to site 7, and ammonia and phosphorus levels are similarly high. Ammonia (5488 ppb) and phosphorus (1315 ppb) concentrations in groundwater samples near the lake indicate substantial nutrient loading.

Site 9:

Soil conditions and water use are similar to sites 7 and 8. Seasonal rather than year-round occupancy has apparently helped the soil maintain its nutrient removal capacity, and nutrient loading to Burt Lake is minor.

Conclusions

Septic system wastewater disposal led to nutrient contamination of groundwater at three of the nine homesites monitored. Sites 7 and 8 contribute excessive nitrogen (greater than 10 mg/l Tot-N) and phosphorus (greater than 1 mg/l TDP) to Burt Lake. Site 1 contributes substantial nitrogen to the lake.

Large variability of nutrient concentrations in groundwater samples generated data that resists statistical interpretation. Groundwater quality trends, however, suggest the following relationships:

Septic systems constructed in fill materials overlying poorly drained soils fail to provide adequate treatment of wastewater, even under moderate loading conditions.

Application of large effluent loads (675 gpd) result in measurable deterioration of groundwater quality, even in soils that are well-suited for wastewater disposal and treatment.

Section III

Communication and Management Programs

Section III

Communication and Management Programs

Environmental communication and management programs for inland lake protection were integrated with septic system research efforts. The scope of these programs went beyond the shoreline of Burt Lake and septic system issues to include a broad spectrum of water quality concerns in northern lower Michigan.

Communication programs aimed at enhancing public awarness of lake ecology, the water quality status of the northern inland lakes, and of how today's land use decisions will paint the water quality picture of the future. The water quality awareness message was carried through several channels. Slide presentations before lake associations, township boards, and other interested groups covered such topics as septic system treatment, wetland ecology, and the role of land use in environmental protection. A number of "investigative tours" on area lakes served as floating forums where concerned citizens could view their lake and its watershed from a more wholistic perspective. Extensive newspaper coverage of the project helped to extend ideas and information to a larger audience. A sample of newspaper articles about the project are presented in Appendix 3.

Two conferences cosponsored by the project and the Regional "208" Cleanwater Planners were held during the course of the project. A conference on wetland ecology brought the "208" planners and representatives of state and county agencies and local officials together to discuss wetland ecology and classification, the "priority" wetlands of the area, and legal aspects of wetland management.

A second conference on on-site wastewater system monitoring was aimed at state and district health departments. Presentations covered a range of monitoring techniques for evaluating septic systems. A summary of the conference is presented in Appendix 4.

Management programs for septic system maintenance and water quality monitoring were developed cooperatively with the residents of Burt Lake. A group of homeowners in the septic system maintenance program contracted to have their septic tanks pumped on a regular basis. The tests involved in the water quality monitoring program include secchi disc readings and chlorophyll *a* and dissolved oxygen measurements. Pamphlets describing these programs are presented in Appendix 5. Pamphlets on greenbelts and zoning were also published.

Inland Lakes Expo '78 was the culminating event of the education and management programs. "Expo" was a water quality carnival where workshops and displays on lake ecology, wastewater treatment, community strategies for lake protection, and several other water quality topics were opened to the northern Michigan community. A copy of the Inland Lakes Expo schedule and newspaper articles covering the event are presented in Appendix 3.

The response to these programs was a clear indication of the public's committment to protect the quality of their water resources. The project aimed at helping the public and the area agencies concerned with water quality to develop their interests and carry them through to implementation as ongoing water quality protection programs.

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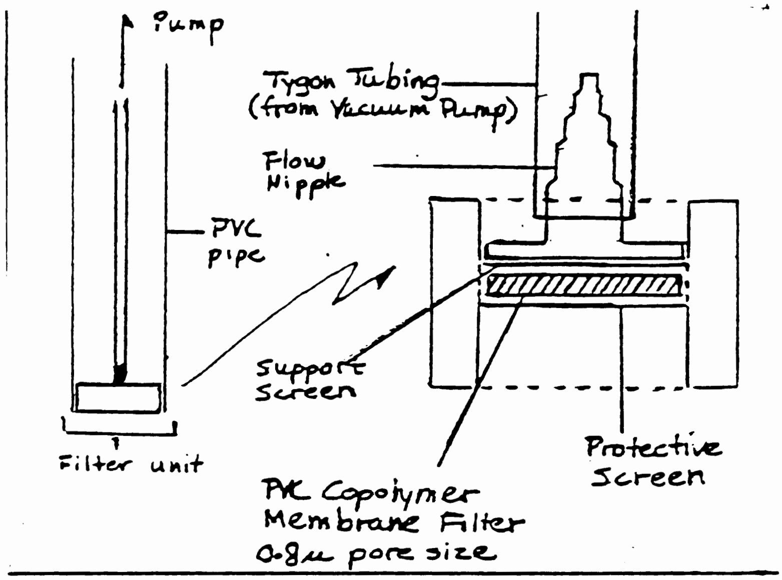
Appendix 1

Experimental Design for PVC Membrane Tension Lysimeter

Appendix 1: Experimental Design for PVC Membrane Tension Lysimeter



*FILTER HOLDER AND PVC MEMBRANES FROM GELMAN INSTRUMENTS, ANN ARBOR

*O.D. 3.5 CM., 2.0 CM. DEPTH
*MEMBRANES 25 MM DIA. AND AVAILABLE IN PORE SIZES 0.45 MICRONS TO 5.0

*NO TESTING HAS BEEN DONE

Appendix 2A
Appendix 2B
Appendix 2C

Additional Laboratory Experiments

by

Brian Marshall
Project C.L.E.A.R.
Water Chemist

Appendix 2A

Phosphorus Contamination of Water
Samples Collected with Porous
Ceramic Cups

Appendix 2A

Phosphorus Contamination of Water Samples Collected with Porous Cups

Foreward

Studies done by Hansen and Harris (1974) have indicated the possibility that phosphorus may be removed from groundwater samples because of adsorption and physical screening processes taking place in the ceramic cup portion of tension lysimeters. If this were the case, our analysis of nutrient concentrations in groundwater samples taken from this type of lysimeter could underestimate the amounts of phosphorus present. Consequently, I have tested new ceramic cups to find out what influence they have on nutrient concentrations. This report will present my experimental findings that unused ceramic cups contain extractable contaminant phosphorus, and contribute, as well as remove, phosphorus from water samples. Recommendations for further study, aimed at finding an improved ceramic cup cleaning procedure, are also given.

Summary

Based upon the results of laboratory tests conducted by Hansen and Harris (1974), an experiment was performed to determine the extent that ceramic cups remove phosphorus from groundwater samples obtained with tension lysimeters. The following results and conclusions were obtained from this test:

1. New ceramic cups actually contain phosphorus, contributing phosphorus to groundwater samples instead of removing it as expected from Hansen and Harris.

2. Washing of the ceramic cup extracts some contaminating phosphorus.
3. Washing with dilute acid removes more extractable phosphorus than does washing with deionized water only.
4. Present cleaning procedures (dilute acid washing) are not sufficient to remove contaminating phosphorus from the ceramic cups.
5. Further experiments need to be conducted to determine a suitable cleaning procedure for the removal of phosphorus from ceramic cups.

Methods

Preparations:
1. Unwashed: none.
2. Deionized water wash: Soak 3 times for 1 hr. each in deionized water.
3. Dilute acid wash: Soak 1 hr. in 10% HCl, followed by 3 times, 1 hr. each in deionized water.

Orthophosphate Solution Concentrations:
1. 50 ppb
2. 300 ppb

Sample Times:
1. Immediately prior to the time that the cermic cup was placed in solution.
2. Immediately after the time that the ceramic cup was placed in solution.
3. After 1 hour.
4. After 4 hours.
5. After 12 hours.
6. After 24 hours.

Results and Discussion

The effects of nutrient retention by ceramic cup tension lysimeters was initially examined by Hansen and Harris in 1974. Of significance to our current groundwater monitoring program, was their discovery that phosphate anions adsorb to excess calcium and magnesium cations located on the surfaces of ceramic cups. This process, in conjunction with physical screening of phosphorus molecules because of the small ceramic cup pore sizes, could result in the underestimation of the phosphorus content in groundwater samples obtained with a ceramic cup tension lysimeter. For this reason, new ceramic cups were tested to determine the magnitude of error that could be expected in our phosphorus analysis of samples taken from these lysimeters.

Twelve identical, new ceramic cups (1.5 inch diameter, 1 micron pore size) were placed in beakers containing 500 ml of solution. The ceramic cups were prepared by three different washing procedures (unwashed, water washed, and dilute acid washed), and then placed into solutions containing two different concentrations of orthophosphate (50 ppb and 300 ppb). Each combination of preparation and solution concentration was run in duplicate. Two additional ceramic cups were placed unwashed in 500 ml of deionized water to serve as a control.

Six 10 ml samples were taken from each beaker at times ranging from just before the cup was placed in solution until 24 hours afterwards. The samples were analyzed for phosphate concentrations with a Technicon Autoanalyzer II, utilizing Standard Methods.

The results of the analysis are given in Table 5 as phosphate concentration in parts per billion (average of duplicate samples). The following observations can be made from this date:

1. All solutions were found to significantly increase in phosphate concentration instead of decreasing as was expected. Even the control, in which there was no phosphorus initially present in the solution, contained large quantities of phosphate after 24 hours.
2. Washed cups yielded less phosphate than unwashed cups.
3. Acid washed cups contributed less contaminating phosphorus than did water washed cups.
4. None of the procedures tested removed all of the extractable phosphorus from the ceramic cups.

From these results it can be concluded that new ceramic cups contain phosphorus, and that washing the cups removes some of this phosphorus, acid washing being more effective than water washing. However, the acid wash procedure, which is currently in use, is not totally effective and should be meliorated. In order to find an improved cleaning procedure for ceramic cups, further testing needs to be designed with the following questions being considered:

1. How long does it take for the phosphorus in the ceramic cup to come to equilibrium with the phosphorus in solution (for solution concentrations from 0 ppb to 1000 ppb)?
2. How many one hour rinses in deionized water are required to remove all of the extractable phosphorus contained in the ceramic cup?

3. What affect does the use of a stronger acid (hot 1:1 HCl) have on the removal of phosphorus from the ceramic cup?

Table 5

Preparation & Concentration	(1) Just before in solution	(2) Just after in solution	(3) After 1 hr.	(4) After 4 hr.	(5) After 12hr.	(6) After 24hr.
Control	0	0	2	20	84	120
50 ppb						
unwashed	50	49	54	62	152	179
water washed	50	50	57	67	121	141
acid washed	50	55	57	70	110	127
300 ppb						
unwashed	300	300	309	335	402	435
water washed	300	300	306	334	370	401
acid washed	300	302	309	322	354	367

Appendix 2B

Copper Tubing Interference of Phosphorus Analyses: An Improved Porous Ceramic Cup Tension Lysimeter Using Polyethylene Tubing

Appendix 2B

Copper Tubing Interference of Phosphorus Analyses: An Improved Porous Ceramic Cup Tension Lysimeter Using Polyethylene Tubing

Foreward

Virtually all tension lysimeters in use today utilize copper tubing for the removal of groundwater samples collected by this device. However, the copper tubing to be used in our lysimeters was found to interfere with our phosphorus determinations. Because of this recent discovery, fabrication of our major groundwater sampling devices, ceramic cup tension lysimeters, has halted. If we are to proceed with our groundwater nutrient monitoring project, an alternative type of tubing must be used. We currently have sufficient quantities of polyethylene tubing in stock to use instead of the proposed copper tubing. But there exists some evidence in relevant literature that polyethylene should not be used in conjunction with phosphorus analyses, because it may extract the phosphorus out of solution, leading to inaccurate concentration measurements. Consequently, I have tested the polyethylene tubing to find out what influence it has on phosphorus concentrations. This report will present my experimental findings that polyethylene tubing does not significantly remove phosphorus from water samples drawn through the tubing. It also recommends the use of polyethylene tubing instead of copper tubing in our tension lysimeters.

Summary

To assess the feasibility of using polyethylene instead of copper

tubing for removing water samples from tension lysimeters, an experiment was conducted to determine the extent to which phosphorus is extracted from solution by polyethylene tubing. Phosphorus solutions of a known concentration were drawn through polyethylene tubing and the collected samples were analyzed for their phosphorus contents.

The following results, conclusions, and recommendation were derived from this test:

Results: In a solution of phosphorus content, no significant difference was found after it was drawn through a polyethylene tube than from before it was drawn through.

Conclusions:

1. Polyethylene tubing does not interfere with concentration measurements due to the extraction of phosphorus from water samples.
2. Polyethylene tubing is preferable to copper tubing for use in tension lysimeters when phosphorus measurements will be conducted from the collected samples.

Recommendation: Construct ceramic cup tension lysimeters that will be used for nutrient analysis with the polyethylene tubing that exists in stock instead of the copper tubing as previously planned.

Methods

Tubing Preparations

1. Unwashed: None
2. Deionized water-washed (minimal cleaning procedure): Draw 500

ml deionized water through tubing.

3. Dilute acid-washed (standard cleaning procedure to remove adsorbed ions): draw 300 ml 10% H_2SO_4 through tubing followed by 5 ml deionized water.

Table 6

SAMPLE TIMES

Sample #	1		2		3		4
Volume (ml.)	25	75	25	175	25	175	25
Cumulative Volume (ml.)	0 25		100 125		300 325		500 525

Results and Discussion

The knowledge that the copper tubing we now have on hand interferes with phosphorus analysis has halted the construction of our major groundwater sampling devices, ceramic cup tension lysimeters. This specific copper tubing has been used previously in the same type of sampling instrument, so it is unknown as to whether the contamination is due to phosphorus adsorbed directly to the inside of the tubing, to corrosion in the tubing, or to positive interference of the analytical method used by the copper itself. Of most importance, however, is to find an alternative type of tubing that can be used without interfering with our nutrient determinations. This has been done as rapidly as possible to avoid any further delay in the construction of lysimeters.

We now have in stock ample amounts of polyethlene tubing which could be used in place of the copper tubing. However, it has been suggested in the literature that polyethylene could extract large amounts of phosphorus from solution, leading to an underestimation of the phosphorus concentration present. This is most commonly noted with regard to storing samples in polyethlene bottles since the phosphorus adsorbs to the bottles's walls when they are in contact for long periods of time (APHA, *Standard Methods*, 14th ed.). Yet, because the water samples are in contact with the tubing only the short time each sample is being removed from the lysimeter, the affect of adsorption onto the polyethylene is not expected to be as great as when storing samples in plastic bottles. This was found to be the case through the following experimental procedure.

A solution of orthophosphate (40 ppb PO_4-P) held in a 10 liter glass container was drawn through each of six equal leng s (1 meter) of new polyethylene tubing (3/16 inch O.D.) with a hand-operated vacuum pump. Each tube was prepared by one of three washing procedures (unwashed, deionized water-washed, and dilute acid-washed), in case the polyethylene tubing contained phosphorus from the manufacturing process. Each procedure was done in duplicate to detect any variation within the experimental method that may be present. Deionized water was drawn through two additional lengths of unwashed tubing to serve as a control. Also one sample was taken before and one after directly from the large container to see if the concentration within this container, and thus the initail concentration of each sample, changed with time.

Four 25 ml samples were taken from each tube after specific volumes had already been drawn through. These volumes ranged from the initial 25 ml to 25 ml after 500 ml had already been pumped through the tubing. This range corresponds to the approximate size of a sample actually collected in the field by a tension lysimeter. The samples were analyzed for phosphate concentrations with a Technicon Autoanalyzer II utilizing the ascorbic acid method following *Standard Methods*.

Methods

The results of the analysis are given in Table 7 as phosphate concentrations in parts per billion. Means, standard deviations, and relative standared deviations are also given. The following observations can be made frcm this data:

1. All measurements were statistically consistant over volume of sample drawn, within the error of the analytical machinery used.
   a. The relative standard deviation of the ascorbic acid analytic procedure is 4.0 - 5.2% (ALPHA, *Standard Methods*, 14th ed.).
   b. All relative standard deviations are within this procedural range (except for the control).
   c. The small mean of the control makes the large relative standard deviation meaningless in this case. That is, it does not indicate a large variation in this data.
2. No significant difference is seen between the various washing procedures, or between the various washing procedures and the entire sample set.

3. The concentration within the glass container has not changed over time significantly.
4. Duplicate data points are within the expected deviation range.

From these results it can be concluded that phosphorus determinations will not be notably affected by using polyethylene tubing to extract samples from the lysimeters. Polyethylene tubing is thus a preferable alternative to copper tubing in groundwater sampling devices used for nutrient assessment. Consequently, we shold reinitiate lysimeter fabrication, substituting the polyethylene tubing we have in stock for the copper tubing originally proposed.

Table 7

RESULTS (ppb PO_4-P)

TUBE	SAMPLE 1	2	3	4	MEAN	STD. DEV.	REL. STD. DEV. (%)
Control							
A	0	4	3	0	1.62	1.60	99
B	2	0	1	3			
Unwashed							
C	40	41	39	40	40.75	1.28	3.1
D	42	41	40	43			
Water-Washed							
E	41	42	41	40	40.12	1.64	4.1
F	42	39	38	38			
Acid-Washed							
G	40	39	39	42	41.12	1.55	3.8
H	42	42	43	42			
Total (unwashed, water-washed, and acid-washed)					40.67	1.49	3.7
Glass container: before - 39			after - 42		40.5	2.12	5.2

Appendix 2C

Phosphorus Analyses Interfered with by High Dissolved Copper (II) Ion Concentrations

Appendix 2C

Phosphorus Analyses Interfered with by High Dissolved Copper (II) Ion Concentrations

Foreward

The copper tubing in our tension lysimeters has been recently replaced with polyethylene tubing, because the copper tubing that was originially to be used was found to interfere positively with our phosphorus determinations. The reason why copper leads to higher phosphorus results than are actually present, and the true cause of the interference, are not precisely known. Nevertheless, because of the widespread use of copper tubing in lysimeters for groundwater sampling and nutrient analyses, it is important to find the exact source of contamination. I have postulated that a possible source of the exaggerated results comes from copper ions that have desorbed from the copper surface into the sample solution, which, when tested, absorb light at the wavelength for phosphorus determinations (880 nm), interfering with the analytic method. To test this hypothesis, I have analyzed solutions of copper (II) ions (Cu^{2+}) by standard phosphorus-determining analytic methods. This report will present my experimental findings that copper (II) ions at high concentrations increase phosphorus analytic results. Further study to find the extent that Cu^{2+} desorbs from the copper tubing into solution, and to examine other possible contamination sources are recommended.

Summary

The positive interference from copper tubing in phosphorus

determinations by automated spectrophotometric methods has been hypothesized to be due to copper (II) ions desorbed from the tubing surface. Mixtures of known phosphate and Cu^{2+} concentrations were measured for phosphate present. Copper (II) was found to increase the phosphate results, in accordance with Beer's Law, over the amounts that were actually present. High concentrations of Cu^{2+} are concluded to interfere with this analytic method. However, it has not been shown that the theoretical methods for the formation and desorption of Cu^{2+} from the surface of the tubing can actually account for a large enough copper (II) ion concentration in solution to explain the interference seen. Further study should be undertaken to determine the extent to which Cu^{2+} desorbs into solution, and to investigate possible other contamination sources.

Introduction

Virtually all tension lysimeters in use today utilize copper tubing for the removal of groundwater samples collected by this device in preparation of nutrient analyses. However, the copper tubing we were to use was found to lead to higher than normal phosphorus measurements when analyses were made by the automated ascorbic acid reduction method in accordance with *Standard Methods*. As a result, we tested polyethylene tubing and now use it as a viable alternative to copper tubing. Yet the problem of contamination from copper tubing may not be universal. It may be present only in old tubing, or perhaps, only in ours. Nevertheless, because of the common use of copper in lysimeters, and because few lysimeter-users realize this potential source of error in phosphorus determinations, it is necessary to find the source of contamination contained in the copper tubing.

The object of this study is to find out if the positive interference could be caused by copper (II) ions dissolved in solution, assuming that a mechanism exists for Cu^{2+} to be formed at the surface and transported into solution. This report will briefly explain the basis and theory behind Cu^{2+} being the expected source of interference. It will then present the experimental procedure, results, and conclusions, followed by recommendations for further study.

Background

The problem of copper tubing leading to higher phosphorus measurements than actually present became apparent during a previous qualitative study to determine if copper removed phosphorus out of solution by adsorption. The test became qualitative when the contamination drove the resulting measurements above the range of the analytic equipment (autoanalyzer). This led to a search for suitable alternative materials for removing samples from lysimeters. Polyethylene tubing was found to be a satisfactory substitute and replaced the copper tubing.

The contamination was unexpected since both the Environmental Protection Agency and the American Public Health Association Standard Methods, as well as a representative from Technicon Instruments Corporation, indicated that there should be no interference due to the copper. However, they refer to low concentrations of copper -- less than 10 ppm (APHA). Such low concentrations are found in most natural waters. But where water samples come in direct contact with copper, as in the lysimeter, much higher Cu^{2+} concentrations can be anticipated to be dissolved in solution.

For Cu^{2+} to positively interfere with the phosphorus measurements, it must absorb light at the wavelength used for phosphorus determinations (880 nm), since the concentrations are measured by spectrophotometric methods. The copper (II) ion is blue and will absorb light at some wavelengths in accordance to Beer's Law. The extent to which it absorbed light at 880 nm was unknown, but was expected to be small since Cu^{2+} was not supposed to interfere significantly with the method.

Metalic copper (Cu) is essentially insoluble in water and must be oxidized before it can be dissolved in water. This is done in the presence of oxygen by the thermodynamically favorable reactions (CRC):

Copper(I): $2Cu + \frac{1}{2}O_2 = Cu_2O$ H = -40.5 kcal/g-mole

Copper(II): $Cu + \frac{1}{2}O_2 = CuO$ H = -37.7 kcal/g-mole

Cu_2O and CuO are also mostly insoluble, but may, by various complicated corrosion reactions, be converted into soluble species. One important end-product, $CuSO_4$, is the predominant species in the green patina commonly found on old copper (Leidheiser). $CuSO_4$ has been used in this study as the source of copper (II) ions.

Experimental Methods

Mixtures of varying concentrations of orthophosphate and copper (II) were mixed together and analyzed for phosphate concentrations with a Technicon Autoanalyzer II (Technicon Instrument Corp., Tarrytown, N.Y.), utilizing the ascorbic acid reduction method following *Standard*

Methods. Three concentrations of phosphate were used in combination with sixteen concentrations of copper (II). Each combination was prepared in triplicate to detect variations within the experimental method. All glassware for solutions was prepared by washing it with 10% H_2SO_4 and rinsed four times with deionized water to remove all contaminating residual ions.

Results and Conclusions

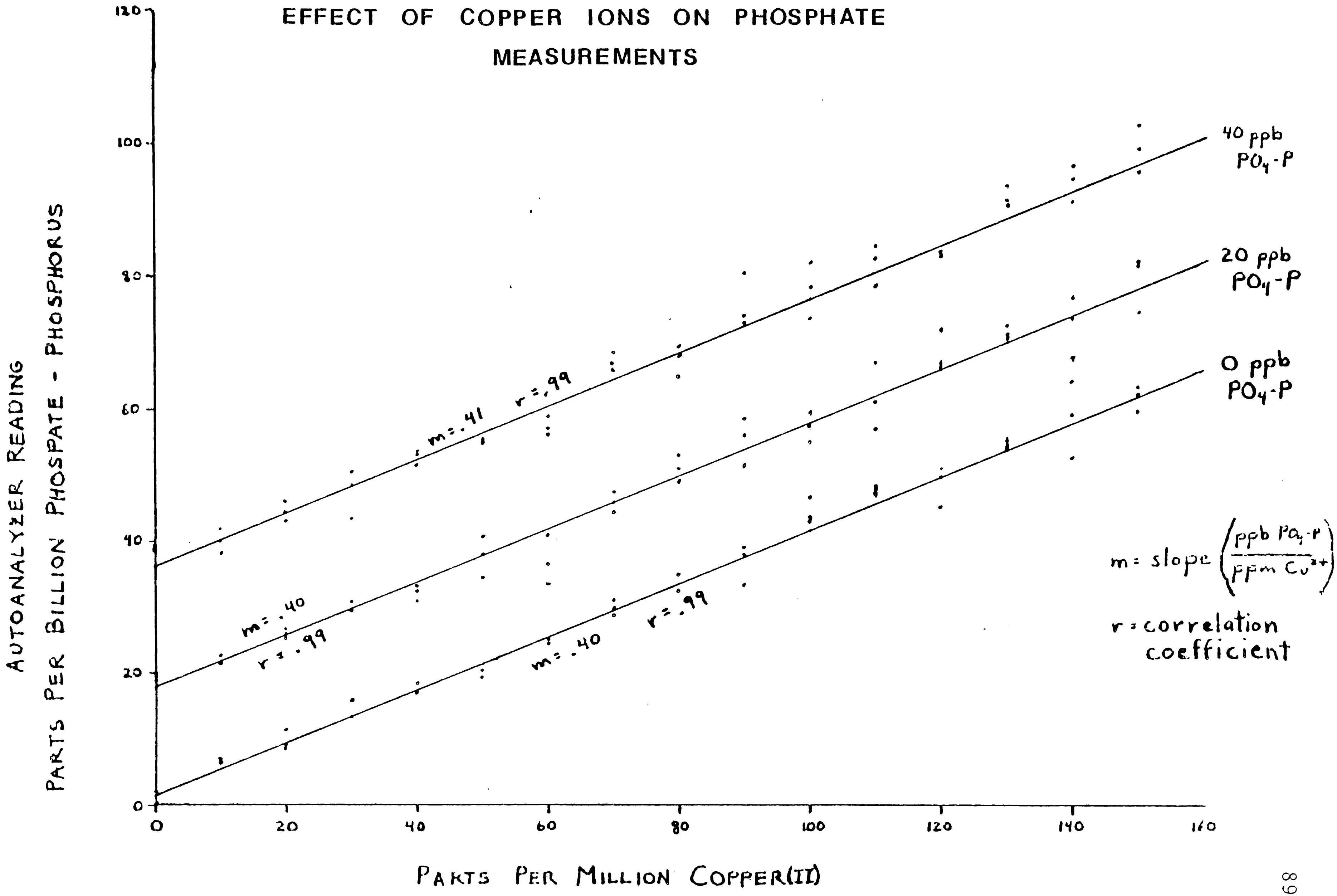
The results of the analyses are given in Figure 7 as parts per billion phosphate phosphorus measured along the ordinate. Each regression line represents a fixed concentration of phosphate with varying concentrations of copper (II) in parts per million along the abscissa. The following observations are derivable from the regression lines on the graph:

1. The phosphate measurements are all increasing with increasing copper (II) ion concentration, with the actual phosphate concentration held constant.
2. The copper (II) ion concentration-phosphate measurement curves are all statistically linear with a correlation coefficient, r=.99 for each phosphate concentration.
3. The slopes of the lines are approximately the same (m=.40, m=.40, and m=.41).
4. The copper (II) ion concentrations that are needed to increase the phosphate reading in the range of parts per billion are very large (parts per million range).

From these observations copper (II) are concluded to absorb light

Figure 7

EFFECT OF COPPER IONS ON PHOSPHATE MEASUREMENTS



at the wavelength used in this phosphate analytical procedure (880 nm), and could, at high enough concentrations, interfere positively with phosphorus analyses. The first three observations are as expected from the assumption that copper (II) ions absorb light at a wavelength of 880 nm according to Beer's Law. However, these results only indicate that copper (II) ions can interfere with the phosphorus analytic procedure, and not that concentrations will ever reach these levels from contact with copper tubing. Consequently, the fourth observation necessitates the substantiation that enough Cu^{2+} can desorb from the tubing to cause the increased phosphate readings found with the copper tubing.

Beer's Law theorizes that the linear relation shown by these results can be extended down to a Cu^{2+} concentration of zero. Thus even the slightest amount of copper (II) ions present will add to the phosphate reading, yet the effect at low concentrations will be undetectable due to experimental variability and the limits of experimental precision.

Recommendations for Further Study

Copper tubing used in lysimeters leads to exaggerated phosphorus concentrations in samples taken from those lysimeters. Because of the prevalent use of copper tubing for lysimeters, it is important to find the source of contamination in the tubing. Experimental evidence in this report has shown that if copper (II) ions are present in large enough concentrations, a higher phosphate concentration is detected than is actually present. Theoretical information has been presented on how the Cu^{2+} could have gotten into solution. It has not been shown, however, that the theoretical mechanisms are sufficient to produce enough ions to cause the increases shown in the laboratory test. Furthermore, other possible sources of contamination have not been thoroughly examined. These include:

1. Adsorbed phosphate or other forms of phosphorus themselves.
2. Other light-absorbing molecules that could adhere to the copper and then be removed when water is drawn through the tubing.

In order to definitively identify the source of contamination form the copper tubing and to evaluate the future use of copper tubing in tension lysimeters, the following questions should be addressed:

1. How much Cu^{2+} does the copper tubing actually desorb into solution? Does this amount correspond to a detectable level as shown in this report?
2. What other contaminants inside the copper tubing could lead to the high phosphate readings? Do feasible mechanisms exist for these contaminants to reach levels in solution great enough to cause positive interference?
3. How does new copper tubing affect phosphate analyses?

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Appendix 3

Selected Examples of Environment Communications

Inland Lakes Expo Spreads Environmental Knowledge

By REG SHARKEY

What are the strategies that Lake Associations can use in protecting their lakes? What are the benefits of the Clean Water Plan? What are the latest techniques for lake management?

These and other environmentally related questions were answered and discussed by a panel of experts at the Inland Lakes Expo '78, held at the U of M Biological Station, Douglas Lake, on Aug. 15. The session was the latest in a series covering Project CLEAR Research Findings that have been offered to county and township officials, lake association directors and lakeside property owners, to help them cope with problems brought about by rapid growth of Northern Michigan.

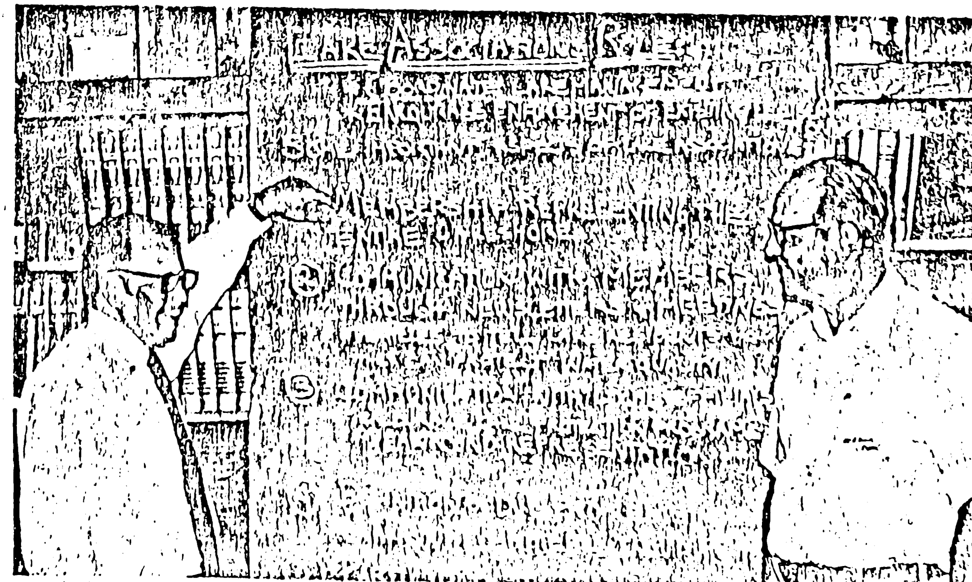
Dr. David Gates, director of the Biological Station, gave an introductory welcome to the 160 participants and gave a brief history of the station. He stated that the work of the station has gained worldwide recognition, and many of the findings and methods used have been adopted.

Arthur Gold, research assistant at the Station, gave a slide-lecture presentation on what happens to lakes as they age; how human populations and development accelerates the process called eutrophication, and how important buffer zones are, and what they accomplish.

Save Ground Water

Donald Winne, president of the Michigan Lakes & Streams Association (a conglomerate of individual lake associations) talked about the functions of his organization in helping to protect the inland water areas of Michigan. He said: "Man has destroyed much of the quality of surface water. Now we must act to save the quality of our ground water."

Fred Bailey and Tom Weaver, of the Northwest Michigan Regional & Development Commission, gave a dual presentation on how plans are implemented to type the different conditions affecting water quality, and how to implement self-help among the different lake associations. It included accomplishing a monitoring system, as well as organizing townships and counties to handle wetland protection and water quality problems. They said a full-time graduate student works for their organization on a six months basis testing water samples sent to their laboratory at Bellaire. Weaver stated that a good project for high school biological students would be the taking and testing of water samples for their particular area.



WARREN PARKER (left), executive director of Walloon Lake Association, and Gordon Cook, of the Seven Lakes Association (Torch Lake), were featured speakers at the lake association effectiveness workshop. (NEWS photo by Reg Sharkey)

Project CLEAR Offers Hope for Our Waters

On My Mind--

By Jan Morley

All of us in Northern Michigan owe Project CLEAR a vote of thanks.

Most of you have probably heard of the University of Michigan program, which stands for Community Lake Environment Awareness and Research. Some of you may have attended Tuesday's EXPO '78 – an environmental conference sponsored by CLEAR students and "Clean Water Planners" from the Northeast and Northwest Michigan Councils of Government. But you might not know how diligently CLEAR students have worked this summer to help all of us help ourselves in preserving and protecting the lakes and streams of the North.

To begin with, the CLEAR research team has been taking ground water samples from a number of homes around Burt Lake which use on-site septic systems. The purpose of their efforts is to find a way to see whether a septic system is doing its job of keeping polluting nutrients out of the lake. The researchers also want to be able to predict how septic systems work in different types of soil, with different use patterns and at different ages.

Members of the CLEAR communications staff have worked with residents of Burt Lake to begin a water quality monitoring and septic system maintenance program. I heard Plymouth Beach resident Don Smith tell about the group septic system maintenance program, and if the other residents of the Plymouth Beach Association are half as enthusiastic as Don, you can be sure they'll be doing their part to keep Burt Lake clean for a long time to come.

CLEAR students have been familiar faces at lake association meetings throughout the area. They've scheduled workshops and presentations describing lake protection strategies for Burt, Crooked-Pickerel, Douglas and Walloon Lakes.

They have given a presentation on the value of wetlands in Emmet County to the Emmet County Commission, and they've met with the Cheboygan County Wetlands Task Force to discuss and suggest wetlands protection strategies. They've given a presentation on how to start a greenbelt at the County Extension offices.

In the past couple of years, they've written numerous pamphlets and reports on profiles of area lakes, the importance of protecting wetlands, on wastewater treatment alternatives, septic system maintenance and other topics.

The people from Project CLEAR have garnered a wealth of information for us to use – to keep our lakes clean, to protect our wetlands, to plan wisely for future growth and development. It's there for the asking. We'd do ourselves and our environment a favor by paying attention to what they have to say. For pamphlets or answers your environmental questions, write to Project CLEAR, University of Michigan Biological Station, Pellston, 49769, or call 616-539-8406.

PETOSKEY NEWS-REVIEW Thursday, August 17, 1978-8

Editorial

Must Plan Now to Meet Challenges

As you will note, much of today's editorial page is devoted to environmental problems – many of them due to continual growth of the area.

You'll also find, on page 11, several other stories pointing out efforts people are making to preserve resources that have helped make this a popular place to live and visit.

The News-Review for years has advocated long-range planning and hard questioning on developments to make sure they are in the best interests. We have been covering many facets of this struggle and the work of planners, zoning boards, appeals boards, waste water treatment, solid waste problems, air and water pollution, energy, jobs, homes, business, highways, parking, school needs and the many other ramifications.

Today we look at some of the efforts volunteers and public agencies are doing here in preserving resources and meeting people problems. Whether we, or you, like it or not, more and more people want to live here. We are told this will increase in the next decades. We'd better prepare for it and this takes advance planning, firm policies, restrictions and enforcement. To do less will see people problems destroy the north as we know it and why so many of us love it.

EDITORIALS APPEARED ON SAME PAGE AS "WHO CARES ABOUT WETLANDS

DR. JOHN GANNON (right), limnologist from the State University of New York discusses water quality problems with C.E. Trout, secretary of the Higgins Lake Property Owners Association, and his wife, Becky. (NEWS photo by Reg Sharkey)

(CONTINUED FROM "INLAND LAKES EXPO SPREADS ENVIRON. KNOWLEDGE.")

the original Earth Day some years ago, and said the most important thing to remember today is: "Don't expect someone else to do the monitoring of our environment. Do it yourself!" He went on to say that lake associations should work closely with township and county governments for, after all, "we are all on the outside fringes of the political groups."

After a lunch break, participants were given choices of three sets of workshops, set up at one hour intervals, so each individual could attend as many sessions as possible. Sessions covered included: greenbelts, water quality monitoring, wetlands protection, wetland field trips, lake association effectiveness, alternate wastewater treatment, zoning and Project CLEAR Findings.

There were displays covering algae control, swimmer's itch and water quality analysis.

A significant thing to come out of the work that has been going on at the U of M Biological Station is a resource directory. According to Dr. Gannon, it is the "bible" by which lake associations, lake shore property owners and government officials can find out who, what and where to go for help. The Resource Directory is available at the biological station and will reduce confusion generated by the different environmental agencies.

PETOSKEY NEWS-REVIEW
AUGUST 18, 1978
THURSDAY

[illegible] FOR THE INLAND LAKES EXPO '7[illegible]

MORNING SESSION

9:30 REGISTRATION, COFFEE, ETC., IN THE DINING HALL

10:00 INTRODUCTORY REMARKS, IN THE CLUBHOUSE

10:30 A LAKE MANAGEMENT OVERVIEW, IN THE CLUBHOUSE

- Inland Lake Protection Strategies, Arthur Gold, U-M Biological Station
- The Role of Lake Associations in Protecting Their Lakes, Donald Winne, Michigan Lakes and Streams Association
- The Benefits of the Clean Water Plans for Lake Associations, Tom Weaver, Northwest Michigan Regional Planning and Development Commission
- Innovative Techniques for Lake Management, John Gannon, State University of New York at Oswego

12:00 LUNCH

AFTERNOON SESSION

During the second half of the day, you can choose among workshops, displays, or informal discussion in the dining hall. Eight or nine workshops will be proceeding simultaneously. The times, places and content of these workshops is described below. Displays will be in the dining room and lake-side lab, and coffee will be available in the dining room throughout the day.

1:30 FIRST SET OF WORKSHOPS

Greenbelts	Alternative Waste Water Treatment
Water Quality Monitoring	Septic System Maintenance
Wetlands Protection	Zoning
Wetlands Field Trip	Project CLEAR Research Findings
Lake Association Effectiveness	

2:30 SECOND SET OF WORKSHOPS

Greenbelts	Alternative Waste Water Treatment
Water Quality Monitoring	Septic System Maintenance
Wetlands Protection	Monitoring Septic System Performance
Lake Association Effectiveness	Zoning

3:30 THIRD SET OF WORKSHOPS

Greenbelts	
Water Quality Monitoring	Alternative Waste Water Treatment
Wetlands Protection	Septic System Maintenance
Wetlands Field Trip	Monitoring Septic System Performance
Lake Association Effectiveness	

DISPLAYS - ALL AFTERNOON, STARTING EVERY HALF HOUR

An Algae Display
Swimmer's Itch
Water Quality Analysis

[illegible] AND LOCATION OF EACH WORKSHOP AND DISPLAY

[illegible] QUALITY MONITORING - LAKE SIDE LAB, RM. 3021
[illegible] by Mark Hummel and Art Gold from CLEAR, this workshop will include a slide-show on starting water quality monitoring programs, and demonstrations of water sampling methods that could be used by anyone.

GREENBELTS - LAKESIDE LAB, ROOM 3017
Sharon Mills from CLEAR will explain what greenbelts are and why they are important on inland lakes. She will show a slide-show that covers how to begin a greenbelt on your property.

WETLANDS PROTECTION WORKSHOP - LAKESIDE LAB, ROOM 3076
Bob Wagner, a regional planner from the Northeast Michigan Council of Governments (NEMCOG), will show slides and discuss the importance and protection of wetlands.

WETLANDS FIELD TRIP - MEET IN FRONT OF THE LIBRARY
Bob Koch from NEMCOG will lead a field trip to one of the local wetland areas. Those who attend this workshop should be prepared to get their feet wet! Bob will cover topics like identifying wetlands, what their significance is in protecting lake water quality, and some natural history of wetlands.

ZONING - LAKE SIDE LAB, THE SEMINAR ROOM
The basics of zoning, who, why, and how, will be explained by Moira Croghan from CLEAR. Lou Stembrecher from NEMCOG will discuss how particular community goals can be converted into zoning ordinances, covering topics like funnel development and environmental zoning. Don Babcock, township supervisor of Burt Township, will describe the process Burt went through to enact a wetlands zoning ordinance, and will relate how the ordinance is working now.

SEPTIC SYSTEM MAINTENANCE - GATES LAB
This workshop, led by Sam Ehlers from CLEAR, will cover how septic systems work, their care and maintenance, and starting group septic system maintenance programs. Don Smith, from Plymouth Beach Association on Burt Lake, will explain the approach Plymouth Beach used in starting a group septic system maintenance program.

ALTERNATIVE WASTE WATER TREATMENT - CRYPTOGAMIC LAB
Michael Tilchin from CLEAR will show a slide show on innovative techniques for waste water disposal: mound systems, aerobic tanks, several waterless toilets, and others. People who attend this workshop will see the Clivus Multrum (a waterless toilet) and the cluster septic system in use at the Biological Station. Federal funding for waste water treatment will also be discussed in this workshop.

LAKE ASSOCIATION EFFECTIVENESS - THE LIBRARY
This workshop will focus on the strategies lake associations use to accomplish their work, and how they can be modified to increase their effectiveness. Marion Secrest from CLEAR will lead this workshop and discussion. Gordon Cook from the Seven Lakes Association and Warren Parker from Walloon Lake will describe how their lake associations have dealt with particular lake management problems.

PROJECT CLEAR RESEARCH FINDINGS - THE CLUBHOUSE
In a special session designed for Burt Lake residents, Joan Schumaker, Kevin Hughes and Mark Torf from CLEAR will describe the summer '78 research findings. People who do not live on Burt Lake and want to find out about CLEAR's research [illegible] should attend the 2:30 and 3:30 sessions on Septic System Monitoring Techniques.

SEPTIC SYSTEM MONITORING TECHNIQUES - THE CLUBHOUSE
Joan Schumaker, Kevin Hughes and Mark Torf will describe a number of different techniques for assessing how well a septic system is working. They will show each method, discuss its advantages and disadvantages, and describe the techniques used in CLEAR's research this summer.

DISPLAYS

WATER ANALYSIS DISPLAY - LAKE SIDE LAB, ROOM 1055
This demonstration, done by Brian Marshall - water chemist of CLEAR, will begin every half hour between 1:30 and 3:30. Ten to twelve people at a time can give Brian water samples and see how to test them for some basic indicators of water quality.

SWIMMER'S ITCH - LAKE SIDE LAB, ROOM 1047
Chris Wood will be available to explain what causes swimmer's itch, how it occurs in lakes, and some steps you can take to prevent or control swimmer's itch.

ALGAE AND ZOOPLANKTON - LAKESIDE LAB, IN THE BOATWELL
Linda Greer and Jean Cairns will display algae and zooplankton collected from local lake water. Using microscopes you will be able to see the animals and plants that typically live in lake water. A session starts every half hour between 1:30 and 3:30.

** The EXPO has been sponsored by the Clean Water Planners of northeast and northwest Michigan, and Project CLEAR from the University of Michigan Biological Station. [illegible]s wor[illegible] been [illegible] by [illegible] National [illegible]ence [illegible]ation [illegible] the [illegible] Foundation of [illegible].

Project CLEAR

Building upon the accomplishments of previous research programs at the University of Michigan Biological Station, Project CLEAR 1978 will research and promote public awareness of three inland lake protection tools: effective on-site wastewater treatment, wetlands protection, and greenbelting. Primarily a student effort, the Project is funded through the National Science and the Kennedy Foundations.

Research

- Testing and comparing newly designed and existing ground water sampling techniques
- Sampling and analyzing groundwater near on-site septic systems around Burt Lake
- Assessing the relationship between ground water nutrient flow intc Burt Lake and characteristics of shoreline home sites (soil, vegetation, slope, and age of the septic system)

Publications

- A manual on ground water sampling/septic system monitoring techniques for sanitarians, septic system installers, and community leaders
- Information packages for lakeshore residents on septic systems, wetlands, water quality monitoring, and greenbelts (Greenbelts are protective buffers of vegetation that encircle the shoreline of inland lakes.)
- Several short booklets on particular lakes that include biological information, natural history, and water resource attitudes of lake residents.
- A final report to the National Science Foundation

Workshops and Presentations

- Slide-shows on lake ecology and inland-lake protection strategies
- Presentations and discussions with township and county planners about wetlands protection and model zoning ordinances (held in conjunction with local lake associations)
- Workshops and meetings with local sanitarians about our research project, septic system monitoring, and alternative on-site wastewater treatment methods
- Workshops for the residents of study sites on Burt Lake
- A workshop for lake association officials from the region about what they can do to facilitate lake protection

Environmental Education

- Radio spots and newspaper articles explaining what residents can do to reduce their impact on lake-water quality
- Short television broadcasts on environmental topics of interest to lake residents

University of Michigan Biological Station, Pellston MI 49769, 616/539-8406

Appendix 4

Monitoring Techniques for On-Site Wastewater Treatment Systems

Appendix 4

MONITORING TECHNIQUES FOR ON-SITE WASTEWATER TREATMENT SYSTEMS

Summary

On Monday, August 14, a conference on Monitoring Techniques for On-site Wastewater Treatment Systems was held at the University of Michigan Biological Station. The purpose of the conference was to explore methods for evaluating septic system performance and to define the role of septic system monitoring in the wastewater management planning process. The following agencies were represented at the Conference:

District Health Department #1 - Lake City, Michigan
District Health Department #2 - Oscoda, Michigan
District Health Department #3 - Charlevoix; Petoskey, Michigan
District Health Department #4 - Alpena; Cheboygan; Rogers City, Michigan

Tri-County Health Department - Beulah, Michigan
Michigan Department of Public Health - Lansing, Michigan
Michigan Department of Natural Resources - Lansing, Michigan
Environmental Photo Interpretation Center/EPA - Warrenton, VA
Northeast Michigan Council of Governments - Gaylord, MI
Northwest Michigan Regional Planning And Development Commission - Traverse City, Michigan
State University of New York - Oswego, New York
University of Michigan Biological Station - Pellston, MI
Huron River Watershed Council - Ann Arbor, Michigan

The monitoring methods and the pertinent points of the discussion are summarized here. Information is organized under the following topics:

*On-site Monitoring Methods
*Role of Septic System Monitoring in 201 Facilities Plans
*Septic System Monitoring at the Local Level

*On-site Monitoring Methods

Community Septic System Survey

The results of a community septic system survey conducted in Bolinas, California were presented by Project CLEAR, UMBS.

The Bolinas survey was undertaken as a cooperative effort by the residents of Bolinas and the Bolinas County Public Utilities District under the direction of a watershed consulting firm.

An eight person Septic System Survey team visited 370 homes, identified failing and problem systems, investigated water use patterns, and gathered information on the age, design, location, and history of repair on the septic system. A Soils and Drainage team investigated and mapped the environmental features of Bolinas that influence septic system performance. When a faulty system was identified, the cause of the problem was determined and corrective measures were taken. Ninety-eight percent of the residents cooperated in the survey, and 69 of 74 problem systems were fixed. Three fourths of those systems required only simple maintenance or minor repair. Costs for ten year maintenance and up grading of on-site systems were projected from survey data.

The great success of the Bolinas study was attributed to the emphasis placed on community education and involvement throughout the survey.

Aerial Photography

Conferees were treated to the premier showing of aerial photo imagery from pilot studies of septic system monitoring through remote sensing. Barry Evans of the Environmental Photo Interpretation Center (EPIC) of EPA stated that the aerial infra-red and color imagery from the initial flights had proven to be an extremely accurate and efficient method for detecting drainfields with drainage problems. In areas of heavy tree cover or where onsite treatment problems were caused by excessive percolation rates the use of aerial photos was somewhat limited.

Aerial photo monitoring of septic systems has been slated for use in the Environmental Impact Assessment process under way on Crooked-Pickerel, Crystal, and five other lakes within EPA Region V where wastewater management plans are being developed. Mr. Evans indicated that the EPA might be willing to coordinate flights and photo interpretation efforts in other areas of northern Michigan. Questions concerning the use of aerial photography for septic system monitoring may be addressed to:

Mr. Barry Evans
EPIC/EPA
Vint Hill Dr.
Warrenton, Virginia 22186

Dye Tests

The use of fluorescent dye tracers as a method for detecting failing septic systems was reviewed by Project CLEAR. Physical and chemical properties of the common dyes were discussed. Rhodamine W.T. (A du Pont trade name. The same dye is available through other companies under other names) was recommended for septic system monitoring because of its low adsorption potential in soils and its resistance to photochemical decay. Fluorometers could be used with the dyes to provide much greater sensitivity in dye detection. Groundwater studies using fluorescent dyes could be used to determine the rate and direction of groundwater movement around the septic field. Information on dyes and the use of fluorometers can be addressed to:

Turner Associates
2524 Pulgas Avenue
Palo Alto, California 94302

or

E.I. du Pont de Nemours & Company
Dyes and Chemicals Division
Wilmington, Delaware 19898

Algal Survey

Tom Weaver of the Northwest Regional Planning and Development Commission (NWRPDC) presented preliminary findings of a cladophora survey of Lake Leelanau. Cladophora is an easily recognized attached macroscopic algae which flourishes in reponse to excessive nutrient inflows from fertilized lawns or septic systems. A high correlation was found between neglected septic systems and the presence of cladophora (72% of those sites with severe problems had never pumped their septic tank). Cladophora was seldom found where septic systems had been properly maintained or where greenbelts existed between the lawn and the lake. Two surveyors covered 30 miles of the shoreline of Lake Leelanau in two and one half days. A limitation of the Algal Survey is that cladophora will only grow where there is a rocky shoreline.

For further information contact:

Northwest Michigan Regional Planning
and Development Commission
2334 Aero Park Court
Traverse City, Michigan 49684

Groundwater Sampling

A method for collecting groundwater samples in order to detect phosphorus loading from septic systems was described by Project CLEAR. A tension lysimeter using a porous ceramic cup attached to a PVC tube can sustain a vacuum and draw groundwater samples from moist and wet soils. The lysimeter approach to site monitoring was developed as part of a research project conducted at the Biological Station.. Groundwater phosphorus concentrations of greater than 1000ppb-P indicated significant phosphorus contamination.. Portable laboratories from the Hach company provide an immediate and affordable means for sample analysis.

A report on tension lysimeters and the results of Biological Station research will be available this fall. For more information write:

Project CLEAR
University of Michigan
Biological Station
4053 Natural Science
Ann Arbor, MI 48109

*The Role of Septic System Monitoring in 201 Facilities Plans

Dr. Randy Frykberg, Water Quality Director of Northeast Michigan Council of Governments (NEMCOG) outlined recent policy changes in Section 201 of the Clean Water Act. Federal funding is now available for wastewater planning and construction that include up-graded and improved on-site wastewater disposal methods. Arthur Gold, of the University of Michigan Biological Station, agreed that the revised funding policy was an important step in the right direction, but stated that the Environmental Impact Statement (EIS) being prepared on alternative wastewater plans for Crooked-Pickerel Lakes was thus far inadequate. Insufficient data on the status of lakeshore on-site wastewater disposal systems and on the environmental features of the region resulted in unrealistic alternatives that could jepordize wetlands and foster accelerated growth. A concensus was reached on the following points:

Documentation of the source and magnitude of existing on-site problems must be included as part of the 201 facilities planning process.

Septic system surveys, algal surveys, and dye, ground-water, and aerial photo methods discussed at the conference all had merit as part of an overall approach to septic system monitoring.

Preparation of EIS's should include input from local municipalities and sanitation experts at an early stage in the planning process.

*Septic System Monitoring on the Local Level

The point was made that lake associations and other groups interested in assessing on-site wastewater problems may wish to carry out septic system monitoring programs without applying for 201 facilities grants. Septic system surveys and algal surveys could meet this need as they require no special equipment and limited technical assistance to conduct. More detailed investigations would require a significant investment in special equipment and technical direction. The role that Health Departments might assume in such a program was not resolved and will require further discussion. Bob Koch, of NEMCOG, introduced the idea of initiating a "lake technician" program. Working with a large lake or several smaller lakes within a watershed, the lake technician would provide the expertise needed to assist lake residents in water quality protection efforts such as septic system monitoring. The qualifications for a lake technician would include:

- Background in limnology
- Familiarity with on-site wastewater systems
- Interest in working with lakeshore communities and local government agencies

The suggestion was made that the lake technician should receive some type of training from the District Health Department of the area.

Mr. Koch said that NEMCOG will submit a grant proposal to fund such a program in the near future.

Conclusions

Conferees emphasized that continued research and wider application of on-site wastewater monitoring methods are necessary if the wastewater management needs of northern Michigan are to be met. It was agreed that a summary of the conference should be sent to those private interests and state and federal units of government involved in the wastewater management planning process.

For further information on
the conference contact:

Mike Tilchin
The University of Michigan
Biological Station
4053 Natural Science
Ann Arbor, Michigan 48109

Appendix 5

Publications

Project CLEAR. 1978. Environmental Education Pamphlets:

"Septic System Maintenance"

"Water Quality Monitoring"

"Greenbelts"

"Zoning"

University of Michigan
Biological Station
Pellston, MI.

Septic System Maintenance Programs

Maintenance Steps Are Based On The Way A Septic System Operates.

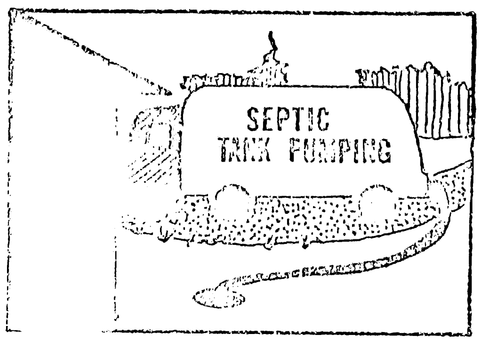
A septic system is a "natural" method of wastewater treatment that relies on an interaction between the biological, chemical and physical processes of micro-organisms, bacteria and the soil.

Wastewater from the home collects in a septic tank where the solids settle. Bacteria that live in the tank decompose the solids, turning them into a thick sludge. The remaining solid-free liquid flows into the drainfield.

In the drainfield the wastewater migrates into the soil towards the groundwater, through the "tile" (perforated pipes). Micro-organisms decompose the organic wastes, and soil particles absorb remaining nutrients before they reach our water resources.

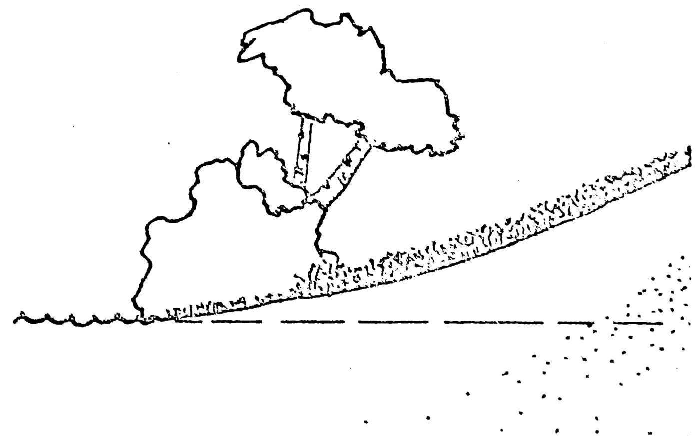
Proper performance from septic systems requires:
- adequate site selection.
- proper construction specifications.
- maintenance of the system.

Information on each of these can be obtained from your county sanitarian.



The Benefits of Maintenance

The benefits of a maintenance program are threefold: one, increased awareness of septic system operation and maintenance; two, more people caring for their septic systems on a regular basis; and three, better water quality and less nutrient pollution of lakes.



Parts of a Septic System

- Promote awareness and participation in the group program by handing out information on septic systems, inviting guest speakers to property owners meetings and soliciting members.
- Inspect and pump septic tanks. If sludge in a tank is not removed when it has reached a high level in the tank, solids in the wastewater won't settle in the tank. Instead, they'll flow directly to the drainfield and clog it, causing serious septic system failures.
- Decide between two different ways to organize pumping and inspection:

Volunteer method: participants in the program each inspect their own tank and pump when needed.

Contract method: the association hires or arranges for a single pumper to inspect and pump.

More information

Public Health Educator
District Health Department No. 3
435 Lake St.
Petoskey, MI 49770
(for Antrim, Charlevoix, Emmet, Otsego counties)

Public Health Educator
District Health Department No. 4
County Office Building
719 Chisholm St.
Alpena, MI
(for Cheboygan, Presque Isle, Montmorency, Alpena counties)

Also at your district health department:
Inland Lake Pollution Problems: Septic Systems and Wastewater Treatment Alternatives (Lakeland Report #14) by the University of Michigan Biological Station

This pamphlet produced through the efforts of Project CLEAR 1978 at the University of Michigan Biological Station, funded by the Elizabeth Kennedy and National Science Foundations.

Septic System Care – Why Bother?

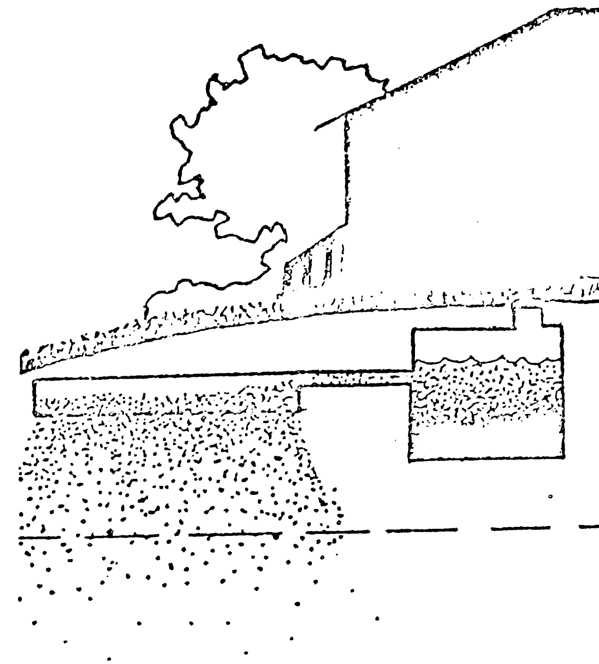
Many homeowners forget about their septic system from the time it is installed until it begins to have problems. Yet with regular septic system maintenance:

- the quality of the lake environment can be preserved. When a septic system is maintained and operates well, untreated wastes are prevented from leaching into the groundwater and directly into the lakes.
- the life of the septic system can be lengthened, saving the homeowner large repair and replacement costs.

Maintenance of septic systems has generally been considered an individual's responsibility, but the lake pollution that results from failing systems affects the community. Group septic system maintenance programs are an effective strategy for limiting pollution from diffuse sources like septic systems. Not only do group maintenance programs increase public awareness about septic system care and operation, but they also provide cost, time and energy saving advantages:

- small failures are corrected through regular septic tank inspection before the homeowner needs costly repairs.
- reduced group pumping rates.
- eligibility for federal grants to improve on-site wastewater treatment.

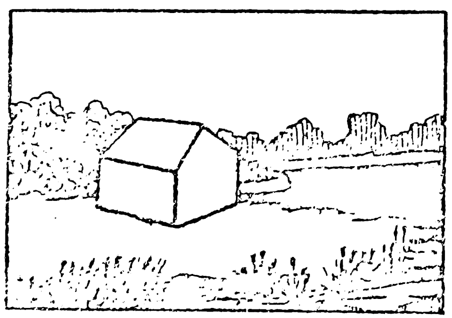
If septic systems are cared for and not abused, they may be our most cost-effective and best engineered on-site treatment facilities.



Maintenance Program

- Contact the county sanitarian for details on maintenance programs and a list of septic tank pumpers in the local area.
- Promote water conservation among program participants. Water conservation helps septic performance because waste treatment is more efficient under drier conditions.
- Map the location of the septic system and drainfield. Mapping the location of the drainfield avoids simple accidents like driving or planting trees over it, and allows easy access to the tank cover which can reduce inspection and pumping costs.
- Increase the success of the program by making it more visible and enjoyable through news coverage and presentations to other property-owners associations.

Water Quality Monitoring



"Should we zone against development of wetlands?"

"Should we dredge an inflowing river to re-open a waterway?"

"What effect will development or dredging have on the water quality?" "How much development can the lake withstand?" "Where are the most sensitive areas on the lakeshore?"

To make effective land use decisions, lakeshore residents need information about their lake.

The Basics . . .

One person can effectively run a simple monitoring program in two hours per week at a cost of $20 to $30 for the first summer, and $20 for each summer thereafter.

This program involves two tests of pollution symptoms, secchi depth and chlorophyll a. The secchi disk is a small black and white disk that is lowered into the water. The depth to which it can be seen is an indication of how clean your lake is. A shallow depth indicates cloudiness, due to growth of algae. Chlorophyll a is a substance found in all green plants. A measure of chlorophyll a in the water is an indication of algae growth, and should correspond to secchi depth.

Write to the DNR Self-Help address on the back of this pamphlet for information and materials to start this program.

A Little Extra

The second level of monitoring includes level one, requires three hours per week, and costs $75 for the first summer and $20 for each following summer.

This program includes sampling the concentration of dissolved oxygen at various depths in the lake three times a year: through the ice in late winter, mid-summer, and after fall overturn.

If the dissolved oxygen at the bottom of the lake is used up, a deep protective layer of material disappears. Nutrients from the bottom then mix with the water, causing growth and accelerated lake aging.

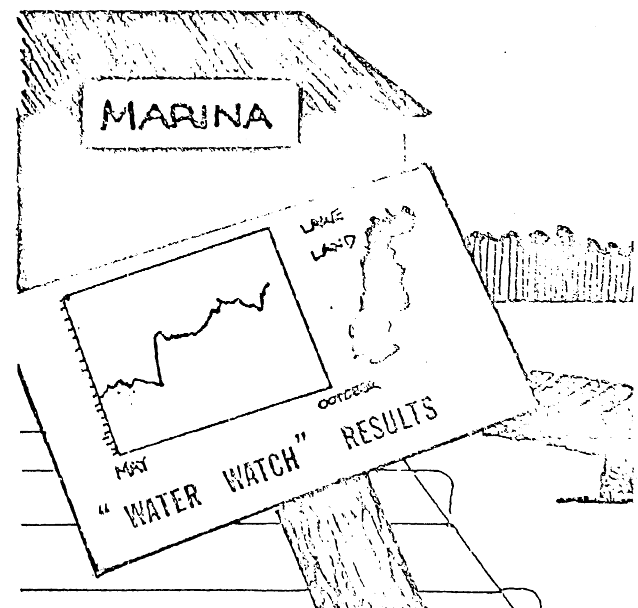
Knowing the concentration of dissolved oxygen in the bottom waters is a good way to predict when a lake is undergoing this accelerated aging.

Student Research

The third level requires approximately five hours per week and a college or university interested in offering a student internship for analyzing water samples.

This program involves collecting water samples three times during the summer, from each inflowing stream, and from the center of the lake. The student intern would analyze samples for nitrogen and phosphorus to identify the streams with the highest levels of nutrients.

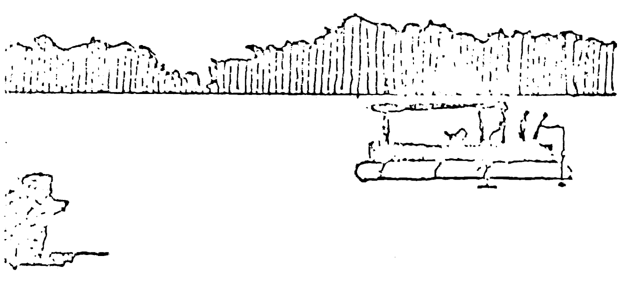
The watershed for each stream can be mapped from United States Geological Service (USGS) maps. Then you know the areas from which nutrients are coming and the areas to work on to keep nutrients out of the lake.



Making Monitoring a Community Effort

Everyone in the community benefits from clean water. The more people who know about the program and hear about its results, the more help you can get in running it, and the more interest you generate in keeping nutrients out of the lake.

- Find out if your lake has a lake association. The association may be interested in beginning a monitoring program.
- Take notes and slides of your efforts to document your results. This information can be used for testifying at public hearings and writing letters to the editor of your local paper.
- Publicize the program and results in the newspaper. Call the editors of your local paper and ask for an interview. Water quality monitoring is interesting, and they will probably be happy to cover it.
- Make posters of your lake that describe the monitoring program briefly. Put these at busy spots in your community and graph the results on them as the monitoring progresses.
- Promote clean-water-consciousness by presenting your results to local groups. Explain how they can all help keep nutrients out of your lake.



Water Quality Monitoring Gets This Needed Information

The biggest threat to clean lakes and streams in northern Michigan is an overload of two nutrients found in septic wastes and fertilizer, nitrogen and phosphorous. They are good fertilizers on land, but work too well in water, where they cause plant and algae growth that can cause your lake to fill in or age prematurely.

Monitoring is a way of keeping track of lake aging, and whether it is steady or accelerated. It can warn you when pollution nears a dramatic impact.

All of the nutrients in your lake come from the surrounding land, or watershed, that drains through rivers and streams into your lake.

To keep nutrients out of the lake, their sources in the watershed must be located and prevented from polluting the rivers, streams and groundwater that drain into the lake. Monitoring can help locate these sources.

By testing before and after the mouth of an inflowing river is dredged, you may be able to document the effect of the dredging. You can then predict the effect of further dredging, which is essential in deciding whether or not to do so again, and helpful in making other land use decisions.

Beginning A Monitoring Program First, Choose a Program

Each of the suggested levels of monitoring can be run alone or in combination. Choose something that you are sure will be done year after year because the real value of monitoring is to document changes, not to record static values from one or two summers.

For more information on each level of monitoring, write or call the Clean Water Planners in your region (addresses listed below). Ask for a list of publicatons that would be helpful in beginning a monitoring program.

Northeastern Michigan Council of Governments
P.O. Box 457
Gaylord, MI 49735
(517) 732-3551

Northwest Michigan Regional Planning
and Development Commission
2334 Aero Park Court
Traverse City, MI 49684
(616) 946-5922

Michigan DNR Self-Help Program
Inland Lakes Management Unit
Stevens T. Mason Bldg.
Lansing, MI 48926

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A Zone of Protection

Lush, fertilized lawns extending to the shore are common in waterfront areas. Unfortunately, homeowners who maintain these lawns inadvertently contribute to the nutrient pollution of their lakes.

Without greenbelts, excess nutrients are more likely to flow into waterways. Nutrients are good fertilizers on land, but work too well in water where they stimulate plant and algae growth that can cause lakes to fill in or "age" prematurely.

Greenbelts are strips of cultivated plants, shrubs, or trees between lawns and the shoreline. Acting as living filters for lakes and streams, greenbelts absorb nutrient pollutants before they can enter the water. By planting greenbelts, shoreline homeowners can limit nutrient inputs from excess fertilization, septic system failures, and soil erosion.

When excessive fertilizer is put on lawns, the nutrients in it percolate into the soil, are not completely used by the grass, move into the groundwater, and thus, flow into the lake. When septic systems fail, waste water is not filtered by the soil, and nutrients migrate into the groundwater, again reaching the lake. In both cases, the roots of the vegetation in a greenbelt would have absorbed nutrients before they entered the lake.

Greenbelts also control shoreline erosion on sloping banks. Their roots keep soil from eroding by minimizing the amount of soil lost to winds, storm water run-off and wave action.

Greenbelts mean more than water quality . . . .

Aside from being an ecologically sound practice and limiting pollution of nearby water, a strip of vegetation along the shore creates an attractive yard and provides food and shelter for wildlife.

FOR FURTHER INFORMATION:

Northwest Michigan Regional Planning
And Development Commission
2334 Aero-Park Ct.
Traverse City, MI 49684

Emmet County Co-operative Extension Service
Emmet County Building
Petoskey, MI 49770

NEMCOG
P.O. Box 457
Gaylord, MI 49735

Cheboygan County Co-operative
Extension Service
Cheboygan County Building
Cheboygan, MI 49721

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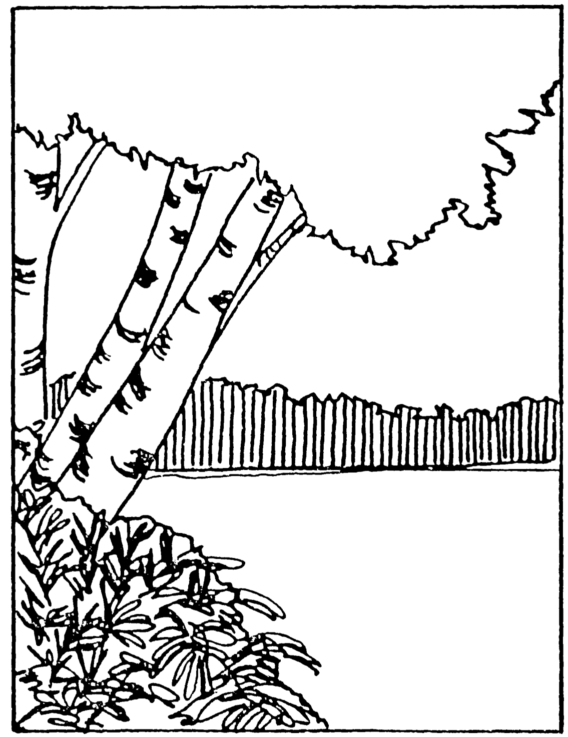
Greenbelts



Starting a Greenbelt on Your Property

Review Your Yard

See how a greenbelt would best fit your homesite. Note the area, the type, and size of vegetation already growing.

The width of a greenbelt can range from a few to many feet. Any vegetation between the lawn and shoreline will buffer the lake from extra nutrients. A strip of vegetation from ten to fifteen feet wide is usually recommended, but this can be modified to fit the landscaping or size of your property.

Assess the Light and Soil Conditions

When choosing plants for greenbelts, your decision should be based on not only what you find esthetically pleasing, but also what plants would grow well in the light and soil conditions of your land.

Since some plants thrive on certain soil types, a soil analysis on a site would provide an idea which plants could do best there. The County Co-operative Extension Service runs a soil sampling program for homeowners.

Contact your County Extension Office to find out how to sample your soil. The results of this simple process can also be used to decide if, and how much, fertilizer is needed on your lawn.

Select the Plants

Once the light and soil conditions on the property have been assessed, find out what plants would grow well there. For suggestions, talk to local nurseries and landscapers, or refer to the University of Michigan Biological Station Lakeland Report #12 on Greenbelts.

After choosing the shrubs or trees which will create your greenbelt, there are several ways you can obtain them:

- Purchase the plants from nearby nurseries or landscapers
- Transplant vegetation from a piece of land similar to your lot
- Allow the natural vegetation to flourish

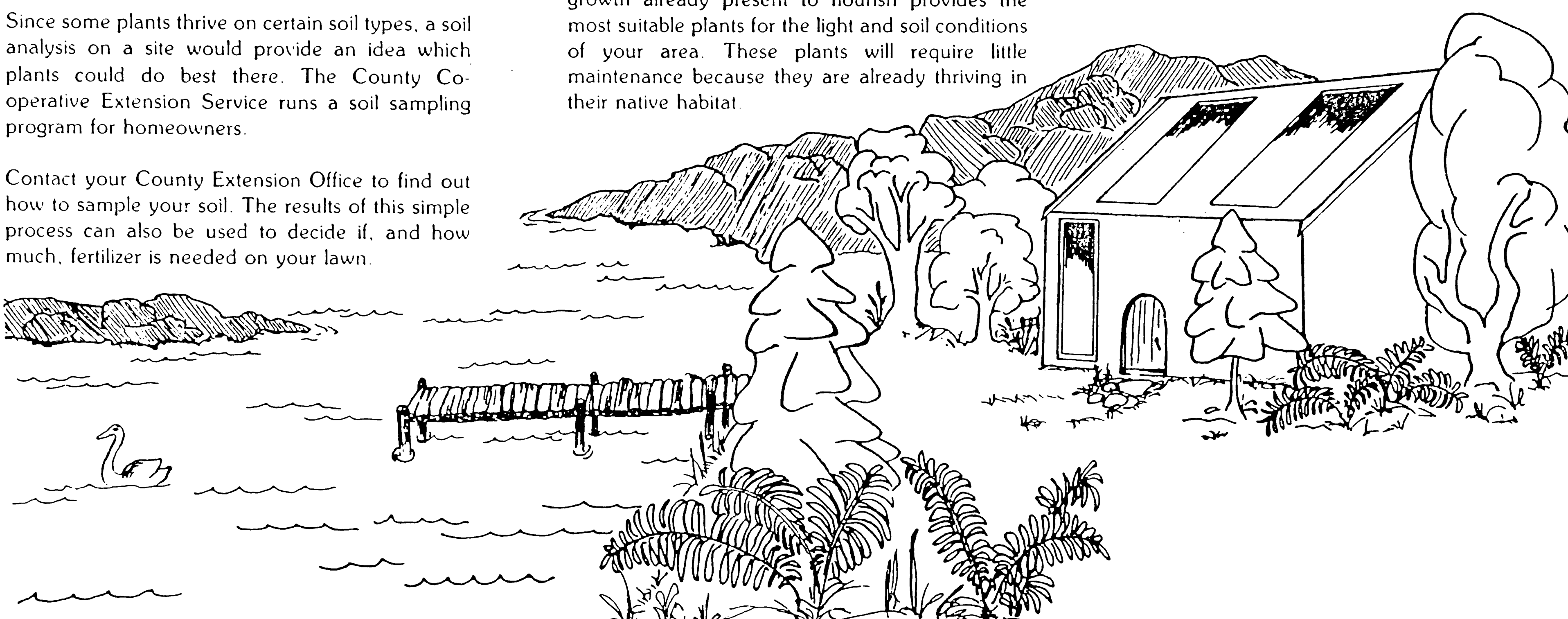
Transplanting native vegetation or allowing the wild growth already present to flourish provides the most suitable plants for the light and soil conditions of your area. These plants will require little maintenance because they are already thriving in their native habitat.

MAKING GREENBELTS A COMMUNITY EFFORT

- Community involvement: Spread information about the importance of greenbelts in protecting water quality among lake shore residents. Lake associations can be effective organizations through which to begin greenbelt programs.

- Group Greenbelting: Work cooperatively through lake associations or with neighbors to begin greenbelts. Working together could encourage participation and lower "group prices" for plants or planting, and at the same time, stimulate community concern and awareness.

- "Built-in" Lake Protection: Communities with the power to zone can adopt greenbelt provisions within their zoning ordinances.



Zoning ordinances are a township's chief tool for resolving land use conflicts and preparing for community development. Knowing the background and process of zoning will enable you to better respond when faced with zoning decisions, and will enable you to participate in the creation of zoning ordinances acceptable to you.

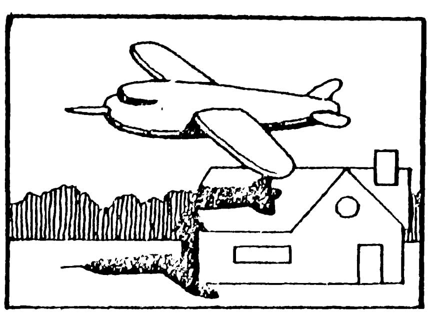
- Zoning ordinances divide all the land contained in a township into zones, or uniform districts. For each zone a particular "land use", such as commercial or natural-open-space, is designated.

- A zoning ordinance can specify the location of buildings on a piece of property, as in a required 200 foot setback from a lake shore.

- Ordinances ensure that new structures are safe and compatible with their surroundings by establishing construction height and area limitations.

Zoning Has Many Benefits

Zoning can help protect individual property owners from future harmful or undesirable land uses on adjacent property. It can assist township economic growth by reserving adequate suitable sites for industrial, commercial and residential uses. Environmentally sensitive, historic, or prime agricultural lands can also be set aside, enjoyed for their inherent benefits, and preserved for the future.



A Zoning Glossary

PRIMARY USES: Each zoning district has primary uses. These are the activities and land uses that are automatically allowed within the zone. An example would be a clothing store within a commercial district.

PERMITTED USES: Beyond primary uses, most zoning districts also have certain permitted uses. These are the land uses which are allowed only with special written permission from the zoning board. For example, a residential home within a commercial zone might be a permitted use.

CODES: Building and sanitary health codes determine construction standards which must be met by all new developments. Codes promote safety, but, unlike zoning, they are not intended to pattern or coordinate community growth.

CONDOMINIUMS: Condominium construction places dwellings close to one another. Although the population density is higher with this clustered development, energy is conserved and greater portions of developable land are left in a natural state.

PERFORMANCE STANDARDS: This is an innovative zoning technique by which local structural, environmental and aesthetic standards are set and included in the zoning ordinance. A developer's plans are then reviewed by the Zoning Board to see if they meet these standards. This ensures that the project will enhance the social and natural environment, without outright exclusion of certain housing types.

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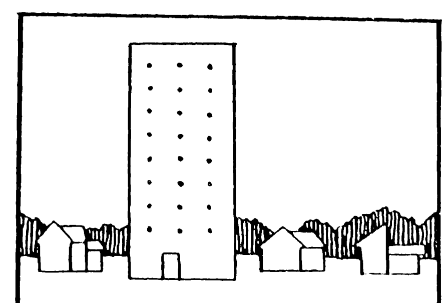
ZONING

A marina is built in a wetland, ruining an area enjoyed by bird watchers and hunters alike.

Housing around an airport claims land which would have been an ideal industrial location. Due to the noise, the sites are less than ideal for homes.

Increased activity from new multi-family dwellings disrupts the homes in an older, established neighborhood.

You have probably read about similar instances where conflicting land uses created problems for a community. Land use changes CAN occur in predictable, sensible patterns if the community government acts wisely.



The zoning process combines the input of citizens, planners, and government officials.

Zoning typically begins when community members inform their township supervisor, in a written petition, that they want zoning ordinances to regulate local growth and avoid haphazard development.

Both the township and county government can enact zoning regulations. Often township zoning is more sensitive than county zoning since it involves a smaller, more familiar territory. In areas where both the township and the county are zoned, the township regulations supersede county ordinances.

Planning is the Basis of Zoning

According to the law, zoning ordinances must express the goals of the community. These goals are defined through a planning study, a survey of the area's natural, social and economic patterns., THE PLANNING COMMISSION is responsible for conducting this study and converting the findings into guidelines for the township to follow in zoning and planning public services.

The commission is a group of 5 to 9 community members who are appointed by the township board. When the study is completed, the commission's findings are published in a planning report, frequently called the "Master Plan".

The Zoning Board

Following completion of a master or township plan, the ZONING BOARD formulates potential zones using the recommendations of the planning commission. The board, a group of 4 to 7 citizens, receives suggestions, reviews all zoning possibilities, and incorporates public opinion into final zoning recommendations for the township. The board holds public meetings for citizens to react to the proposed zoning regions. When completed, the board's final recommendations are sent to the township board for review.

Township Approval

The township board, which consists of an elected supervisor, a clerk, and several trustees and constables, has the power to pass or reject the recommendations of the zoning board.

After the township board approves a zoning ordinance, citizens retain an opportunity to veto it through a referendum. If, within 30 days of the township board's action, 15% of the residents sign a petition requesting a referendum, a yes or no vote on the zoning ordinance will be held.

Enforcement and Administration

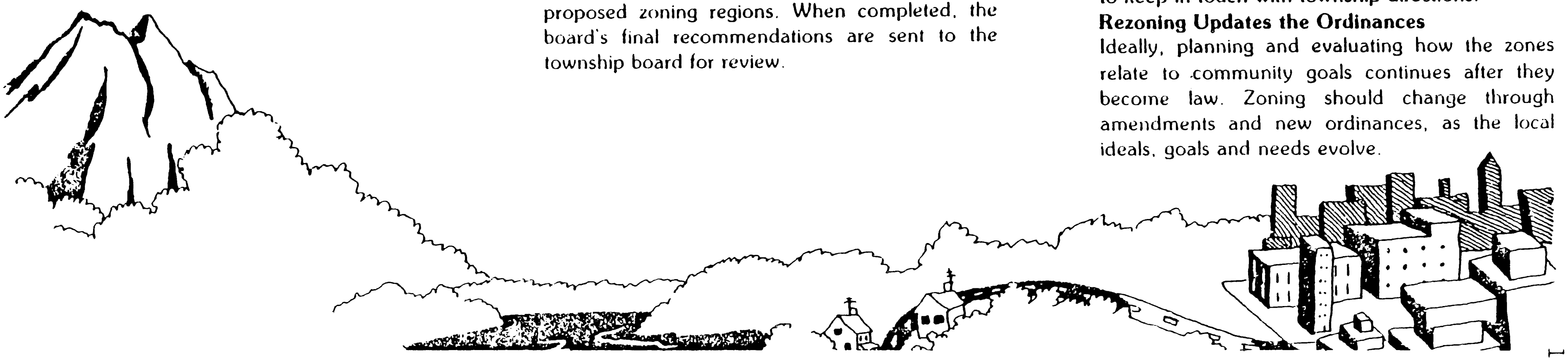
Once a zoning recommendation is approved by the township board and the residents, it becomes a zoning ordinance or law. It is enforceable by the police with fines or jail sentences for violations.

A BOARD OF APPEALS is established to review cases where an individual's rights are in conflict with the zoning regulations. The Zoning Board of Appeals reviews earlier decisions and interprets the ordinances. It may grant variances to property owners, enabling them to violate the zoning regulation.

The role of the appeals board is very important. Their meetings are public and should be attended to keep in touch with township directions.

Rezoning Updates the Ordinances

Ideally, planning and evaluating how the zones relate to community goals continues after they become law. Zoning should change through amendments and new ordinances, as the local ideals, goals and needs evolve.



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