Section 4 Organics

4.0 INTRODUCTION

This section presents the initial results of an investigation of the presence of organic chemicals in Long Island's ground and surface waters, and describes the data, sampling and analytical techniques, and the uncertainties associated with this study.

The information contained in this section is the result of a sampling and analysis program conducted to support the development of a 208 Areawide Waste Treatment Management Plan for Nassau and Suffolk Counties, New York. The organic chemicals study was conducted under severe time and budgetary constraints and must therefore be supplemented and expanded with additional field work and laboratory analyses.

The study demonstrated the presence of a number of organic chemicals in Long Island's ground and surface waters. The nature and extent of this demonstration, however, is subject to a number of uncertainties related to the statistical significance implied by the number of samples obtained and analyzed; the replication of analytical results obtained from multiple sampling for volatile compounds; the problems associated with sample collection, transportation, storage, and preparation; and the quality assurance problems inherent in a state-of-the-art laboratory procedure conducted at the parts per billion level.

Along with the problems associated with collection and analysis, there is significant uncertainty relating to probable risk, threshold exposure level, and other public health implications of the data.

Some of the major problems in the interpretation and evaluation of organic chemical data concern the identification of probable sources. Some of these chemicals seem to be pervasive in the environment, while others are found in a few instances and may not be found at all in replicate sampling. Many of these chemicals are related to industrial activities and processes, but they also have been found in places that have not seen any such activity. Identification of groundwater sources is especially difficult because of slow groundwater velocities, the varying rates of diffusion, and the essentially probabilistic nature of virtually all groundwater investigations.

4.1 REVIEW OF PRIOR STUDIES IN NASSAU AND SUFFOLK COUNTIES

Except for some widely publicized chemicals such as carbon tetrachloride and pesticides, the presence of organic contaminants in water has only recently attracted concern. Because of a lack of emphasis on organics monitoring in water surveys, and the relatively recent development of precise analytical techniques, organic chemicals data for the Long Island region are incomplete.

Baier (1976) reviews USGS data on pesticides in Long Island groundwater and concluded that pesticide contamination should not be considered a major pollution problem for Long Island's groundwater. Table 4–1 summarizes the results of samples from 197 test wells in Suffolk County. Few significant occurrences of pesticides are noted.

Slimak and Harris (1976) conducted a sampling program of various water media on Long Island, including stormwater runoff, effluent from secondary and tertiary domestic sewage treatment plants, and percolates of effluent. Qualitative analyses were performed by GC/MS. Various phthalates, stearates and paraffins were identified. Other organic contaminants found

Table 4–1

PESTICIDES IDENTIFIED IN USGS TEST WELLS LOCATED IN SUFFOLK COUNTY

Well No.	Pesticides and/or Herbicides (μg/l) identified in general screening process	Levels observed in subsequent resampling event (μg/l)
S43808	Dieldrin = .01	less than .01
S43815	PCB = trace	
S43819	Silvex = .01	less than .01
S45208	PCB = trace	
S46912	DDE = .01 DDT = .02 Dieldrin = .09	all less than .01
S46913	DDD = .04 DDE = .02 DDT = .08 Dieldrin = .11	all less than .01
S46914	Dieldrin = .02	less than .01
S46963	2, 4-D = trace	less than .01
S47222	Silvex = trace	less than .01
S47230	Silvex = trace	less than .01
S47235	DDD = trace DDE = trace	both less than .01
S47977	2, 4-D = .07	less than .01
S48425	2, 4-D = trace	less than .01
S48946	PCB = trace	
S51575	DDD = 8.1	DDD = 1.6
S51583	Diledrin = .01	less than .01

Source: Baier, 1976.

included benzene, toluene, xylene, chloroform, and several other hydrocarbons. Table 4–2 summarizes the results of the five samples taken. A large number of chemicals was observed.

The Nassau County Department of Health (1977a) and the Suffolk County Department of Health Services (1978) assembled results of sampling of Nassau and Suffolk County municipal water supplies, which was performed concurrently with the ERCO study. Significant (10μg/l) concentrations of volatile organics were found to contaminate water supply wells in some locales. For example, the most frequently observed contaminant, trichloroethylene, occurred in 25 of 303 samples in Nassau, and 46 of 125 samples in Suffolk. Chronological analysis of data seemed to show decreases in measured amounts over time. However, methods were not standardized, and different labs were used in a chronological sequence, so no firm conclusions could be drawn. Tables 4–3 and 4–4 summarize the results.

The Nassau and Suffolk County Health Departments and the Long Island Water Conference established interim guidelines for contaminants in Long Island water supply wells (Tables 4–5, 4–6 and 4–7) by endorsing the New York State Health Department guidelines for "restricted" and "reserve" wells.

In an attempt to identify the origins of organic chemicals in groundwater, the Nassau County Department of Health examined many common consumer products that contain potential organic contaminants, and surveyed the usage of some of these products within the County (see Tables 4–8 through 4–12). These NCDH studies served to demonstrate, on a preliminary basis, the diversity of potential sources for organic contaminants.

4.2 POTENTIAL HEALTH RISKS DUE TO ORGANIC COMPOUNDS IN WATER

Health risks from organic compounds include: (1) toxic effects; (2) carcinogenic effects from low levels in drinking water; (3) bio-accumulation in certain organs of shellfish, fish and other wildlife; and (4) tainting of shellfish and fish by hydrocarbons and other odor and taste inducing organics. Of these problems, the first and second are of major concern; the third was of concern in Long Island in the past when DDT and related pesticides were in common use (Porter *et al.*, 1977) and is now mainly of concern with respect to fish that spawn in areas such as the Hudson River, where substances such as PCBs occur (Beck *et al.*, 1978). The fourth has not been shown to be a problem on Long Island. The organic chemicals study was limited to the first and second types of effects.

> "The potential for existing concentrations of organic pesticides and other organic contaminants in drinking water to adversely affect health, cannot be answered with certainty at this time. The key issue is whether or not certain organic chemicals found in very low concentrations can cause or increase the rate of cancer development in man. Even though several of these chemicals have demonstrated carcinogenicity in laboratory animals, the extrapolation of such results to man remains difficult for a number of reasons.
>
> "Because the bioassays that have been used to establish carcinogenicity of certain organic chemicals are conducted at doses which are hundreds to thousands of times greater than the levels at which these chemicals occur in water, the risks at these low levels must be obtained by extrapolation from higher doses. There is no hard evidence that low level oral exposure to any of these chemicals produces cancer. An argument has been made that the dose levels used to establish carcinogenicity are so

Table 4–2

ORGANICS OBSERVED ON LONG ISLAND IN 1976

	Volatile Organics	Fractions From the Extraction Procedure				
		Neutral Fraction	Acidic Fraction	Acid Esterified Fraction	Basic Fraction	Particulate Extract
Untreated storm-water runoff	benzene toluene ethyl benzene p-xylene n-xylene	ethyl phthalate butyl phthalate isobutyl phthalate (T) ethyl hexyl phthalate dioctyl phthalate 2 additional phthalate compounds	methyl-18 methoxyabiatate 2-isopropyl-1, 3-dioxolane ethyl benzaldehyde (T) diethyl phthalate methyl palmitate butyl phthalate dioctyl phthalate	methyl nonanoate phenyl eicosane (T) methyl myristate methyl palmitate methyl stearate squalene (T)	diethyl phthalate dibutyl phthalate dioctyl phthalate	ethyl phthalate ethyl hexyl phthalate dioctyl phthalate 2 additional phthalate compounds
Groundwater percolate of untreated storm-water runoff	methylene chloride benzene toluene 3 additional aromatic BC's	ethyl phthalate ethyl hexyl phthalate phthalate compound dioctyl phthalate	diethyl phthalate butyl phthalate 2-isopropyl-1, 3-dioxolane dioctyl phthalate 1-decyne (T)	benzyl-2 (benzyl thio) propionate (T) methyl myristate (T) diethyl phthalate methyl palmitate methyl stearate butyl phthalate dioctyl phthalate squalene (T)	dioctyl phthalate	ethyl phthalate butyl phthalate ethyl hexyl phthalate dioctyl phthalate phthalate compound
Blank	methylene chloride (T)	butyl phthalate isobutyl phthalate butyl isobutyl phthalate	ND	ND	butyl phthalate octyl phthalate	ND
Medford effluent, tertiary treatment	ND	isobutyl phthalate butyl phthalate butyl isobutyl phthalate dibutoxyethane (T) iso-octyl phthalate	ND	ND	isobutyl phthalate	isobutyl phthalate butyl phthalate butyl isobutyl phthalate

Table 4--2 . . . cont'd.

	Volatile Organics	Fractions From the Extraction Procedure				
		Neutral Fraction	Acidic Fraction	Acid Esterified Fraction	Basic Fraction	Particulate Extract
Groundwater percolate of Medford effluent, tertiary treatment	chloroform	isobutyl phthalate butyl phthalate butyl isobutyl phthalate	methyl isoxanoate nor-octyl eicosane nor-decyl docosane b-butyl docosane 11-n decyl docosane n-pentyl beneicosane 10-n-10-n hexyleicosane n-octyl heptadecane methyl tricosane n-nonacosane n-datriaccotane n-octyl tetracosane	ND	ND	ND
Wantagh effluent, secondary treatment	perchloro-ethylene o-dichloro-benzene	ND	isobutyl phthalate butyl phthalate	butyl phthalate	butyl phthalate methyl undecane methyl decane	butyl phthalate isobutyl phthalate butyl isobutyl phthalate

Key: (T) = tentative identification.
ND = no compounds detected in sample.

Table 4–3

SUMMARY OF VOLATILE ORGANIC SAMPLING
OF NASSAU COUNTY MUNICIPAL WATER SUPPLIES

Organic Compounds[1][2]	number of samples observed at ≥10μg/l[3]	number of samples observed at ≥50μg/l[3]	number of samples observed at ≥100μg/l[3]
1, 1, 2 trichloroethylene	25	7	2
1, 1, 1 trichloroethane	16	7	4
chloroform	11	1	0
tetrachloroethylene	7	5	4
1, 2 dichloroethylene	6	0	0
benzene	3	1	0
toluene	2	0	0
bromodichloromethane	1	0	0
vinyl chloride	0	0	0
trifluorotrichloroethane	0	0	0
carbon tetrachloride	0	0	0
methylene chloride	0	0	0
ethyl ether	0	0	0

[1] *All samples were collected between June 1975 and May 1977.*

[2] *Samples were analyzed by various labs using a variety of analytical methods.*

[3] *The total number of samples is 303; not all compounds were analyzed for in all samples.*

Source: NCHD, 1977a.

high that they overwhelm normal detoxification or repair mechanisms or both, and produce cancer by some mechanism that does not operate under low dose conditions. Experimental animals subjected to such high doses could be considered a population different from those exposed to lower doses that do not produce pathological alterations and changes in pharmacokinetic parameters, or biochemistry.

"Extrapolating from laboratory animals to man would be more meaningful if comparative metabolic information between the different species was available. Some species do not metabolize a parent compound to its activated form so that use of these species in toxicological bioassays is inappropriate if the compound undergoes activation in man. The converse situation also is true. Differences may also occur with respect to other parameters such as rates of biotransformation, absorption, excretion, and biological half life.

Table 4–4

SUMMARY OF VOLATILE ORGANIC SAMPLING
OF SUFFOLK COUNTY MUNICIPAL WATER SUPPLIES

Organic Compounds[1][2]	No. of Samples Observed at ≥10μg/l[3]	No. of Samples Observed at ≥50μg/l[3]	No. of Samples Observed at ≥100μg/l[3]	Total No. of Samples Analyzed
1, 1, 2 trichloroethylene	46	29	19	125
1, 1, 1 trichloroethane	41	16	7	121
tetrachloroethylene	18	3	1	122
chlorofrom	8	2	1	123
carbon tetrachloride	4	0	0	105
1, 2 dichloroethylene	2	0	0	30
toluene	1	0	0	48
benzene	1	0	0	49
vinyl chloride	0	0	0	29
trichlorotrifloroethane	0	0	0	45
bromodichloromethane	0	0	0	62
dichloromethane	0	0	0	7
chlorodibromomethane	0	0	0	1

[1] Samples were collected between February 1976 and January 1978.

[2] Analyses were done by the following labs: NYSHD, Stony Brook; NYSHD, Albany; EPA, Ada, Okla.; New York Industrial Testing Lab; EPA, Edison, N. J.

Source: SCDHS, 1978.

"Risk assessments based on extrapolations which fail to consider species differences with respect to sensitivity, tissue susceptibility, kinetics, pathology or biotransformation pathways may be inappropriate. This kind of information is not presently available.

"In light of such uncertainties, a cautious approach must be adopted when dealing with potentially harmful chemicals. Even more uncertainty exists when one considers the possibility that some of these chemicals may also be mutagenic or teratogenic. The methodologies used to establish these effects are even less applicable to man than cancer bioassays.

"For many of the organic compounds identified in drinking water, virtually no toxicity data are available. Ideally, all of these agents (as well as any new ones) should be subjected to an exten-

Table 4–5

NEW YORK STATE INTERIM GUIDELINES
FOR ORGANIC CONTAMINANTS IN WATER SUPPLIES

Maximum Allowable Concentrations of Contaminants

Constituent	Allowable Concentration (μg/l)
Vinyl chloride	10
Other individual organics contaminants (listed below) measured for any one substance	50
Total of organics contaminants (listed below) measured for the sum of all individual concentration levels	100

These guidelines apply to the following organic chemicals:

Benzene
Carbon tetrachloride
Chloroform
1, 1, 2 trichloroethylene
Tetrachloroethylene
Bromodichloromethane
Toluene
1, 2 Dichloroethylene
Chloroethyl ethyl ether
Chloromethyl ethyl ether
Methyl chloride

Source: New York State Department of Health Interim Guidelines.

sive battery of toxicity tests including chronic bioassay. In practice, there is a need to determine those agents for which the generation of data is most pressing.

"... A number of assays using bacteria and yeast have shown promise in yielding high correlations between mutagenic activity and known carcinogenic activity for certain classes of materials. These may prove to be useful in establishing a first level screen for potential carcinogens."[1]

At present, the best approach for assessing health risks on Long Island, taking into account the above-mentioned uncertainties, is a balanced use of the NAS guidelines, the EPA and N. Y. State Health Department guidelines, and the use of best judgment for compounds not included in those guidelines and criteria.

Table 4–6

BASIS OF WELL CATEGORY ASSIGNMENTS

Category	Basis for Assignment*	Limitations on Use
"Presumptive Unacceptable"	(1) After having been in the Unrestricted Category, one analysis with one or more contaminants in excess of the allowable concentrations (Table 4–5).	To be decided on a case-by-case basis, with the understanding that the well not be used if at all possible. Blending of water with uncontaminated water from an adjacent well on the site is recognized as an acceptable procedure.
"Restricted"	(1) After having been in Presumptive Unacceptable Category, one or more consecutive analyses with one or more contaminants over the allowable concentrations (Table 4–5).	Well not to be used except in emergency, or on being granted approval of the Health Department. Blending of water with uncontaminated water from an adjacent well on the site is recognized as an acceptable procedure.
"Reserve"	(1) After having been in Restricted Category, a minimum of two consecutive analyses at least 24 hours apart, showing the contamination below the allowable concentrations, would be required. (2) After having been in the Presumptive Unacceptable Category, one analysis showing the contamination below the allowable concentrations would be required.	Unrestricted wells to be used first.
"Unrestricted"	(1) After having been in the Reserve Category, a minimum of two consecutive analyses at least 24 hours apart, showing the contamination below the allowable concentrations, would be required. (2) Not previously in the Restricted or Reserve Categories, and having no individual constituent and/or total organic concentration in excess of the allowable concentration.	None.

*As of 6/16/77.

Note: All resampling must include all constituents that were analyzed for in previous samples.
Source: Holzmacher et al., 1977.

Table 4–7

SUMMARY OF "RESTRICTED" AND "RESERVE" WELLS IN NASSAU AND SUFFOLK COUNTIES

Summary of wells in each category by county as of March 15, 1977 (1) (2)

Category	County: Nassau	County: Suffolk
Restricted	2	5
Reserve	4	1

Summary of contaminant levels observed which resulted in restrictions (1) (2)

Contaminant	Observed Level: ≥10 µg/l	≥50 µg/l	≥100 µg/l
Carbon Tetrachloride	2	1	0
Chloroform	6	3	1
Trichloroethylene	21	14	8
Tetrachloroethylene	5	4	3
Trichloroethane	6	3	2

Summary of Nassau wells in each category as of March 16, 1978 (3) (4)

	Status: March 15, 1978	Status: Dec. 31, 1977	Status: June 1977
Presumptive Unacceptable	0	1	4
Restricted	24*	24*	17*
Reserved	2	2	2
Unrestricted but previously reserved, restricted, or unacceptable	9	7	4

**Includes 19 industrial source wells restricted to industrial use only.*

[1]Source: Holzmacher et al., 1977.

[2]All samples collected between 11/29/76 and 3/15/77.

[3]As of 3/30/77.

[4]Source: Myott, 1978.

Table 4–8

NASSAU COUNTY DEPARTMENT OF HEALTH CONSUMER PRODUCTS SURVEY (by Generic Category)

Product Category	Organic Chemical Ingredients Listed
Household Cleansers	Petroleum distillates, glycol ethers, xylenols, isopropanol
Drain Cleaners	1, 1, 1 Trichloroethane
Toilet Cleaners	Chlorinated phenols, xylene sulfonates
Laundry Soil and Stain Removers	Petroleum distillates, tetrachloroethylene
Spot Removers and Cleaning Fluids	Petroleum hydrocarbons, benzene, trichloroethylene, 1, 1, 1 trichloroethane
Hand Cleaners	Petroleum distillates, benzaldehyde
Metal Polishes	Petroleum distillates, petroleum naptha, isopropanol
Cesspool Cleaners	Tetrachloroethylene, methylene chloride, dichlorobenzene
Cleaning Solvents	Pure strength benzene, acetone, trichloroethylene
Paint and Lacquer Thinners	Benzene, toluene, acetone, butyl acetate, methyl ketones
Paint and Varnish Removers, Deglossers	Methylene chloride, toluene, acetone, xylene, ethanol, methanol
Paint Brush Cleaners	Aliphatic hydrocarbons, toluene, acetone, methyl ethyl ketones, methanol, glycol ethers
Degreasers for Engines and Metals	Chlorinated hydrocarbons, dichloro-perchloroethylene, toluene, phenols
Degreasers for Driveways, Garages	Petroleum solvents, alcohols, glycol ether
Engine Flushes	Petroleum solvents, ketones, glycol ethers
Radiator Flushes	Petroleum distillates, butanol
Antifreeze	Ethylene glycol, methanol
Auto Transmission, Crankcase Additives	Petroleum distillates, xylene
Car Washes	Alkyl benzene sulfonates
Car Waxes, Polishes	Petroleum distillates, aliphatic hydrocarbons
Bug and Tar Removers	Petroleum distillates, xylene

Source: Dowling, 1977; Mackay, 1977.

Table 4–9

NASSAU COUNTY DEPARTMENT OF HEALTH
CONSUMER PRODUCTS SURVEY (by Brand Name)*

Brand Name	Product Usage	Compound
Carbona Spray Spot Remover	Spot Remover	Methylene chloride
Dax (Kocatah)	Scalp Conditioner	Tar oil
3-in-1 Plastic Wood	Wood Filler	Toluene
Flecto Varathane	Spray Paint	Toluene/Xylene
Saf-te Strip	Paint Remover	Methylene chloride
Bix (2 types)	Paint Remover	Toluene, Methylene chloride
Rock Miracle	Paint Remover	Methylene chloride
Formula A	Paint Remover	Methylene chloride
The Remover	Paint Remover	Methylene chloride
Amazon	Sealer	Creosote oil
Cabots	Tree Healer/Paint	Creosote oil
Nankes	Lacquer Thinner	Toluene
Harmel	Spray Enamel Primer	Methylene chloride
Harmel	Spray Enamel Black	Vinyl toluene soya alkdresin carbon black
Miniwax	Polyurethane Sealer	Toluene diisocyanante
Weldwood Woodlife	Wood Preservative	Pentachlorophenols
LS Liquid Sandpaper	Liquid Sanding	Xylene naphtha
Zip Strip	Paint Remover	Methylene chloride
Heddy	Graffiti Remover	Methylene chloride
Weldwood	Spray 'N' Glue	Methylene chloride
Afta	Solvent	Trichloroethylene
Shout	Stain Remover	Tetrachloroethylene
Fabspray Vinyl Colorspray	Paint	Toluene
Lacquer Thinner	Paint Thinner	Toluene
Woodlife	Wood Preservative	Pentachlorophenol
Lysol	Disinfectant	Xylenols
Warner DeGreaser	Auto Degreaser	Methylene chloride
Lan-o-Sheen	Engines	1, 1, 2 Trichloroethylene
Ortho	Pruning	Asphalt
Pratt Spray's	Insects	Xylene
Grumbacher	Retouch Varnish	Methylene chloride
Choke	Choke Cleaner	Methylene chloride
Drainz	Cesspool Cleaner	Petroleum distillate
Snap	Choke Cleaner	Xylene
Warner	Choke/PVC Cleaner	Toluene, Methylene chloride
Zing Semi-Paste	Paint Remover	Toluene, Methylene chloride
Red Devil	Brush Cleaner	Benzene
Red Devil	Paint/Varnish Remover	Benzene, Methylene chloride
Five Star	Lacquer-Thinner	Toluene
Bendite	Epoxy Primer	Halogenated Aromatic Hydrocarbon
Rust-Oleum	Spray Rust Preventative	Toluene, Xylene
Bernzomatic	Flat Tire Fixer	Toluene
Doublesealed	Lacquer Thinner	Toluene
Rich	Liquid Roof Coating	Asbestos fibre
Black Jack	Plastic Asbestos Cement	Asbestos fibre
Empire	Asbestos Cement	Asbestos fibre
Umbrella	Water Proofing	Aromatic Hydrocarbons
NYBCO Silver Touch	Silver Spray Enamel	Toluene
NYBCO Silver Touch	Wet Look Enamel	Toluene
KR2 Spot Lifter	Spot Remover	Chlorinated hydrocarbons
Baldwin	Lacquer Thinner	Toluene
Gumout	Choke Cleaner	Xylenes
STP	Carburetor Cleaner	Xylenes
RP Superfilter Coat	Odor & Dust Removing Air Filter Adhesive for Washable Filters	Hexachlorophene
Imperial Wonder Paste	Paint Remover	Methylene chloride

Table 4–9 . . . Cont'd.

Brand Name	Product Usage	Compound
TM-4	Paint and Finish Remover	Methylene chloride
Weldwood Multipurpose Floor Cement	Cement	Toluene
Weldwood Waterproof Cement	Cement	Toluene
Asphalt Asbestos Fibre Roof Plastic	Roof Coating	Asbestos
Empire Asbestos Cement	Cement	Asbestos
Asphalt Asbestos Roof Fix Roof Coating	Roof Coating	Asbestos
Digest	Sewage Grease and Waste Solvent	Trichlorobenzene
Bilco Creosote Oil Compound	Wood Sealer	Asbestos
3-in-1 Plastic Wood Solvent	Solvent	Toluene
Duro Liquid Solder	Metal Repair Cement	Toluene

**These products were identified in a one day survey of supermarkets and hardware stores by the Nassau County Department of Health.*

Source: Dowling, 1977; Mackay, 1977.

4.2.1 National Academy of Sciences Guidelines

The National Academy of Sciences has recently reviewed the existing literature on environmental pollutants, and has divided the organic contaminants of water supplies into four categories: (1) known or suspected carcinogens (Table 4–13), (2) noncarcinogenic toxins (Table 4–14), (3) compounds which have been insufficiently studied with respect to chronic toxicity (Table 4–15), and (4) compounds which have not been subjected to chronic toxicity tests (Table 4–16).

The NAS results are relevant to Long Island. Table 4–13 indicates health risks in terms of the probability of occurrence of cancer fatalities. In order to apply a set of standards, these risk numbers must be translated into allowable concentrations levels. This requires establishment of an acceptable risk level for cancer. Chloroform, carbon tetrachloride, and trichloroethylene occur on Long Island in all types of aquifer water samples. Therefore, the presence of these contaminants can reasonably be inferred to impose cancer risks according to *animal* carcinogenicity studies summarized in Table 4–13.

Phthalates were detected at concentrations equal to or greater than ten $\mu g/l$ in a number of samples on Long Island (mainly from shallow aquifer wells), and in some cases were detected at concentrations greater than 50 $\mu g/l$. These levels were found by the NAS to constitute a toxicity risk, but not a cancer risk. The NAS (Table 4–14) reported that 38.5 $\mu g/l$ is the threshold level for the safe consumption of di-n-butyl phthalate. Therefore, the observed concentration of di-n-butyl phthalate exceeds these levels in some Long Island shallow aquifer wells.

According to the NAS, many of the groundwater contaminants that are of concern on Long Island have not been sufficiently studied for their toxicity or carcinogenicity (see Tables 4–15 and 4–16), including tetrachloroethylene; 1, 2-dichloroethane; bromoform; bromodichloromethane; and propyl benzene. Others, such as 1, 1, 1-trichloroethane and dibromochloromethane, were not included in the NAS study. Thus, despite the existence of information enabling the assessment of health risks for a few of the organic chemicals of concern on Long Island, major uncertainties about the health risks of many others have not been resolved by the NAS.

4.2.2 EPA and New York State Guidelines

The EPA-proposed maximum contaminant levels (MCL's) for organics are limited to trihalomethanes, for which a 100 $\mu g/l$ composite level is proposed. The New York State maximum allowable concentrations, which are presented in Table 4–5, were established in anticipation of the EPA proposal and are somewhat more comprehensive. Potential public health risks can be assessed by the frequency of violation of these standards, which were based on the same data used in the NAS report; however, many contaminants present in Long Island aquifers were not examined by the NAS (see Section 4.2.1).

In an attempt to limit public exposure to these chemicals, the USEPA is proposing the use of activated carbon in the treatment of all public water supplies serving more than 75,000 people.

4.2.3 Compounds of Unknown Health Risk

Compounds such as 1, 1, 1-trichloroethane, which occurred in 49 percent of the samples of this study, and tetrachlorethylene, which occurred in 33 percent of the samples, are not addressed in the toxicologic literature.

A literature search was performed for this study using the 1972–1977 DIALOG data base, which abstracts most of the published literature on health and environmental toxicology, and includes about 90 percent of the citations included in the TOXLINE search. Some 193 relevant citations were identified in a preliminary screen, of which 27 turned out to be applicable to Long Island. Dibutylphthalate (see Table 4–14), dioctyl-phthalate (not listed in the NAS report), and naphthalenes (also not listed) have been studied for a variety of toxic effects that are reported in the literature. Mutagenic screens or carcinogenicity tests for chemicals identified in Long

Table 4—10

CESSPOOL CLEANERS AND DRAIN OPENERS USED IN NASSAU COUNTY: SUMMARY OF KNOWN INGREDIENTS AND SALES INFORMATION

Brand Name	Manufacturer	Ingredients	Source of Information	Gallons Sold Yearly[1]
Action Degreaser	Action Chemicals, Inc. Brooklyn, N. Y.	Petroleum Distillates Orthodichlorobenzene	Product Label	2,210
Cess-Flo	Pequa Industries, Inc. Massapequa Park, N. Y.	Petroleum Distillates	Product Label	650
Drainz	Jan-Cyn Manufacturers 155 Oval Drive Central Islip, N. Y. 11722	Methylene Chloride—35% 1, 1, 1-Trichloroethane—31% Aliphatic/Aromatic Fractions—35%	Laboratory Analysis	27,155
Drainz Super Strength Concentrate	Jan-Cyn Manufacturers 155 Oval Drive Central Islip, N. Y. 11722	Similar to "Drainz"		4,100
Hercules Wham EPA Reg. No. 7687-2	Hercules Chemical Corp. New York, N. Y. 10011	Orthodichlorobenzene—80% Inert—20%	Product Label	2,500 (mfgrs. estimate)
The Unstuffers Liquid Cleaner for Septic Tanks & Cesspools	Coastal Industries, Inc. 190 Jony Drive Carlstadt, N. J. 07072	Solvent Blend	Per manufacturer's representative	2,330
Clog-Buster	Action Chemicals, Inc. Brooklyn, N. Y.	Petroleum Distillates	Product Label	210
Drano Aerosol Plunger	The Drackett Company 5020 Spring Grove Ave. Cincinnati, Ohio	Utilizes pressure to open drain		3,200
Glamorene Drain Power	Glamorene Product Corp. 175 Entin Road Clifton, N. J. 07014	Utilizes pressure to open drain 1, 1, 1,-Trichloroethane Chlorofluorocarbon propellant oil of pepper, perfume	Per manufacturer's representative	3,040
Kitchen Drano	The Drackett Company 5020 Spring Grove Ave. Cincinnati, Ohio 45232	1, 1, 1-Trichloroethane—75% Paraffinic Oil—25%	Per manufacturer's representative	2,210

[1] *Actual response of 60% of surveyed retail establishments.*

Source: NCDH, 1977b.

Table 4—11

ESTIMATES OF CESSPOOL CLEANER SALES IN NASSAU COUNTY (by Chemical)

Chemical	Quantity (Gallons/Year)
Methylene Chloride	17,400
1, 1, 1-Trichloroethane	18,600
Orthodichlorobenzene	3,300
Other Aromatic and Halogenated Compounds	17,600
Total Suspected Carcinogenic or Other Harmful Organics	**56,900**
Petroleum Distillates	10,600
Grand Total	**67,500**

Source: NCDH, 1977b.

Island groundwater and not studied by the NAS (see Tables 4—13 and 4—14) were not found in the literature. Some EPA screening programs are known to be in progress, and these data are needed before further evaluations of health risks can be made.

Chemicals of unknown health risk are being identified in water supply and other groundwater samples. Since the few chlorinated volatile organics that have been studied present cancer risks, it is prudent to assume that the presence of any halogenated volatile organic chemical constitutes a potential health risk. However, the presence of a health risk does not necessarily mean that wells should be closed, or that treatment measures should be instituted. First, further toxicological screening studies, such as those under way by the EPA, must be examined. Second, acceptable levels of risk must be established, since a level of zero risk is unlikely to be achievable.

4.3 NASSAU-SUFFOLK 208 ORGANIC CHEMICALS SAMPLING STUDY METHODOLOGY

4.3.1 Sampling

The sampling plan for this study was devised by the Nassau-Suffolk 208 Technical Advisory Committee. All samples were collected by the Suffolk County Department of Health Services (SCDHS). A typical sampling event involved the collection of five samples for both volatile and methylene chloride (CH_2Cl_2) extraction analyses on a Tuesday, and the shipping of samples the following day.

Except for samples QA-1 to QA-24, all sample containers were prepared by ERCO. For volatile organics analyses (VOA's), new containers were used for all samples. The 250 milliliter glass containers were washed and baked at 250° C for three hours. Containers were then sealed with a teflon septum and closed with a screw cap. For samples QA-1 to QA-24, the SCDHS provided and prepared sample bottles. Samples were then collected by the SCDHS. Samples were filled to the top of the container and resealed with the teflon septa. Samples were immediately brought to 4° C and shipped to ERCO at that temperature. Samples were shipped by truck from Long Island to Cambridge. At the laboratory, VOA samples were stored at 4° C.

Samples for CH_2Cl_2 extraction were collected in five gallon bottles that were washed and CH_2Cl_2-rinsed by ERCO. The bottles were then sealed with foil-lined stoppers. The SCDHS rerinsed all bottles with CH_2Cl_2, and then with water from the medium to be sampled, prior to sampling. Two hundred milliliters of CH_2Cl_2 was added to each five gallon sample immediately after collection, and then the bottles were resealed with the foil-line stoppers.

4.3.2 Volatile Organics Analysis

Volatile Organics Analysis (VOA) is a technique which allows detection of that fraction of the organic components in water that vaporize (volatilize) at room temperature. During the past two years, considerable advances have been made in VOA techniques, Thus, the samples reported on in this report have been analyzed by an evolving technique. The final 24 samples (QA-1 to QA-24) were analyzed in a state-of-the-art system with excellent accuracy for identification of fourteen components, and with a precision of plus or minus twenty percent. The previous samples were analyzed with techniques giving somewhat lower precision and lower accuracy with respect to the resolution of some of the compounds.

The 118 samples were analyzed in four batches. Each succeeding batch was analyzed using more advanced techniques. The essential elements of the four techniques are given in Table 4—17.

The Electron Capture Detector (ECD) used for the first set of samples, JDW-1 to JDW-39, is not the ideal detector for the measurement of the suite of halogenated organics of concern in drinking water because it does not enjoy a linearity of response for most volatile components. Further, it has an uneven detection capability, *i.e.,* some volatile components are detected with great sensitivity, while others are detected with poor sensitivity.

The second set of samples, JDW-41 to PWG-28, were analyzed using a different gas chromatograph column and temperature program (see Table 4—17) and a detector that is superior to the electron capture detector in its stability, linearity of response over wide concentration ranges, and its reliability. However, sensitivity for nonhalogenated nonionized compounds is low. Significant problems were encountered in the use of the sample concentrator hardware. These problems resulted in the inability to resolve some of the chemically similar components. This showed up as apparently very high chloroform levels. Compounds which should have eluted just prior to and following chloroform appeared as one large "chloroform peak." Similar problems have been encountered by virtually all users of this hardware. How-

Table 4—12

INDUSTRIAL ORGANIC CHEMICAL USAGE IN NASSAU COUNTY: STATUS AS OF NOVEMBER 1977
(Gallons/Year)

Industry	No. Companies	Standard Industrial Classification No.	Priority I Total	Trichloroethylene	Benzene	Tetrachloroethylene	Toluene	Methylene Chloride	Priority II Total	1, 1, 2-Trichloroethane	Xylene	Priority III Total	1, 1, 1-Trichloroethane	Acetone	Freons	MEK	Miscellaneous
Printers	93	(271-279)	1,824		174		660	990	312	312		55,349	120	275		20	54,934
Electrical & Electronic Products	53	(361-365)	70,502	15,167	10	3,800	1,525	50,000	19,416	19,356	60	242,332	2,720	2,440	2,220	7,412	227,540
Mechanical & Engine Repair	50	(353-371-373)	3,482	2,245		625		612	135		135	22,375	102		360	26	21,807
Tool & Machine	88	(345, 346 356, 359)	24,882	14,804	8	5,400	3,430	1,160	7,100	5,000	2,100	70,857	2,600	85		5,530	62,642
Consumer Products	65	(386, 355, 395, 209, 229, 239, 284)	14,536		34	11,000	1,162	2,340	205	55	150	68,751	1,890	59			66,802
Chemical Products	15	(281-289)	409,560	5,400	170	3,080	166,000	234,910	21,600	19,000	2,600	297,770	4,910		4,500		288,360
Misc. Manufacturers	80	(399)	13,982	8,092	65	885	4,190	780	86,230	75,955	10,275	177,070	17,380	3,210	220	4,823	151,437
Aerospace	1	(3721-3761) (3728)	125,070	103,850			21,220		1,230		1,230	60,610	23,375		3,000	19,100	15,135
Dry Cleaners (Extrapolated)	400		350,000			350,000											
Totals	**845**		**1,013,838**	**149,638**	**461**	**374,760**	**198,187**	**290,792**	**136,228**	**119,678**	**16,415**	**995,114**	**53,177**	**6,069**	**10,300**	**36,911**	**888,657**

Source: NCDH, 1978.

Table 4–13

CATEGORIES OF KNOWN OR SUSPECTED ORGANIC CHEMICAL CARCINOGENS FOUND IN DRINKING WATER

Compound	Highest observed concentrations in finished water in U. S. (μg/l)	Upper 95% Confidence estimate of lifetime cancer risk per μg/liter
Human Carcinogen		
Vinyl Chloride	10	5.1×10^{-7}
Suspected Human Carcinogens		
Benzene	10	ID
Benzo (a) pyrene	D	ID
Animal Carcinogens		
Dieldrin	8	2.6×10^{-4}
Kepone	ND	4.4×10^{-4}
Heptachlor	D	4.2×10^{-5}
Chlordane	0.1	1.8×10^{-5}
DDT	D	1.2×10^{-5}
Lindane (γ-BHC)	0.01	9.3×10^{-6}
α-BHC	D	6.5×10^{-6}
β-BHC	D	4.2×10^{-6}
PCB (Aroclor 1260)	3	3.1×10^{-6}
ETU	ND[3]	2.2×10^{-6}
Chloroform	366	3.7×10^{-7}
Carbon tetrachloride	5	1.5×10^{-7}
PCNB	ND	1.4×10^{-7}
Trichloroethylene	0.5	1.3×10^{-7}
Diphenylhydrazine	1	ID
Aldrin	D	ID
Suspected Animal Carcinogens		
Bis (2-chloroethyl) ether	0.42	1.2×10^{-6}
Endrin	0.08	ID
Heptachlor epoxide	D	ID

ID = Insufficient data to permit a statistical extrapolation of risk.
ND = Not detected.
D = Detected but not quantified.
Source: NAS, 1977.

ever, these problems should not affect the validity of the data obtained for these 34 samples for other compounds eluting after chloroform.

The third set of samples, PWG-29 to PWG-55, were analyzed after operating modifications of the sample concentrator hardware were made. Gas flow rates were changed to improve peak resolution. However, even with these advances in analytical procedures, there was difficulty in resolving 1, 2 dichloroethane from chloroform and Cl_3–from CCl_4. These substances are very close in their relative retention indices. All other volatile compounds were resolved in this third set of samples.

The fourth and final set of samples, QA-1 to QA-24, were analyzed using a drastically modified (ERCO design) purge and trap unit and a Tracor 700 Hall detector with significantly altered operating conditions.[2] Modifications were also made in the gas chromatography technique. These two modifications resulted in a greatly increased ability to resolve the more volatile compounds. Temperature programming and gas flow changes were also instituted to optimize resolution. The completely modified system was tested with two EPA-supplied performance evaluation samples. Replicate analyses of these samples showed reproducible resolution of all peaks to within twenty percent.

4.3.3 Methylene Chloride Extractable Organics Analysis

The methylene chloride (CH_2Cl_2) extractable organics have an approximate boiling range of 80° C to 260° C, and correspond to the neutral and acid extractables in the EPA protocol for priority pollutants.

The screening for organic contamination was carried out by the extraction of the five-gallon water samples followed by gas chromatograph analysis. The 112 samples were analyzed in two batches. The procedures followed differed somewhat in the extraction stage for the two batches.

The first batch included samples JDW-1 to PWG-15. For these samples, extraction of the sample was carried out under neutral conditions. Some 600 ml of nanograde CH_2Cl_2 was added to the sample. After thorough mixing, the CH_2Cl_2 was siphoned through a teflon tube to a separating funnel to separate the extract from any water. The extract was then reduced to approximately 5cc in a Kuderna-Danish evaporator. The extracts were further concentrated under a stream of pre-purified nitrogen.

The second batch included samples PWG-16 to QA-24. For these samples, both neutral and acid extractions were performed. The two extracts were then combined, since sufficient analytical time was not available to generate two separate chromatograms for each sample. The procedure was as follows: first, 300 cc of nanograde CH_2Cl_2 was added to the sample; second, after thorough mixing and settling, the CH_2Cl_2 was siphoned through a teflon tube into a CH_2Cl_2-rinsed glass bottle; third, ten cc of sulphuric acid was added to the remaining water phase; fourth, 300 cc more of CH_2Cl_2 was added, mixed, and allowed to settle; fifth, the solvent layer was siphoned through a teflon tube into the bottle already containing the neutral extract;

Table 4—14

ORGANIC PESTICIDES AND OTHER ORGANIC CONTAMINANTS FOUND IN DRINKING WATER, WITH SUPPORTING DATA ON CHRONIC TOXICITY

Compound	Maximum Observed Concentrations in H_2O, µg/l	Maximum Dose Producing No Observed Adverse Effect mg/kg/day	Uncertainty Factor†	ADI†† mg/kg/day	Suggested No-Adverse Effect Level from H_2O, µg/l Assumptions* 1	2
2, 4-D	0.04	12.5	1,000	0.0125	87.5	4.4
2, 4, 5-T		10.0	100	0.1	700	35.0
TCDD		10^{-5}	100	10^{-7}	7×10^{-4}	3.5×10^{-5}
2, 4, 5-TP	detected**	0.75	1,000	0.00075	5.25	0.25
MCPA		1.25	1,000	0.00125	8.75	0.14
Amiben		250	1,000	0.25	1,750.0	87.5
Dicamba		1.25	1,000	0.001125	8.75	0.14
Alachlor	2.9	100	1,000	0.1	700.0	35.0
Butachlor	0.06	10	1,000	0.01	70.0	3.5
Propachlor		100	1,000	0.1	700.0	35.0
Propanil		20	1,000	0.02	140.0	7.0
Aldicarb		0.1	100	0.001	7.0	0.35
Bromacil		12.5	1,000	0.0125	87.5	4.4
Paraquat		8.5	1,000	0.0085	59.5	2.98
Trifluralin (also for Nitralin and Benefin)	detected**	10	100	0.1	700.0	35.0
Methoxychlor		10	100	0.1	700.0	35.4
Toxaphene		1.25	1,000	0.00125	8.75	0.44
Azinphosmethyl		0.125	10	0.0125	87.5	4.4
Diazinon		0.02	10	0.002	14.0	0.7
Phorate (also for Disulfoton)		0.01	100	0.0001	0.7	0.035
Carbaryl		8.2	100	0.082	574	28.7
Ziram (and Ferbam)		12.5	1,000	0.0125	87.5	
Captan		50	1,000	0.05	350	17.5
Folpet		160	1,000	0.16	1120	56.0
HCB	6.0	1	1,000	0.001	7	0.35
PDB	1.0	13.4	1,000	0.0134	93.8	4.7
Parathion (and Methyl parathion)		0.043	10	0.0043	30	1.5
Malathion		0.2	10	0.02	140	7.6
Maneb (and Zineb)		5.0	1,000	0.005	35	1.75
Thiram		5.0	1,000	0.005	35	1.75
Atrazine	5.0	21.5	1,000	0.0215	150	7.5
Propazine	detected**	46.4	1,000	0.0464	325	16.0
Simazine	detected**	215.0	1,000	0.215	1,505	75.25
di-n-butyl phthalate	5.0	110	1,000	0.11	770	38.5
di (2-ethyl hexyl) phthalate	30.0	60	100	0.6	4,200	210.8
hexachlorophene	0.01	1	1,000	0.001	7	0.35
methyl methacrylate	1.0	100	1,000	0.1	700	35.2
pentachlorophenol	1.4	3	1,000	0.003	21	1.25
styrene	1.0	133	1,000	0.133	931	46.5

† *Uncertainty factor—the factor of 10 was used where good chronic human exposure data was available and supported by chronic oral toxicity data in other species, the factor of 100 was used where good chronic oral toxicity data were available in some animal species, and the factor of 1000 was used with limited chronic toxicity data or when the only data available were from innalation studies.*

†† *Acceptable Daily Intake (ADI)—Maximum dose producing no observed adverse effect divided by the Uncertainty factor.*

* *Assumptions: Average weight of human adult = 70 kg. Average daily intake of water for man = 2 liters.*

1. *20% of total ADI assigned to water*
   30% from other sources
2. *1% of total ADI assigned to water*
   99% from other sources

** *Detected but not quantified.*

Source: NAS, 1977.

Table 4–15

ORGANIC PESTICIDES AND OTHER ORGANIC CONTAMINANTS FOUND IN DRINKING WATER, WITH INSUFFICIENT DATA ON CHRONIC TOXICITY

	Highest Concentration in Finished Water, μg/l
Acetaldehyde	0.1
Bromobenzene	detected
Bromoform	detected
Carbon disulfide	detected
Chloral	5.0
Chlorobenzene	5.6
Cyanogen chloride	0.1
1, 2-Dichloroethane	21.0
2, 4-Dichlorophenol	36.0
2, 4-Dimethylphenol	detected
e-Caprolactam	detected
Hexachloroethane	4.4
o-Methoxyphenol	detected
Methyl chloride	detected
Methylene chloride	7.0
Phenylacetic acid	4.0
Phthalic anhydride	detected
Propylbenzene	<5.0
t-Butyl alcohol	0.01
Tetrachloroethane	4.0
Tetrachloroethylene	<5.0
Toluene	11.0
Trichlorobenzene	1.0
1, 1, 2-Trichloroethane	detected
Nicotine	3.0
Cyanazine	detected
xylene	<5.0

detected = detected but not quantified
Source: NAS, 1977.

and sixth, the CH_2Cl_2 extract was passed through a separating funnel and reduced in volume, as was done with the first batch.

Each extract was then analyzed by gas chromatography using a Hewlett-Packard Model 5840 GC with a flame ionization detector (FID). The HP 5840 was equipped with an automatic integrator which computed the amounts of individually resolved compounds. The column used was a 6-foot SP-2100 prepared by Supelco, Inc. Gas chromatographic conditions were as follows:

T_{inj} = 260° C
T_{det} = 300° C
T_{oven} = 50° C for 4 minutes
50–250° C at 8°/minute
250° C isothermal for 20 minutes

Table 4–16

ORGANIC CONTAMINANTS FOUND IN DRINKING WATER, WITH INFORMATION ON CHRONIC TOXICITY LACKING

Compound	Highest Concentration in Finished Water, μg/l	Highest Concentration in Raw Water, μg/l
1, 2-Bis (chloroethoxy) ethane	0.03	
Bis (2-chloroisopropyl) ether	1.58	
Bromochlorobenzenes	detected	
Bromodichloromethane	116	11
Butyl bromide	detected	
Chloroethyl methyl ether	detected	
Chlorodibromomethane	100	1.4
Chlorohydroxybenzophenone	detected	
Chloromethyl ethyl ether	detected	
Chloropropene	detected	
Crotonaldehyde	5.0	
Dibromobenzene	detected	
Dibromodichloroethane	0.63	
1, 3-Dichlorobenzene	<3.0	
Dichlorodifluoroethane	detected	
Dichloroiodomethane	0.5	
1, 1-Dichloro-2-hexane	1.0	
1, 2-Dichloropropane	<1.0	
1, 3-Dichloropropene	<1.0	
1, 2-Dimethoxybenzene	detected	
4, 6-Dinitro-2-aminophenol	detected	
Dioctyladipate	20.0	
Hexachloro-1, 3-butadiene	0.07	
Isodecane	5.0	
Metachloronitrobenzene	detected	
Methylstearate	detected	
Nonane	4.0	
Octyl chloride	detected	
Pentachlorophenyl methyl ether	0.1	
1, 1, 3, 3-Tetrachloroacetone	1.0	1.0
2, 4, 6-Trichlorophenol	detected	
Trimethylbenzene	6.1	

Source: NAS, 1977.

Table 4—17

SUMMARY OF VOLATILE ORGANICS ANALYSIS (VOA) METHODS AND INSTRUMENTATION

	Sample Batch			
	JDW-1 to JDW-39	JDW-41 to PWG-28	PWG-29 to PWG-55	QA-1 to QA-24
Purge & Trap Instrument	Specially-fabricated Bellar & Lichtenberg apparatus[1]	Tekmar Liquid Sample Concentrator[2]	Tekmar Liquid Sample Concentrator	ERCO-designed purge trap
Gas Chromatograph	Perkin-Elmer 3920	Perkin-Elmer 3920	Perkin-Elmer 3920	Perkin-Elmer 3920
Column	6' Chromasorb 101	0.2% Carbowax 1500 on 60/80 Carbopac C	0.2% Carbowax 1500 on 60/80 Carbopac C	8' Chromasorb 101 1' precolumn 3% carbowax 1500 on 60/80 Carbopac C Chromasorb WAW
Detector	Perkin-Elmer ECD	Tracor 700 Hall[2]	Tracor 700 Hall	Tracor 700 Hall
Temperature Program	50°–200° C at 8°/min 2 min at 200° C	60°–160° C @ 8°/min 2 min at 160° C	60°–160° C @ 8°/min 4 min at 160° C	30°–160° C @ 8°/min 2 min at 160° C

[1] *Drs. Bellar and Lichtenberg were consulted in the construction of this unit. The work was done in connection with EPA Contract 68-01-2925 reported on in "Accumulation of Organic Pollutants by Solid Adsorbants," EPA Publication No. 560/7-77-002. See Bellar and Lichtenberg (1974).*

[2] *These two pieces of apparatus were recommended by EPA-Cincinnati which had made a similar instrumentation conversion at approximately the same time.*

Representative samples were subjected to analysis by combined gas chromatography/mass spectrometry (GC/MS) using the same analytical conditions as for the GC analysis. GC/MS was performed on an average of one sample in seven.

Concentrations of individual organic components were determined by integration of peak areas. A response factor, which relates area to amount of compound, was calculated daily by injections of two standard hydrocarbons, nC_{14} and nC_{28}. The response factor to all classes of organics was assumed to be the same.

Standards for several hydrocarbons were run daily to verify retention times and FID sensitivity. The nC_{14} and nC_{28} standards were run daily to verify calibration of the column and detector. Blanks were run daily, and after samples showing significant concentrations of contaminants.

4.3.4 Sample Storage

Samples for volatile organics analysis (VOA) were stored refrigerated in sealed glass containers filled to the brim. Samples for non-volatile organics analysis were stored at room temperature in glass containers sealed with foil-lined stoppers.

Storage times, between sample receipt and sample analysis, ranged from 20 days to over 6 months during the 208 organic chemicals study. Ideally, in a routine operating situation, storage times would be less than a week. However, VOA is not, as yet, a routine procedure, and storage was required in some cases. A previous study (Brass *et al.*, 1977) showed that extensive sample storage does not significantly affect analytic results. Thus, it is unlikely that sample storage significantly affected VOA sample results during the 208 Study.

4.3.5 Quality Control and Detection Parameters

Several quality control measures were followed to ensure the validity of the results. These included routine machine quality control procedures, analysis of control samples, and analysis of a series of EPA performance review samples.

For VOA, standard quality control included daily runs of a series of standards for each volatile compound screened, daily runs of blanks, and runs of blanks after each sample containing significant concentrations of contaminants.

For CH_2Cl_2 extracts, standard quality control included daily runs of

standards for nC_{14} and nC_{28} alkanes to verify calibration of the column and detector, daily runs of other standards to verify retention times and FID sensitivity, and the frequent use of blanks. Control samples included samples of distilled water and precipitation.

Several EPA performance review samples for VOA were run.[3] Two were run before and during analysis of samples PWG-29 to PWG-55. These samples showed some lack of resolution at the low end of the chromatogram. Results were very good for chromatograms above chloroform. Third and fourth samples run before analysis of samples QA-1 to QA-24 showed very good qualitative and quantitative results for all parts of the spectrum. The results suggested that samples run under those conditions, samples QA-1 to QA-24, were accurate to within about 20 percent.

The routine detection limit of the FID is 30 nanograms. This has been verified by ERCO for their instruments. A recent experimental program (ERCO, 1976) showed a recovery efficiency of approximately 70 percent for 20-liter samples. At that recovery efficiency, the detection of 30 nanograms of material translates to .3 parts per billion. Thus approximately .3 ppb is the minimum detectable organic contaminant concentration for the FID.

ERCO also participated in a quality assurance program along with New York State Department of Health labs in Albany and Stony Brook, and an EPA Laboratory at Ada, Oklahoma. The New York State labs have been used by Nassau and Suffolk County to analyze public drinking water supply samples for volatile organics. The EPA lab at Ada has been in the forefront of research in volatile organics sampling and analysis methodologies.

Samples QA-1 through QA-13, collected by Suffolk County Department of Health Services personnel, were utilized. Every attempt was made to ensure that each laboratory was given identical samples, and each lab was instructed to analyze the samples the morning after they were received. Each lab used its own analysis procedure; ERCO's technique is outlined in Section 4.3.2 (see Table 4–17).

The results of the program indicated that a wide range of values were obtained for many of the samples. This range was even greater than an order of magnitude in some cases. The cause of this appears to be the analytical technique used by each lab. The New York State labs showed very similar results using identical analytical procedures. EPA in Ada, Oklahoma, also produced results within tolerable limits (except for QA-10) of those produced by NYS. As a whole, the results from ERCO tended to be greater than the results produced by the other labs and, in some instances, substantially greater. It must be noted that the correct results are not known since these were naturally occurring waters and not laboratory prepared standards.

From the results obtained, it is apparent that great care must be taken when a regulatory agency uses organic test results to either open or close a public supply well. What is required is a standard method, as has been developed for other chemical constituents, in order to achieve reproducible results. Such a standard should be indicative of the danger posed by these compounds, and should be compatible with the state-of-the-art of the analytical procedure, as well as its confidence levels.

Ada Labs consistently was able to extract dichloromethane and 1, 2 dichloromethylene. In verbal conversations with ERCO, EPA indicated that dichloromethane was found, but not reported, since that chemical is used as a fixative for the non-volatile faction and would be present in the sampling vehicle as an air pollutant. No other labs identified these two organics. NYS Stony Brook detected 1, 1, 2 trifluorotrichloroethane, whereas no other lab detected this compound.

4.4 NASSAU-SUFFOLK 208 ORGANIC CHEMICALS SAMPLING STUDY RESULTS

4.4.1 Sampling Data

The organic chemicals detected in the 208 sampling program are presented in full in Tables 4–18 through 4–23. Each separate table presents results from a set of samples analyzed under one set of analytical conditions. In some cases, stations were not sampled for both volatiles and methylene chloride extractables. In some other cases, samples were collected, but one or the other of the sample fractions included a sample matrix which prevented analysis.

For the VOA, four different tables are given. Table 4–18 presents those samples analyzed using the ECD detector. The suite of compounds that can be detected using the ECD detector are not the same as those detected when using the Hall detector. Tables 4–19 through 4–21 give results for three sets of operating conditions using the Tekmar purger and Hall detector. The technique became more refined as each set was run. Thus, the set presented in Table 4–21 was run under conditions allowing the most accuracy and resolution. Samples included in Table 4–18 can only, at best, be interpreted with respect to the presence or absence of a contaminant. Samples included in Tables 4–19 through 4–21 can be interpreted with respect to levels observed as well as the presence or absence of contaminants. The quantitative accuracy of samples QA-1 to QA-24, in particular, is backed up by a highly rigorous quality control program (see Section 4.3.5).

For the methylene chloride extractables, the samples were analyzed in two batches, which are presented in Tables 4–22 and 4–23. The methodology used for analysis of each batch was slightly different, as discussed in Section 4.3.3. In the second batch, some of the identified substances were classified to a greater level of detail than in the first. As long as this difference in treatment of the two sets of data is taken into account, the two batches of samples are comparable for purposes of interpretation.

4.4.2 Interpretation of Summary Statistics

The 124 samples taken represent 102 different sample stations. In most cases, only one sample was collected at each station. Thus, there is little

Table 4—18

ANALYTICAL RESULTS FOR SAMPLES JDW-1 TO JDW-39
(in μg/l)

Volatile Organic Compounds in Order of Elution

SAMPLE*	MEDIUM OR AQUIFER**	Diethyl Ether	Chloro-form	Tri-chloro-ethane	Tri-chloro-ethylene	Tetra-chloro-ethylene
JDW-1	Water Distribution	ND	1	ND	<1	<1
JDW-2	Glacial	ND	1	ND	1	1
JDW-3	Glacial	1	2	ND	2	1
JDW-4	Glacial	4	2	ND	1	1
JDW-5	Glacial	ND	1	ND	1	<1
JDW-6	Glacial	ND	1	ND	1	1
JDW-7	Glacial	ND	<1	ND	<1	1
JDW-8	Glacial	ND	1	ND	1	1
JDW-9	Glacial	2	2	ND	2	1
JDW-10	Glacial	ND	1	ND	1	<1
JDW-11	Glacial	3	1	ND	2	2
JDW-13	Glacial	<1	1	ND	1	ND
JDW-14	Glacial	ND	1	ND	1	<1
JDW-15	Glacial	ND	1	ND	1	<1
JDW-16	Glacial	3	2	ND	2	1
JDW-17	Glacial	ND	1	ND	1	1
JDW-18	Glacial	ND	1	ND	1	1
JDW-19	Glacial (ws)	ND	1	ND	1	1
JDW-20	Glacial (ws)	1	1	ND	1	<1
JDW-21	Glacial (ws)	ND	<1	ND	ND	<1
JDW-22	Glacial (ws)	ND	2	ND	1	1
JDW-23	Glacial	ND	2	ND	1	<1
JDW-24	Glacial	ND	2	ND	1	<1
JDW-25	Magothy	<1	2	ND	1	<1
JDW-26	Glacial	ND	2	ND	1	<1
JDW-27	Glacial	<1	1	ND	1	<1
JDW-28	Glacial	<1	1	ND	1	1
JDW-29	Glacial	ND	2	ND	2	<1
JDW-30	Glacial	ND	1	ND	1	<1
JDW-31	Effluent	ND	1	ND	1	<1
JDW-32	Effluent	ND	2	ND	2	<1
JDW-33	Magothy (ws)	ND	<1	ND	<1	<1
JDW-34	Magothy (ws)	<1	1	ND	1	1
JDW-35	Magothy (ws)	<1	2	ND	1	<2
JDW-36	Glacial	ND	2	ND	1	<1
JDW-37	Magothy (ws)	<1	1	ND	<1	<1
JDW-38	Magothy (ws)	ND	<1	ND	<1	<1
JDW-39	Magothy (ws)	ND	1	ND	1	<1

**Samples were analyzed using a Bellar-Lichtenberg type purge and trap method on a Perkin-Elmer 3920 G. C., and a Perkin-Elmer Electron Capture Detector (ECD).*

***(ws) denotes water supply.*

statistical validity associated with looking at the contaminant levels at individual sites. For example, one should reject from the onset the notion that a given aquifer site or well is contaminated, or that a specific water supply well should be shut down. Such types of judgements would need to be based on averages of several measurements. Later in this section, the establishment of the minimum number of samples needed to calculate such averages, and hypotheses about patterns at individual well sites (that need to be checked by performing further sampling), are discussed.

Results obtained by sampling twenty-one sampling stations twice for methylene chloride extractable substances showed that considerable variation occurs. Similar comparisons for the volatiles from this program were not possible because of the methodology changes made. However, the same sort of comparisons for Nassau County Health Department data were made, and showed similar variations. These results point out clearly that values from one-time sampling events cannot be confidently assigned to individual wells.

The sampling results have been analyzed by media and chemical species in Tables 4—24 through 4—26.

4.4.2.1 Water Media Characteristics.

Glacial Aquifer. Over one-third of the sixty wells tested were significantly contaminated by volatiles, and over one-half by methylene chloride extractables (see Table 4—24). One-fifth of the wells contained organic contaminants at the 50 parts per billion level, the level currently in use as a cancer health risk threshold (see Section 4.2). The sample size was sufficiently large for there to be little doubt that organic contaminants reside in the Glacial aquifer at statistically significant levels.

Magothy Aquifer. Volatile organics appear to have penetrated to the Magothy aquifer to a statistically significant extent; CH_2Cl_2 extractables were not measured at significant ($\geq$ 10 μg/l) levels (See Table 4—24). However, the sample size of Magothy wells tested was marginally small. Hence, no firm conclusions were possible from these data.

Effluent. Volatile and CH_2Cl_2 extractable organics were present in the effluents that were sampled (see Table 4—24). Most of these were sewage treatment plant effluents, some of which were recharged. The halogenated volatile organics may have resulted from the chlorination of the effluents.

Lloyd Aquifer, Water Supplies, and Surface Waters. The number of samples collected was too small to allow statistical analyses (see Table 4—24).

4.4.2.2 Chemical Species Characteristics.

Trichloroethylene; Chloroform; 1, 1, 1 Trichloroethane; and Tetrachloroethylene. Three of these substances occurred in at least fifty percent of the stations tested (see Table 4—25). Incidence of 50 parts per billion observations was over four percent. Many of the occurrences noted in this study were in Glacial aquifer wells. However, sampling of Nassau County water wells (NCDH, 1977a) showed a statistically significant level of occurrence of these contaminants in water supply wells, many of which draw from the Magothy. As noted in Section 4.2, chloroform and trichloroethylene

Table 4—19

ANALYTICAL RESULTS FOR SAMPLES JDW-41 TO PWG-28

(in μg/l)

SAMPLE*	MEDIUM	Unresolved compounds including chloroform, 1,1 dichloroethylene and 1,1 dichloroethane**	Carbon Tetrachloride	Bromodichloromethane	Trichloroethylene	Dibromochloromethane	Trichloroethane	Bromoform	Tetrachloroethylene
		Volatile Organic Compounds in Order of Elution							
JDW-41	Magothy	>1	4	<1	89	8	28	8	3
JDW-42	Effluent	>1	<1	ND	3	ND	ND	ND	<1
JDW-43	Water Distribution	>1	1	ND	5	3	4	2	6
JDW-44	Water Distribution	>1	1	<1	6	ND	4	ND	4
JDW-45	Water Distribution	>1	2	ND	6	47	4	19	2
JDW-50	Effluent	ND	<1	ND	<1	ND	ND	ND	ND
PWG-1	Glacial	>1	3	<1	79	3	34	ND	2
PWG-2	Glacial	>1	3	3	62	2	10	ND	2
PWG-3	Glacial	>1	2	1	44	2	7	ND	1
PWG-4	Glacial	>1	1	ND	19	<1	4	ND	ND
PWG-5	Glacial	>1	1	<1	18	<1	2	ND	ND
PWG-6	Glacial	>1	1	<1	13	<1	1	ND	ND
PWG-7	Glacial	>1	2	<1	75	3	24	ND	<1
PWG-8	Glacial	>1	28	ND	6	<1	<1	ND	2
PWG-10	Glacial	>1	1	ND	13	ND	1	ND	ND
PWG-11	Glacial	>1	2	ND	63	ND	14	ND	ND
PWG-12	Glacial	>1	1	ND	22	3	3	ND	ND
PWG-13	Effluent	>1	<1	ND	16	3	60	ND	ND
PWG-14	Glacial	>1	1	ND	8	ND	1	ND	ND
PWG-15	Effluent	>1	3	<1	58	2	26	ND	<1
PWG-16	Glacial	>1	<1	ND	2	ND	1	ND	<1
PWG-17	Effluent	>1	2	ND	57	2	35	ND	<1
PWG-18 (19)	Glacial	>1	3	<1	11	2	1	ND	ND
PWG-19 (18)	Water Distribution	>1	1	<1	50	<1	22	ND	<1
PWG-20	Glacial	>1	2	<1	60	2	18	<1	<1
PWG-21	Control	>1	<1	ND	5	ND	1	ND	<1
PWG-22	Control	>1	1	ND	7	ND	1	ND	<1
PWG-23	Control	>1	1	ND	12	<1	2	ND	<1
PWG-25	Glacial	<1	<1	ND	<1	ND	ND	ND	ND
PWG-26	Glacial	>1	<1	ND	1	ND	<1	ND	<1
PWG-27	Effluent	>1	1	ND	12	1	21	ND	ND
PWG-28	Effluent	>1	2	ND	12	ND	1	ND	ND

Samples were analyzed using a Tekmar liquid sample concentrator or a Perkin-Elmer 3920 G. C. and a Tracor 700 Hall Electrolytic Conductivity Detector. This method did not resolve out compounds eluting before chloroform; hence, the first column of the table represents a group of compounds

***These results are not interpretable since quantification of mixed peaks is inaccurate, but are included for completeness.*

Table 4—20

ANALYTICAL RESULTS FOR SAMPLES PWG-29 TO PWG-55
(in µg/l)

SAMPLE NUMBER	MEDIUM *	Volatile Organic Compounds in Order of Elution												
		Tri-chloro-fluoro-methane	1,1 di-chloro-ethylene	1,1 di-chloro-ethane	Chloro-form	1,2 di-chloro-ethane	1,1,1 tri-chloro-ethane	Carbon tetra-chloride	Bromo di-chloro-methane	Tri-chloro-ethylene	Di-bromo-chloro-methane	Bromo-form	Tetra chloro-ethylene	1 chloro-propane
PWG 29	Magothy (ws)	ND	ND	ND	38	ND	4	ND	ND	13	ND	ND	ND	ND
PWG 30	Magothy (ws)	ND	ND	ND	12	ND	43	ND	ND	221	ND	5	6	ND
PWG 31	Glacial	UNRESOLVED COMPONENTS - NOT ANALYZABLE												
PWG 32	Glacial	ND	ND	ND	6	ND	19	ND	ND	14	ND	1	ND	ND
PWG 33	Glacial	ND	ND	ND	41	ND	4	ND	ND	13	ND	ND	ND	ND
PWG 34	Glacial	UNRESOLVED COMPONENTS - NOT ANALYZABLE												
PWG 35	Glacial	ND	ND	ND	48	ND	5	ND	ND	15	ND	ND	ND	ND
PWG 39	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 40	Effluent	ND	ND	ND	11	ND	21	ND	ND	4	ND	ND	ND	ND
PWG 41	Glacial	ND	ND	ND	3	ND	ND	ND	ND	<1	ND	ND	ND	ND
PWG 42	Glacial	ND	ND	ND	28	ND	3	ND	ND	11	ND	ND	ND	ND
PWG 43	Lake	ND	ND	ND	14	ND	2	ND	ND	6	ND	ND	ND	ND
PWG 44	Lagoon	ND	ND	ND	8	ND	112	ND	ND	7	ND	ND	31	ND
PWG 45	Effluent	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 46	Glacial	ND	ND	ND	10	ND	7	ND	ND	5	ND	ND	<1	ND
PWG 47	Lloyd	ND	ND	ND	24	ND	3	ND	ND	12	ND	ND	ND	ND
PWG 48	Magothy	ND	ND	ND	14	ND	2	ND	ND	7	ND	ND	ND	ND
PWG 49	Influent to Recharge Basin	ND	ND	ND	88	ND	20	ND	ND	3	ND	ND	21	ND
PWG 50	Glacial	ND	ND	ND	4	ND	2	ND	ND	4	ND	ND	84	ND
PWG 51	Glacial	ND	ND	ND	2	ND	8	ND	ND	1	ND	ND	24	27
PWG 52	Glacial	ND	ND	ND	50	ND	ND	ND	ND	1	ND	ND	ND	ND
PWG 53	Glacial	ND	ND	ND	17	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 55	Glacial	ND	ND	ND	40	ND	9	ND	ND	10	ND	ND	ND	ND

Samples were analyzed using a Tekmar liquid sample concentrator with modifications on a Perkin-Elmer 3920 G. C. and a Tracor 700 Hall Electrolytic Conductivity detector. Methodology was modified from that used for samples JDW-41 to PWG-28 allowing a better peak resolution.

**(ws) denotes water supply.*

Table 4—21

ANALYTICAL RESULTS FOR SAMPLES QA-1 TO QA-24
(in μg/l)

SAMPLE NUMBER	MEDIUM*	Volatile Organic Compounds in Order of Elution										
		Freon-11 Trichloro-fluoro-methane	1,1 Di-chloro-ethylene	1,1 Di-chloro-ethane	Chloro-form $CHCl_3$	1,2 Di-chloro-ethane	1,1,1 Tri-chloro-ethane	Carbon Tetra-chloride	Bromodi-chloro-methane	Tri-chloro-ethylene	Dibromo-chloro-methane	Tetra-chloro-ethylene
QA-1	Recharge Basin	ND	ND	ND	50	ND	19	ND	4	80	ND	3
QA-2	Glacial	2	3	30	10	ND	275	ND	1	275	ND	218
QA-3	Glacial	ND	2	14	ND	ND	104	ND	592	ND	ND	88
QA-4	Magothy (ws)	ND	ND	ND	14	2	4	1	ND	34	ND	ND
QA-5	Magothy (ws)	ND	ND	ND	ND	ND	40	ND	ND	ND	ND	ND
QA-6	Magothy (ws)	ND	ND	ND	145	ND	32	ND	17	122	ND	3
QA-7	Magothy (ws)	6	ND	ND	45	4	11	8	1	8	ND	12
QA-8	Recharge Basin	ND	ND	14	ND	ND	56	ND	ND	23	ND	10
QA-9	Glacial	ND	ND	5	1	ND	14	ND	ND	2	ND	150
QA-10	Magothy (Ws)	ND	2	ND	ND	1	7	ND	ND	109	ND	10
QA-11	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	ND
QA-12	Glacial	ND	ND	ND	1	ND	ND	ND	ND	1	ND	150
QA-13	Glacial	ND	ND	ND	2	ND	ND	ND	ND	400	ND	5
QA-14	Quench Water	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND
QA-15	Recharge Basin Influent	ND	ND	ND	1	ND	ND	ND	ND	1	ND	ND
QA-16	Leachate	NOT ANALYZABLE										
QA-17	Glacial (ws)	ND	ND	ND	22	ND	ND	ND	17	ND	7	ND
QA-19	Glacial (ws)	ND	2	5	40	ND	16	8	ND	285	ND	19
QA-20	Glacial	2	ND	ND	1	ND	3	ND	ND	1	ND	2
QA-21	Magothy	ND	ND	ND	25	ND	290	ND	ND	3	ND	5
QA-22	Magothy	1	ND	ND	2	ND	ND	ND	ND	ND	ND	ND
QA-23	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA-24	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA-25	Precipitation 11/7-8/77	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND

Samples were analyzed by the ERCO-Scott Purge and Trap method on a Perkin-Elmer Model 3920 G. C. and a Tracor 700 Hall Electrolytic Conductivity detector. This set of samples was run on a system which successfully ran an EPA-Edison, NJ performance sample with resolution of all peaks. Extra resolution of peaks was brought about by instrument and methodology (gas flow, etc.) modifications which allowed identification of a larger number of chlorinated species. All numbers are in parts per billion.

**(ws) denotes water supply.*

Table 4–22

METHYLENE CHLORIDE EXTRACTABLE ORGANIC FRACTION FOR SAMPLES JDW-1 TO PWG-15
(in μg/l)

SAMPLE	MEDIUM OR AQUIFER*	Naph-thalene	Methyl Naph-thalene	Dimethyl Naph-thalene	Ethyl Toluene	C_4 Benzene	Fluo-rene	Dibutyl Phthalate	Octyl phenols	Dioctyl Phthalate	Bromo form	Penta-chloro-propane	Dibutoxy-ethoxy Ethyl Methane	Plasticizer (composi-tion uni-dentified)
JDW-1	Water Distribution	<1	1	<1	ND	ND	ND	3	3	ND	ND	ND	ND	ND
JDW-2	Glacial	ND	2	1	ND	ND	1	2	11	ND	ND	ND	ND	ND
JDW-3	Glacial	ND	2	1	ND	ND	1	1	4	ND	ND	ND	ND	ND
JDW-4	Glacial	17	8	1	2	ND	1	12	11	ND	ND	ND	ND	3
JDW-5	Glacial	13	16	3	1	ND	1	15	8	ND	ND	ND	ND	3
JDW-6	Glacial	1	4	1	1	1	<1	6	2	ND	ND	ND	ND	ND
JDW-7	Glacial	8	6	8	1	4	1	95	3	ND	ND	ND	ND	ND
JDW-8	Glacial	2	6	4	1	2	1	67	1	ND	ND	ND	ND	ND
JDW-9	Glacial	1	4	4	<1	2	1	58	2	ND	ND	ND	ND	ND
JDW-10	Glacial	1	3	2	ND	<1	<1	37	1	ND	ND	ND	ND	ND
JDW-11	Glacial	1	2	2	ND	1	6	30	1	ND	ND	ND	ND	ND
JDW-13	Glacial	12	28	19	2	19	1	ND	30	ND	ND	ND	ND	5
JDW-14	Glacial	2	6	5	<1	4	1	92	109	ND	ND	ND	ND	ND
JDW-15	Glacial	7	18	16	4	4	3	171	4	ND	ND	ND	ND	3
JDW-16	Glacial	1	5	4	ND	1	1	80	1	ND	ND	ND	ND	ND
JDW-17	Glacial	1	5	4	<1	1	<1	73	1	ND	ND	ND	ND	ND
JDW-18	Glacial	3	3	2	ND	ND	ND	44	1	ND	ND	ND	ND	ND
JDW-19	Glacial (ws)	ND	ND	ND	ND	ND	<1	1	<1	ND	ND	ND	ND	ND
JDW-20	Glacial (ws)	ND	ND	ND	ND	ND	ND	<1	<1	ND	ND	ND	ND	ND
JDW-21	Glacial (ws)	ND	ND	ND	ND	ND	<1	1	1	ND	ND	ND	ND	ND
JDW-22	Glacial (ws)	ND	ND	ND	<1	ND	<1	1	<1	ND	ND	ND	ND	ND
JDW-23	Glacial	1	ND	1	ND	1	ND	ND	3	ND	ND	ND	ND	ND
JDW-24	Glacial	1	<1	1	ND	1	ND	ND	3	ND	ND	ND	ND	ND
JDW-25	Magothy	<1	ND	<1	ND	ND	ND	ND	1	ND	ND	ND	ND	ND
JDW-26	Glacial	1	<1	1	<1	1	ND	ND	3	ND	ND	ND	ND	ND
JDW-27	Glacial	1	<1	<1	ND	<1	ND	ND	3	ND	ND	ND	ND	ND
JDW-28	Glacial	ND	1	1	<1	1	<1	ND	1	ND	ND	ND	ND	ND
JDW-29	Glacial	ND	<1	1	ND	ND	ND	ND	1	ND	ND	ND	ND	ND
JDW-30	Glacial	2	2	1	ND	12	6	ND	9	ND	ND	ND	ND	ND

(ws) denotes water supply.

Table 4–22 . . . . Cont'd.

SAMPLE	MEDIUM OR AQUIFER*	Naph-thalene	Methyl Naph-thalene	Dimethyl Naph-thalene	Ethyl Toluene	C_4 Benzene	Fluo-rene	Dibutyl Phthalate	Octyl phenols	Dioctyl Phthalate	Bromo form	Penta-chloro-propane	Dibutoxy-ethoxy Ethyl Methane	Plasticizer (composi-tion uni-dentified)
JDW-31	Effluent	ND	3	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND
JDW-32	Effluent	ND	<1	ND	ND	ND	ND	<1	ND	2	ND	ND	ND	ND
JDW-33	Magothy (ws)	ND	1	ND	ND	ND	ND	<1	ND	2	ND	ND	ND	ND
JDW-34	Magothy (ws)	ND	1	ND	ND	ND	ND	<1	ND	4	ND	ND	ND	ND
JDW-35	Magothy (ws)	ND	1	ND	ND	ND	ND	<1	ND	6	ND	ND	ND	ND
JDW-36	Glacial	ND	1	ND	ND	ND	ND	<1	ND	9	ND	ND	ND	ND
JDW-37	Magothy (ws)	ND	1	ND	ND	ND	ND	<1	ND	4	ND	ND	ND	ND
JDW-38	Magothy (ws)	ND	1	ND	ND	ND	ND	2	ND	7	ND	ND	ND	ND
JDW-39	Magothy (ws)	ND	1	ND	ND	ND	ND	2	ND	8	ND	ND	ND	ND
JDW-40	Magothy (ws)	ND	ND	ND	ND	ND	ND	1	ND	2	ND	ND	ND	ND
JDW-41	Magothy (ws)	ND	1	ND	ND	ND	ND	1	ND	2	ND	ND	ND	ND
JDW-42	Effluent	ND	ND	ND	ND	ND	ND	3	ND	2	ND	ND	ND	ND
JDW-43	Water Distribution	ND	1	ND	ND	ND	ND	<1	ND	4	19	4	ND	ND
JDW-44	Water Distribution	ND	<1	ND	ND	ND	ND	<1	ND	2	12	2	ND	ND
JDW-45	Water Distribution	ND	ND	ND	ND	ND	ND	<1	ND	2	41	4	ND	ND
JDW-50	Effluent					NOT ANALYZABLE								
PWG-1	Glacial	ND	1	ND	ND	ND	ND	17	ND	4	ND	ND	18	11
PWG-2	Glacial	ND	1	ND	ND	ND	ND	22	ND	2	ND	ND	21	12
PWG-3	Glacial	ND	1	ND	ND	ND	ND		ND	2	ND	ND	10	6
PWG-4	Glacial	ND	1	ND	ND	ND	ND	10	ND	2	ND	ND	8	4
PWG-5	Glacial	ND	<1	ND	ND	ND	ND	8	ND	2	ND	ND	5	3
PWG-6	Glacial	ND	1	1	ND	ND	ND	19	ND	6	ND	ND	16	7
PWG-7	Glacial	ND	1	2	ND	ND	ND	36	ND	2	ND	ND	2	ND
PWG-8	Glacial	ND	2	4	ND	ND	ND	53	ND	1	ND	ND	3	ND
PWG-10	Glacial	ND	4	7	ND	ND	ND	34	ND	1	ND	ND	2	2
PWG-11	Glacial	ND	<1	1	ND	ND	ND	ND	ND	1	ND	ND	5	1
PWG-12	Glacial	ND	<1	1	ND	ND	ND	ND	ND	7	ND	ND	ND	3
PWG-13	Effluent	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	107	ND
PWG-14	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	2	ND	ND	1	2
PWG-15	Effluent	ND	ND	ND	ND	ND	ND	2	ND	3	ND	ND	1	5

(ws) denotes water supply.

Table 4--23

METHYLENE CHLORIDE EXTRACTABLE ORGANIC FRACTION FOR SAMPLES PWG-16 TO QA-24
(in μg/l)

METHYLENE CHLORIDE EXTRACTABLE ORGANIC COMPOUNDS

SAMPLE NUMBER	MEDIUM*	ethyl benzene	o,m xylenes	p xylene	isopropyl benzene (cumene)	o-dichlorobenzene	diethyl benzene	DMN (dimethyl naphthalene)	methyl naphthalene	ethyl naphthalene	2,3 dimethyl naphthalene	acenaphthene	t-butyl phenol	C_{14} alkane	C_{15} alkane	fluorene	C_{16} alkane	diethyl phthalate	C_{17} alkane	C_{18} phytane	dibutyl phthalate	C_{19} alkane	di-tert butyl phthalate	C_{20} alkane	C_{21} alkane	C_{22} alkane	phthalate	phthalate compound	phthalate derivative	dioctyl phthalate	C_{23} alkane	C_{24} alkane	C_{25} alkane	C_{26} alkane	thymol	C_{28} alkane	tri-t-butyl orthoformate	cyclohexanone	trimethyl hexanoic acid	p-ethyl-cumene	tributyl phosphate	C_3 naphthalene	$C_{22}H_{16}$	$C_{23}H_{48}$	toluene	naphthalenes
PWG 16	Glacial	ND	ND	ND	ND	ND	ND	ND	3	ND	ND	12	ND	ND	ND	ND	ND	ND	ND	9	30	ND	ND	32	7	ND	9	ND	ND	8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8	ND	ND	ND	ND	ND
PWG 17	Effluent	ND	ND	ND	ND	ND	ND	2	3	ND	ND	ND	ND	ND	ND	ND	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	2
PWG 18	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	1	ND	ND	ND	ND	<1	ND	ND	ND	ND	4	ND	ND	ND	ND	16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 19	Water Distr.	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	<1	<1	ND	<1
PWG 20	Glacial	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND
PWG 21	Control	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 22	Control	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	14	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 23	Control	ND	ND	ND	ND	ND	ND	6	ND	ND	ND	ND	ND	ND	ND	8	ND	ND	ND	ND	ND	ND	15	ND	ND	ND	1	1	1	6	ND	ND	ND	2	ND	2	ND	12	20	ND	ND	ND	ND	ND	ND	ND
PWG 25	Glacial	ND	ND	<1	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 26	Glacial	ND	ND	ND	ND	ND	ND	<1	ND	ND	<1	ND	ND	<1	ND	ND	ND	ND	ND	<1	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 27	Effluent	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	4	ND	ND	7	ND	4	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 28	Effluent	ND	ND	ND	ND	ND	ND	ND	1	ND	3	2	2	ND	ND	2	ND	1	ND	1	2	ND	8	ND	ND	ND	ND	1	7	2	ND	ND	ND	ND	11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 29	Magothy (ws)	1	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 30	Magothy (ws)	ND	<1	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 31	Glacial	ND	ND	5	ND	ND	ND	ND	ND	10	14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	8	4	3	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 32	Glacial	ND	ND	ND	ND	<1	ND	<1	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 33	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	<1	ND	<1	ND	ND	ND	ND	ND	ND	ND	1	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 34	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	1	1	2	1	1	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 35	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	1	ND	1	1	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 36	Glacial	ND	ND	3	ND	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	4	ND	4	2	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 37	Effluent	ND	ND	ND	ND	ND	ND	1	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	<1	1	ND	1	ND	ND	2	ND	ND	ND	ND	3	ND	7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 38	Glacial	ND	ND	ND	ND	ND	46	ND	ND	ND	6	ND	ND	ND	ND	2	ND	ND	ND	2	ND	ND	3	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 39	Glacial	ND	ND	ND	ND	ND	ND	<1	1	<1	ND	1	1	ND	ND	ND	1	ND	ND	ND	1	ND	2	ND	ND	ND	4	ND	3	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 40	Effluent	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	1	ND	<1	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 41	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 42	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 43	Lake	ND	ND	ND	ND	ND	ND	2	2	1	ND	1	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	1	ND	ND	ND	2	ND	1	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 45	Effluent	ND	ND	ND	ND	ND	ND	ND	2	1	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	2	ND	ND	ND	40	5	12	ND	ND	ND	ND	ND	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 46	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 47	Lloyd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	<1	<1	ND	ND	ND	ND	ND	<1	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

*(ws) denotes water supply.

Table 4–23 . . . . Cont'd.

METHYLENE CHLORIDE EXTRACTABLE ORGANIC COMPOUNDS

SAMPLE NUMBER	MEDIUM*	ethyl benzene	o,m xylenes	p xylene	isopropyl benzene (cumene)	o-dichlorobenzene	diethyl benzene	DMN (dimethyl naphthalene)	methyl naphthalene	ethyl naphthalene	2,3 dimethyl naphthalene	acenaphthene	t-butyl phenol	C_{14} alkane	C_{15} alkane	fluorene	C_{16} alkane	diethyl phthalate	C_{17} alkane	C_{18} phytane	dibutyl phthalate	C_{19} alkane	di-tert butyl phthalate	C_{20} alkane	C_{21} alkane	C_{22} alkane	phthalate	phthalate compound	phthalate derivative	dioctyl phthalate	C_{23} alkane	C_{24} alkane	C_{25} alkane	C_{26} alkane	thymol	C_{28} alkane	tri-t-butyl orthoformate	cyclohexanone	trimethyl hexanoic acid	p-ethyl-cumene	tributyl phosphate	C_3 naphthalene	$C_{22}H_{16}$	$C_{23}H_{48}$	toluene	naphthalenes
PWG 48	Magothy	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2	ND	2	3	ND	2	ND	ND	ND	ND	22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 49	Recharge Basin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16	ND	ND	ND	ND	ND	2	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 50	Glacial	ND	ND	ND	ND	ND	ND	ND	2	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	80	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 51	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12	ND	ND	ND	2	ND	15	ND	ND	ND	3	ND	ND	<1	1	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 52	Glacial	ND	ND	ND	ND	ND	1	ND	1	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	58	ND	ND	ND	3	ND	2	1	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 53	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	<1	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 54	Glacial	ND	ND	ND	ND	ND	ND	ND	<1	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	<1	<1	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 55	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	<1	<1	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 1	Recharge Basin	ND	ND	ND	<1	ND	<1	8	1	6	ND	ND	ND	ND	ND	1	1	ND	<1	<1	ND	ND	<1	1	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	1	ND	ND	ND	ND	ND
QA 2	Glacial	ND	ND	<1	<1	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	<1	ND	ND	ND	ND	ND	ND	ND	<1	ND	<1	<1	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 3	Glacial	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	<1	ND	ND	<1	ND	<1	<1	ND	ND	ND	ND	ND	ND	ND	<1	1	<1	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 4	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	3	ND	ND	<1	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 5	Magothy (ws)	ND	ND	<1	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND
QA 6	Magothy (ws)	ND	1	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	2	ND	ND	<1	ND	ND	ND	ND	ND	<1	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND
QA 14	Quench Water	ND	ND	<1	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	2	ND	1	ND	ND	1	ND	1	ND	ND	7	ND	ND	1	ND	ND	5	1	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 15	Recharge Basin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	2	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 17	Glacial (ws)	ND	110	10	290	ND	15	ND	28	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	400	ND	ND	ND	ND	ND	ND	ND	ND	710	ND	540	ND	ND	ND	ND	ND	ND	ND	ND
QA 18	Magothy	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	<1	ND	ND	<1	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 19	Glacial (ws)	ND	ND	ND	ND	ND	ND	ND	220	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 20	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	<1	ND	ND	ND	3	ND	ND	<1	ND	ND	ND	ND	ND	ND	26	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 21	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	1	ND	ND	ND	7	ND	1	1	ND	ND	ND	ND	ND	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 22	Glacial	ND	ND	1	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	<1	ND	ND	ND	<1	ND	<1	<1	ND	ND	ND	ND	ND	ND	<1	<1	ND	ND	ND	ND	ND	ND	ND	ND
QA 23	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	<1	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 24	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

*(ws) denotes water supply.

Table 4–24

SUMMARY STATISTICS–ORGANIC CONTAMINANTS IN WATER, NASSAU AND SUFFOLK COUNTIES

Medium	Volatiles*				Methylene Chloride Extractables			
	No. stations	No. stations w/at least 1 compound >10 μg/l	No. stations w/at least 1 compound >50 μg/l	No. stations w/at least 1 compound >100 μg/l	No. stations	No. stations w/at least 1 compound >10 μg/l	No. stations w/at least 1 compound >50 μg/l	No. stations w/at least 1 compound >100 μg/l
Effluent	12	7	4	0	14	5	1	1
Magothy	14	10	5	3	18	1	0	0
Glacial	37	30	13	6	68	32	12	3
Water Distribution	4	3	2	0	5	3	0	0
Lloyd	1	1	0	0	1	1	0	0
Surface Water	1	1	0	0	1	1	0	0

**Only includes samples JDW-41 to QA-25.*

Table 4–25

SUMMARY STATISTICS–VOLATILE ORGANIC COMPOUNDS

Compound	No. stations measured*	No. stations detected	No. stations occurring @ >10 μg/l	No. stations occurring @ >50 μg/l
trichloroethylene	78	62 (79%)	35 (44%)	15 (19%)
chloroform	44	34 (75%)	20 (45%)	4 (9%)
1, 1, 1 trichloroethane	78	57 (73%)	25 (32%)	6 (8%)
carbon tetrachloride	78	28 (36%)	1 (1%)	0
tetrachloroethylene	78	23 (29%)	10 (13%)	5 (6%)
dibromochloromethane	78	15 (19%)	0	0
1, 1 dichloroethane	44	5 (11%)	3 (7%)	0
bromodichloromethane	78	8 (10%)	3 (4%)	1 (1%)
freon-11	44	4 (9%)	0	0
1, 1 dichloroethylene	44	4 (9%)	0	0
1, 2 dichloroethane	44	3 (7%)	0	0
bromoform	78	5 (6%)	1 (1%)	0
1 chloropropane	44	1 (2%)	1 (2%)	0

**Only results from samples JDW 41 to QA 25 have been considered quantitatively reliable for purposes of this summary.*

appear on the National Academy of Sciences' list of known animal carcinogens. Thus, the presence of these chemicals in the Magothy aquifer may represent a potential health risk. Identification and control of the sources of these contaminants should be of high priority.

Carbon Tetrachloride and Dibromochloromethane. These contaminants were observed in well over fifteen percent of the samples (see Table 4–25). Although they were widely present, they were only found at low levels. Thus, although their wide distribution is of concern, they cannot at present be considered to impose significant potential health risks.

Other Volatile Organic Contaminants. Eight other volatile compounds were observed (see Table 4–25). They occurred in only a small number of wells at generally small concentrations. However, in the final set of samples (QA-1 to QA-24), which were analyzed under the best conditions, both 1, 1 dichloroethane and bromodichloromethane occurred at significant levels.

Phthalates. This general class of CH_2Cl_2 extractable organics occurred ubiquitously. Phthalate compounds were detected at very high levels in about eight percent of the samples (see Table 4–26). Phthalates occur as plasticizers. Thus the presence of phthalates may have been partially due to use of plastic tubing as part of the sampling devices. Nevertheless, since phthalates occur on the NAS list of chronic toxins, it is only prudent to consider the high observed phthalate levels as a possible potential health risk.

Methylene Chloride Extractable Organic Contaminants. A wide variety of compounds were observed in the samples. Some occurred at levels greater than 50 parts per billion (see Table 4–26). Eighteen substances occurred at levels greater than ten parts per billion. However, information on health risks imposed by these substances is scanty. Thus the risk levels cannot presently be assessed.

Table 4–26

SUMMARY STATISTICS–METHYLENE CHLORIDE EXTRACTABLE ORGANIC COMPOUNDS

Compounds detected at >10 μg/l for at least one station	Number of Stations >1 μg/l	Number of Stations >10 μg/l	Number of Stations >50 μg/l
methyl naphthalene	45	2	1
dimethyl naphthalene	37	3	0
dibutyl phthalate	34	20	8
octyl phenols	27	4	1
C_4 benzene	20	4	0
di-tert-butyl phthalate	20	6	2
phthalate (composition undetermined)	19	2	1
naphthalene	19	3	0
phthalate derivative (composition undetermined)	14	1	0
dibutoxy-ethoxy-ethyl methane	13	4	1
phthalate compound (composition undetermined)	8	1	0
acenaphthene	6	1	0
C_{16} alkane	6	2	0
C_{28} alkane	6	1	1
tri-t-butyl orthoformate	6	1	0
diethyl benzene	5	2	0
2, 3 dimethyl naphthalene	4	1	0
thymol	3	1	0
cyclohexane	3	2	1
o, m xylenes	2	1	1
isopropyl benzene	2	1	1
C_{20} alkane	2	1	0
trimethyl hexanoic acid	1	1	0

4.4.3 Patterns of Occurrence

The samples can be divided into several groups characterized by effluent types and overlying land use. A summary of the results tabulated according to these groups is given in Table 4–27. The results indicate that organics in the Upper Glacial aquifer are not necessarily restricted to locales underlying specific sources. Percent occurrences at $\geq$ 10 μg/l range from 100 to 43 percent. Organic contamination of greater than 10 μg/l is observed in 100 percent of the leachate and leachate plume samples, and samples collected under commercial/industrial and wooded areas.

An additional indication of patterns of contamination is given in Tables 4–28 and 4–29, which present the highest tenth percentile of observed organic chemical contamination ranked by highest contaminant level per sample and number of chemicals observed at concentrations $\geq$ 10 μg/l.

4.4.4 External Factors and Analytical Limits

The information obtained during this sampling program is limited by the analytical conditions and the sampling plan. Some of these limiting conditions are relevant in the interpretation of results presented here.

4.4.4.1 Limitations of the Sampling Plan. The sampling plan imposes the following limits on how the data should be used:

Data points were determined by existing well locations and depths. The existing wells are clumped in some areas of the Island, and leave other locales unrepresented. For example, many of the sampling wells are located along the Nassau-Suffolk border in a north-south line. Also, the majority of well samples were selected from the Glacial aquifer, leaving the Magothy and Lloyd under-represented. In addition, there is no simple method for extrapolating from the data collected to unsampled aquifers or sections of the Island.

Few water supply wells were included in the sampling plan. Hence, little direct information about the condition of water supplies was provided by the study.

Few deep wells were included. Hence, little information about the condition of deep groundwater was provided by the study.

No multiple-depth samples were taken at one site. Thus, no information about how organics are traveling through the groundwater column in zones of recharge was provided.

Few replicates were taken. Thus the variations of organic concentrations in the groundwater could not be well defined.

4.4.4.2 Limitations of the Analytical Method. While the analytical techniques used were capable of identifying a large number of organic compounds, these compounds form only a small fraction of the total organic content of a sample. Those classes of compounds which were *not* observed include the following:

Water-Soluble Organics. Highly water-soluble materials, in particular, very polar compounds, are not extracted from the water in appreciable amounts by lipophilic methylene chloride. Among these compounds are strong acids and bases, sugars, proteins, and some phenolic materials.

Non-Volatile Organics. Gas chromatography, as employed in this study, can only be used to analyze those materials that can be vaporized at 250° C and which will pass totally through the analytical column at a temperature of 250° C or less. This limits the analysis to molecules of size approximately C_{35} or less. It also eliminates from the analysis any compounds that are destroyed by the high injection-port temperatures.

Volatile Organics. The Bellar-Lichtenberg purge and trap volatile analysis methodology can only be used to analyze those materials which can be vaporized at room temperatures.

Non-Halogenated Non-Ionized Volatile Organics. The Hall detector generally is only useful for detection of halogenated ionized compounds.

While the project was in progress, EPA issued a protocol enabling the screening of organic components in water samples. It involved three

Table 4—27

EFFLUENT AND GLACIAL CONTAMINANT LEVELS RANKED BY FREQUENCY OF OCCURRENCE OF CONTAMINANTS AT ≥10 μg/l*

	# SAMPLES W/OBSERVATIONS ≥10 μg/l			# SAMPLES W/OBSERVATIONS ≥50 μg/l			# SAMPLES ANALYZED		
	Volatile Organics[2]	Methylene Chloride Extractable Organics	All Organics[1]	Volatile Organics[2]	Methylene Chloride Extractable Organics	All Organics[1]	Volatile Organics[2]	Methylene Chloride Extractable Organics	All Organics
EFFLUENT									
Effluent Type:									
Leachate	1	1	2 (100%)	1	1	2 (100%)	2	1	2
Domestic Chlorinated STP Effluent	4	2	5 (71%)	3	1	3 (43%)	4	7	7
Runoff Effluent	1	1	1 (50%)	1	0	1 (50%)	2	2	2
GLACIAL									
Overlying Land Use/ Aquifer Characteristics:									
Leachate Plumes	3	2	4 (100%)	3	0	3 (75%)	3	3	4
Commercial/Industrial Unsewered	2	2	3 (100%)	1	1	1 (33%)	2	3	3
Wooded	3	1	3 (100%)	1	0	1 (33%)	3	3	3
Agricultural	7	3	7 (87%)	3	0	3 (37%)	7	8	8
Runoff Recharge	6	3	6 (75%)	3	1	4 (50%)	8	8	8
Residential Sewered	1	7	8 (73%)	1	3	4 (50%)	1	10	11
Domestic STP Recharge	3	4	5 (63%)	0	0	0	7	8	8
Residential Unsewered	5	6	8 (50%)	4	5	7 (44%)	6	16	16
Mixed Unsewered	3	1	3 (43%)	1	1	2 (28%)	3	7	7

[1] *Percent of total number of samples analyzed (see Column 9).*

[2] *Only results from samples JSW-41 to QA-25 have been considered quantitatively reliable for the purpose of this summary.*

* *Samples were biased toward contaminated areas.*

extractions: base-neutral, acid, and pesticide. Volatiles were included as a fourth category. The extracts were all run on GC/MS to identify the most prevalent components at critical locations. Additional locations were looked at only for those components. This offered a better way to conduct such a program, but it was far more expensive. For example, a typical screening sample cost between $900 and $3000 in 1978, depending upon the laboratory selected. Verification samples were often half this price, depending upon the number of components to identify and quantify. While the expense

Table 4–28

HIGHEST 10th PERCENTILE OF OBSERVED CONTAMINANT LEVELS ORDERED BY HIGHEST CONTAMINANT LEVEL PER SAMPLE

Sample Type*	Sample No.	Highest Contaminant Level
Glacial-residential-unsewered	QA 3	592 μg/l bromodichloromethane
Glacial-mixed-unsewered (WS)	QA 17	400 μg/l phthalate compound "a"
Magothy (WS)	QA 13	500 μg/l trichloroethylene
Glacial-agricultural	QA 21	290 μg/l 1, 1, 1-trichloroethane
Glacial-residential-unsewered	QA 19	285 μg/l trichloroethylene
Glacial-residential-unsewered	QA 2	275 μg/l 1, 1, 1-trichloroethane
Magothy (WS)	PWG 30	221 μg/l trichloroethylene
Glacial-residential-unsewered	JDW 15	171 μg/l dibutyl phthalate
Glacial-leachate plume	QA 9	150 μg/l tetrachloroethylene
Glacial-mixed-unsewered (WS)	QA 12	150 μg/l tetrachloroethylene
Magothy (WS)	QA 6	145 μg/l chloroform
Scavenger waste lagoon	PWG 44	112 μg/l 1, 1, 1-trichloroethane
Glacial-residential-unsewered	JDW 14	109 μg/l octyl phenols
Magothy (WS)	QA 10	109 μg/l trichloroethylene

(WS) = water supply well.

Table 4–29

HIGHEST 10th PERCENTILE OF OBSERVED CONTAMINANT LEVELS ORDERED BY NUMBER OF CHEMICALS OBSERVED AT $\geq$10 μg/l PER SAMPLE

Sample	Sample No.	No. Organic Chemicals Observed at $\geq$10 μg/l
Glacial-mixed-unsewered (WS)	QA 17	8
Glacial-residential-unsewered	QA 19	5
Glacial-residential-unsewered	QA 2	5
Glacial-runoff recharge	PWG 1	5
Glacial-runoff recharge	PWG 2	5
Glacial-commerical/industrial-unsewered	JDW 13	5
Glacial-residential-unsewered	QA 3	4
Magothy (WS)	QA 6	4
Glacial-residential-sewered	QA 8	4
Control (passed through plastic tubing)	PWG 23	4
Runoff	PWG 49	4
Glacial-residential-unsewered	PWG 51	4

may have been great, the information retrieved was more useful in locating potential water quality problems.

While this project took place, rapid advances in the state-of-the-art of VOA methods were made. ERCO strived throughout to keep up with the technology to assure that results would be as accurate and valid as possible. This resulted in an inability to aggregate the entire VOA data set for interpretation.

Less desirable VOA methods, such as extraction or head space techniques, which are still used in many commercial labs, could have been used throughout this project. However, as EPA Cincinnati has recognized, there are serious problems associated with the use of such methods. Such an approach would have produced results with little validity.

The ERCO system used for samples QA-1 to QA-24 operated with ± 20 percent accuracy, provided good resolution of peaks, and allowed good recovery efficiency and reproducibility. The ERCO system is still under review by EPA.

4.5 CONCLUSIONS

From the results of this study, and using the results of prior studies, it can be concluded that high (> 50 ppb [μg/l]) levels of volatile organic compounds occur locally in the Long Island Upper Glacial and Magothy aquifers. Methylene chloride extractable compounds occur at high levels locally in the Upper Glacial aquifer. Employing the 1977 NAS study as a reference, it can be further concluded that these high levels of organic contaminants constitute a potential public health risk if the aquifer is used for public water supply. Some sources of the contaminants can be suggested, but no firm conclusions are possible.

4.5.1 Levels of Contamination: Volatiles

Trichloroethylene, chloroform, 1, 1, 1-trichloroethane, tetrachloroethylene, and bromodichloromethane have all been observed at > 50 μg/l. Thus, these compounds are of particular concern due to their high environmental levels.

Trichloroethylene, chloroform, and 1, 1, 1-trichloroethane have all been observed in 50 percent or more of the samples. Thus, those compounds are of particular concern due to their widespread occurrence.

Nine other volatile organics have been positively identified in several of the samples; some at high levels. Thus, there are a large number of contaminants with which control strategies must deal.

Total volatile organics contamination at levels greater than 50 μg/l has been noted locally in the Magothy aquifer. Occurrence of these contaminants at Magothy depths suggests that volatile organic contaminants may travel more rapidly through aquifers than non-volatiles. Magothy contamination by volatiles constitutes a potential local threat to the water supply.

4.5.2 Levels Of Contamination: Methylene Chloride Extractables

Several methylene chloride extractable organics have been observed at > 50 μg/l in the samples. Each of these ten compounds is of concern for its high environmental levels.

Phthalates, napthalenes, C_4 benzenes, and octyl phenols have been identified in a large number of samples. Thus, these compounds are of particular concern due to their widespread occurrence.

Methylene chloride extractable organics have not significantly penetrated the Magothy aquifer.

Methylene chloride extractable organics are especially troublesome because such a large number of compounds have been found in significant quantities. This makes monitoring efforts expensive and time consuming.

Sample PWG-23, a control sample run through 50 feet of plastic sampling hose, suggests that the sampling procedure may introduce the phthalate family of synthetics at levels up to 20 μg/l. However, one experimental sample provides little basis for conclusions.

4.5.3 Public Health Risks

Of the chemicals for which risk levels have been established—chloroform, carbon tetrachloride, trichloroethylene, phthalate compounds— all have been observed on Long Island at levels greater than 50 μg/l. Thus, present levels of those contaminants constitute a definite potential health risk. Samples from certain wells suggest that, if consumption of water in some specific locales is continued without treatment (or the provision of alternate sources), impact on public health may occur.

Chlorinated volatiles, other than the three mentioned above, occur in the groundwater. Although definitive dose response studies have not been performed, it is likely that these contaminants are harmful. Thus, present levels of these contaminants constitute a possible health risk.

The health risks due to presence of methylene chloride extractable organics, other than those in Tables 4—13 and 4—14, cannot be determined at this time.

Organic contaminants that are suspected carcinogens may present some level of risk even at very low levels. Since it is not feasible to reduce environmental levels to zero, cancer risk due to organic contaminants cannot diminish to zero and, thus, an acceptable level of risk must be established.

4.6 RECOMMENDED RESEARCH

The following research studies should be undertaken as a continuation of this study:

Inventory the sources of organic contaminants. A quantitative inventory is needed to identify the relative importance of non-point, wastewater treatment plant, and industrial point sources of the organic chemical compounds found at high levels in the groundwater. Some preliminary steps in this direction are currently being undertaken by the NCDH.

Utilize bacterial screens for dose-response assessment. The Ames screen, or a similar bacterial screen, should be used for those chemicals detected in Long Island groundwater that are not listed in Table 4—13. This involves determining bacterial mutation induced by the contaminants as an initial step in the identification of carcinogens, and in the intelligent establishment of health standards.

Determine the level of Magothy contamination. Additional analysis of existing NCDH and SCDHS data on supply wells should be combined with further sampling work to gain an overall picture of the quality of the Magothy aquifer.

Sample sources such as landfill leachates, chlorinated and unchlorinated wastewater treatment plant effluents, recharge basins, residential areas, and agricultural areas. A sampling effort is needed to fully characterize the transport of organic contaminants from surface sources. Detailed studies may be needed for specific major sources that may be identified by an inventory.

Study vertical transport. Sampling studies of gradients in vertical columns are needed to characterize the downward transport of organic contaminants. Such studies are only suitable in Magothy recharge zones.

Study variability at individual sites. Sampling studies involving replicates at particular sites are needed to establish the variance of each of the organic contaminants in each medium.

Utilize bioaccumulation screens. Fish and shellfish samples should be analyzed to screen for the occurrence of bioaccumulation of organic contaminants.

Test water distribution systems. All water distribution systems should be characterized as to organic contaminant levels as a first step in setting up a monitoring program, especially for the presence of precursor compounds which may become trihalomethanes upon chlorination.

Improve guidelines and standards. Current State and Federal guidelines are inadequate. Drinking water standards for Nassau and Suffolk Counties need to be researched and established. The use of bacterial screens is an important first step. Standards need to be established at a bi-county level to be fully responsive to the special contaminant problems occurring on Long Island.

Improve analytical procedures and quality control. An adequate interlab calibration program needs to be established to ensure the validity of all future analytical work that may be done relative to organic chemicals on Long Island. This should include the establishment of a quality control reference lab.

Investigate treatment methods for water supplies. In addition to granular activated carbon, treatment methods for water supplies should be investigated, with special emphasis on removal of lower molecular weight compounds such as the volatile organic compounds found in the bi-county area.

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NOTES

[1]National Academy of Sciences, 1977.

[2]These modifications were designed by Mark Scott, ERCO, in conjunction with EPA laboratories which had been working on the various methodology and hardware deficiencies during the duration of this sampling program. This ERCO purge and trap system has since been judged EPA-acceptable based upon accuracy of results for EPA Performance Evaluation Standards.

[3]The EPA has requested that the numerical results not be published since the performance sample sets are still being used to referee various labs.

LIST OF ABBREVIATIONS

CH_2Cl_2	methylene chloride
EPA	(U. S.) Environmental Protection Agency
ERCO	Energy Resources Company Inc.
FID	flame ionization detector
GC	gas chromatography
GC/MS	gas chromatography/mass spectrometry
LIWC	Long Island Water Conference
NCDH	Nassau County Department of Health
NYSHD	New York State Health Department
PCB	polychlorinated biphenyl
SCDHS	Suffolk County Department of Health Services
USGS	United States Geological Survey
$\mu g/l$	micrograms per liter (10^{-6} grams per liter)

GLOSSARY

Accuracy. The degree of conformity to some recognized standard value.

Ames Screen. A particular bacterial screening procedure developed by Bruce Ames of Stanford.

Aquifer. A water-bearing bed or stratum of permeable rock, sand, or gravel capable of yielding considerable quantities of water to wells or springs.

Bacterial Screen. Sets of procedures which involve inoculation of bacterial populations with different concentrations of a substance to determine the proportion of a bacterial population which mutate when exposed to the substance.

Bioassay. Exposure of biological individuals to a range of concentrations of a substance under controlled conditions to determine the effect of the exposure.

Blank Sample. Sample which does not contain the substance(s) to be tested for.

Carcinogenic Risk. The chance of mortality due to cancer incidence; usually expressed as a probability (a fraction of one).

Chlorinated Organic. Organic chemical with chloride ion(s) substituted for hydrogen(s).

Chronic Toxicity. The occurrence of mortality due to long-term low-level exposure to a substance or condition.

Column, G. C. Tube, usually stainless steel or glass, packed with a substance such as clay, silica gel, or alumina, by which means gases are separated.

Criteria Level. Threshold level of effect established (by the EPA) as a recommended level but not enforceable as would be a standard level.

Detection Limit. Concentration level below which a substance cannot be detected.

Detector, G. C. Device which monitors the passage of substances out of the end of a G. C. column.

DIALOG. A computerized abstracting service for health and environmentally related citations.

Dose-Response Relationship. A curve or other relationship showing the level of toxicity expected for each possible level of exposure.

Elute. To remove adsorbed material from an adsorbent by means of a solvent.

Gas Chromatography (G. C.). A process of separating gases in a mixture of solution by selective adsorption on clay, silica gel, or alumina as the mixture passes over the adsorbent media.

Gas Chromatography/Mass Spectrometry (G.C./M.S.). A process which couples gas chromatographic separation with mass spectrometric analysis of the compounds present.

Halogens. Any of the five elements fluorine, chlorine, bromine, iodine, and astatine.

Halogenated Organic. Organic chemical with halogen ion(s) substituted for hydrogen(s).

Kuderna-Danish. A special laboratoy device for the evaporation of solvent from a sample.

Linearity of Response. Consistent sensitivity of a laboratory instrument to a substance over a wide range of concentration levels.

Lipophilic. Promoting the solubilization or absorption of fats or other lipides.

Methylene Chloride (CH_2Cl_2) Extractable Organics. Those organic chemicals soluble in CH_2Cl_2 and which volatilize at 250° C or less.

Performance Review Sample, EPA. Spiked samples distributed to various labs to allow standardization and evaluation of quantitative and qualitative laboratory results.

Polar. Molecules with distinct negative and/or positive poles or charges in water or solvent.

Pyrolyze. Cause to react at elevated temperatures in the absence of oxygen.

Precision. The degree of refinement with which a measurement is performed.

Recovery Efficiency, G. C. The proportion of a substance which passes completely through the extraction and gas chromatographic procedure.

Reserve Wells. With reference to LIWC Guidelines (Holzmacher, 1977), wells which have been removed from the restricted list. No restrictions on use are imposed.

Resolution. The ability to separate a mixture into its component parts.

Restricted Wells. With reference to LIWC Guidelines (Holzmacher, 1977), wells not to be used for supply except in emergencies. These wells contain contaminants at levels exceeding standards.

Retention Index. A coefficient specifying the relative retention time of a gas in the chromatographic column.

Retention Time. The length of time a gas will be retained in the gas chromatographic column before elution.

Sensitivity. The concentration level to which a substance can be detected.

Spiked Samples. Samples containing known concentrations of various compounds used to test analytical resolution and recovery efficiency.

Standard Levels. Threshold level which has been established by an agency as an allowable level for an effluent stream or ambient body.

Standard Samples. A set of samples containing a compound of known concentrations used to test linearity of response and to calibrate a G. C. for quantification.

TOXLINE. A computerized abstracting service of toxicological citations.

Unresolved Compounds (G. C.). Components not separated into discrete peaks in a gas chromatograph.

Volatile Organics. Those organic compounds which vaporize at room temperature.

Section 5 Nitrates

5.0 INTRODUCTION

To what extent is nitrogen a potential or actual contaminant in Long Island's waters? This question presupposes two others: what are the major sources of nitrogen; and what is the fate of the nitrogen in the environment? Both questions are deceptively simple.

This section describes studies that have, in part, attempted to answer them. One of the aims of this section is to identify the more important uncertainties. This section presents methods and results that may be of value in managing nitrogen on Long Island.

The management of nitrogen appears to be essential to protect the region's drinking water supplies and the ecological balance of marine bays. Given current high levels of water consumption and use, the risks of degrading the water resources, whether it be the contamination of groundwater or the pollution of surface waters, are very high. Urban development and overuse of groundwater in Kings and Queens Counties have already caused contamination of the water supply on the western end of the Island.

The marine environs adjacent to the western end of Long Island have also been adversely affected, especially by sewage effluents and the dumping of sludge, provoking apprehension that the marine water resources of the whole of Long Island could decline in quality as Nassau and Suffolk also become further urbanized. Nitrogen is regarded as one of the key factors in that potential decline.

In this section, aspects of the nitrogen balance are briefly described; the development of the Island with respect to nitrogen is outlined; and the major sources and fate of nitrogen, as determined by recent studies, are discussed. The impact of nitrogen on the region's water resources is assessed. Finally, work undertaken at Cornell University, which is attempting to construct detailed nitrogen budgets for Nassau and Suffolk, is described and interpreted.

5.1 ASPECTS OF THE NITROGEN CYCLE

Since the early 1800's, man has known that nitrogen is a critical nutrient. Nitrogen is a component of all protoplasm, including, specifically, protein and nucleic acids. On the average, nitrogen constitutes more than fifteen percent of living organisms. Nitrogen is required by crops in amounts greater than any other nutrient. Requirements exceed 200 lbs/acre/year for some crops.

Nitrogen is also plentiful. In the atmosphere, it constitutes about 80 percent of the total volume. An even greater reservoir of nitrogen exists in primary rocks, where the quantity of nitrogen bound up is estimated to be 50 times greater than that in the atmosphere (Hutchinson, 1944). The nitrogen in rocks is held largely in a combined form, such as ammonium, and could, therefore, be utilized by living matter, were it accessible. Although the rate at which such nitrogen becomes biologically available is not known, it

is believed to have a relatively minor role in the nitrogen cycle, compared to atmospheric nitrogen.

Living matter depends primarily on the atmosphere as its source of nitrogen. However, dinitrogen, as the molecule N_2 is called, is inert because of the strength of the bond between the two nitrogen atoms. The conversion of dinitrogen into a nitrogenous form that is available for plants is performed by a specialized group of microbes. These include bacteria, many of which are symbiotic, and blue-green algae. In a process called fixation, the microbes are able to reduce N_2 to ammonium using a catalytic enzyme called nitrogenase. The ammoniacal nitrogen can then be incorporated into the principal biospheric reservoirs in various forms of nitrogen: nitrite, nitrate, urea, protein and nucleic acids.

Organisms that fix dinitrogen play a highly critical role in the nitrogen cycle. In fact, nitrogen fixation is one of the major factors limiting life on earth. Although estimates are speculative, it is believed that nitrogen fixation in terrestrial and aquatic environments varies broadly from about 150 mg/m^2 to over 1000 mg/m^2.

Nitrogen is also fixed naturally by electrical storms, which dissociate nitrogen and oxygen molecules that recombine to form an oxide of nitrogen. This reacts with water vapor to produce nitric acid, which is carried in precipitation to the ground, where it becomes available for living organisms.

Since the industrial revolution, man has increasingly been unable to rely on natural fixation to satisfy his need for nitrogen. Until the early 1900's, immediate sources of nitrogen were supplemented by inorganic nitrogen from mineral deposits (salt petre) and dried organic wastes of seabirds or bats.

Currently, about 95 percent of all the nitrogen applied as fertilizer in the U. S. is produced by artificial fixation. There are nearly 100 industrial complexes in the Nation capable of producing a total of about twenty million metric tons per year.

These figures demonstrate the potential augmentation of the amount of nitrogen entering the biosphere due to man's activities. It is estimated that approximately 80 million metric tons of nitrogen are fixed synthetically every year, which is more than one-third of that fixed naturally. Some of the environmental consequences of this augmentation are readily evident, the accelerated enrichment of surface waters and contamination of groundwater being major examples.

An important characteristic of nitrogen is that, once in the biosphere, most nitrogenous compounds are easily transformed. Organic forms are readily decomposed by biochemical processes. Inorganic nitrogen is either soluble or volatile. Hence nitrogen does not accumulate in the biosphere in large deposits, as do sulphur or carbon. Doubtless, there is some long term biochemical enrichment of the lithosphere as a result of the formation of sedimentary rocks, with a corresponding loss from the atmosphere. However, this loss is partly offset by the release of nitrogen from primary rocks.

There is no evidence that there is a significant loss of nitrogen from the atmosphere in the long term because the process of biological denitrification returns an amount of nitrogen to the atmosphere commensurate with that which is fixed. Denitrification is brought about by certain bacteria that are able to grow in either the presence or absence of oxygen. If oxygen is absent, then denitrifying bacteria are able to reduce nitrate (NO_3) to dinitrogen (N_2) or nitrous oxide (N_2O). These gaseous products eventually escape to the atmosphere and are temporarily lost to the biosphere.

The artifical augmentation of the flow of nitrogen in the environment has undoubtedly increased denitrification. Unfortunately, from the point of view of the nitrogen balance, denitrification is the most difficult component to quantify. Anaerobic conditions in the field may arise under diverse circumstances that may be transient; may occur at a multitude of micro sites; or may be general, and yet remain impractical to monitor. This difficulty has moved Cooke (1967) to assert that attempts to construct a balance sheet are bound to fail, at least with respect to crops. It is an anomaly of the nitrogen cycle that nitrification, the bacterial oxidation of ammonia to nitrate, requires oxygen, whereas the reduction of nitrate to gaseous nitrogen requires its absence. There is no doubt, however, that many regional nitrogen computations reveal a large loss that may be as much as 50 percent of the total budget (Porter, 1975). In the absence of evidence that nitrogen is being stored in the biosphere, it appears reasonable to attribute the unaccounted nitrogen loss primarily to denitrification.

In summary, the life sustaining components of the natural nitrogen cycle depend on microbial fixation and denitrification. Over recent decades, however, man has disrupted this natural cycle by means of artificial fixation.

Excessive augmentation of the nitrogen cycle places ground and surface water at risk. This is due to the natural interaction of the nitrogen and water cycles. Flowing water is a primary agent in the transport of nitrogen compounds. In its nitrate form, nitrogen can be leached from the soil by water. Other organic and inorganic forms of nitrogen may be removed by water flowing over land. Man also uses water to carry off his wastes. The surface or groundwaters that eventually receive this nitrogen may be undesirably affected if, as a result, a drinking water supply is contaminated or an ecosystem is substantially altered.

Degradation of groundwater quality and enrichment of surface waters by nitrogen has occurred to a marked degree on Long Island. An assessment of the causes of such changes is the subject of this section.

5.2 HISTORICAL BACKGROUND TO THE PROBLEM OF NITROGEN ON LONG ISLAND

In a recent study of nitrogen isotope ratios of nitrate in Nassau and Suffolk Counties, Kreitler *et al.* (1978) concluded that the source of nitrate in the Magothy "is from a dominant agricultural source plus animal wastes." If this conclusion is correct, it explains an apparent anomaly in levels of

nitrate in the groundwater in Nassau. For some time it has been apparent that older water in the Magothy aquifer had high levels of nitrogen which, in many areas, were higher than those found in the overlying Glacial aquifer. Since the water in the Magothy predated much of the urban development in the County, it was puzzling that newer water was of better quality, since the use of cesspools and septic tanks in the original developments were an obvious major source of nitrate-nitrogen.

An explanation of the anomaly could be that earlier agricultural activity had introduced significant amounts of nitrate to the groundwater. The history of farming on Long Island as a potential source of nitrogen is briefly discussed below.

Long Island has a history of intensive farming. The coincidence of fertile soils and a favorable climate with a ready market in New York City promoted a thriving agricultural industry on the Island. In the early nineteenth century, the enthusiasm of the farmers led to exhaustion of the soils. The land was rescued from premature retirement when it was discovered that fish made excellent fertilizers. The farmers organized fishing fleets to obtain sufficient quantities of fish. The fish were incorporated into the soil (*i.e.* one fish per hill of corn, a practice known to the Indians) or were broadcast on the surface (Talmage, 1977).

Extension of the Long Island Railroad throughout the Island also facilitated the use of organic fertilizers. The Railroad provided stable manure from New York City at 80 cents per wagon load, while at the same time, of course, making the city more accessible as a market. In the 1870's, according to Talmage, commercially prepared fertilizers became available and were widely used by the farmers.

The history of farming in the 20th century in Nassau and Suffolk may be noted from Table 5–1. According to the U.S. Census data almost half of the area in the two counties was in agricultural use at the beginning of the century. It may further be noted that the number of animals raised was significant. These livestock made their own contribution to the flow of nitrogen, in addition to that provided by imported manure.

Although it is accepted that the use of fertilizers has greatly increased during the last two decades, on Long Island the data suggest that fertilizers, both organic and inorganic, were generously applied earlier in this century.

For example, in 1915, extension personnel were quoted by the *Brooklyn Daily Eagle* as saying "that farmers in almost every section of the Island have been driven to the excessive use of commercial fertilizer as a substitute for the barnyard variety, but it is a poor substitute, as it lacks the water-holding properties of the natural fertilizer, and it does not keep the ground loosened up for the inhalation of air." The "barnyard variety" referred to was dairy manure, which was in increasingly short supply on the Island. This was due to the imposition of strict health regulations governing the handling of milk, and dairy farmers, rather than accept the regulations, discontinued production.

In 1929, a survey of Long Island potato farms was conducted by the Department of Agricultural Economics, Cornell University. The annual average rate of commercial fertilizer application applied by the growers to their potato crops was found to be 100 pounds of nitrogen per acre. In addition, 61 farmers out of the 112 included in the study applied an average 7.7 tons of manure per acre as an additional source of nitrogen (Underwood, 1933). Underwood also reported that the costs of applying fertilizers in 1912, and 1929, were 33 and 23 percent, respectively, of the total cost of production. This compares to an estimated sixteen percent in 1976 (Snyder, 1977). Farming methods have greatly changed over the past seventy years, so the above cost figures must be viewed with caution. For example, pesticides now constitute a major cost, which was not the case early in this century. This notwithstanding, the data indicate that fertilizers have been a major factor in farming production for a considerable period. It may therefore be concluded, as suggested by Kreitler *et al.* (1978), that previously farmed lands were a possible major source of nitrogen to groundwater.

The potential significance of previous land use was probably obscured as Nassau County developed in the 1930's and 1940's, and as malfunctioning cesspools and septic tanks subsequently became a conspicuous cause of groundwater contamination. In 1949, for example, detection of nitrate contamination in shallow public supply wells in the Levittown area produced an awareness that led eventually to abandonment of the Upper Glacial aquifer in the County as a source of water supply (Nassau Department of Health, 1971). Since that time, many reports have indicated the potential hazards of domestic disposal systems in heavily populated areas of Long Island (Smith and Baier, 1969; Cohen *et al.*, 1968; SCDEC, 1972; Perlmutter and Koch, 1972).

Apart from domestic wastewater, another potential source associated with urbanization that was identified by several reports is nitrogenous fertilizers applied to lawns (Holzmacher *et al.*, 1970; Miller *et al.*, 1974). It is now fully recognized that the cumulative effects of the many sources of nitrogen created by man must now be identified and controlled if the region's valuable water resources are to be preserved.

5.3 HUMAN WASTEWATER ON LONG ISLAND

5.3.1 Introduction

It is estimated that approximately 46 billion gallons of wastewater are produced annually in Nassau and Suffolk Counties. Of this flow, nearly 60 percent is treated by some type of on-site disposal system, such as septic tank systems. This percentage is comparatively high. In the entire United States, 29 percent of the population disposes of its waste through on-site disposal units. Nassau and Suffolk constitute two out of only four counties in the whole Nation with more than 100,000 domestic waste disposal systems (USEPA, 1977b). It follows that nitrogen from individual domestic disposal units is a main component in the region's nitrogen budget.

Table 5–1

AGRICULTURAL DATA FOR NASSAU AND SUFFOLK COUNTIES, 1900–1974

County	Total Acreage	Acreage in Farmland	Cropland Harvested (Acres)	Value of Land & Bldgs. Per Acre	Number of Livestock: Total Cattle	Horses	Poultry	Ducks (Other Poultry)	Hogs	Beef	Sheep	Goats
Nassau												
Year												
1900	–	88,452	–	–	–	–	–	–	–	–	–	–
1910	–	55,770	–	–	–	–	–	–	–	–	–	–
1920	175,360	59,353	–	765.79	2,442	3,065	76,815	5,836	2,340	240	387	22
1925	"	42,991	27,316	1,036.80	1,601	1,780	69,903	–	219	–	90	20
1930	"	23,477	19,066	1,522.22	1,119	648	76,402	1,703	215	191	97	2
1935	"	27,895	19,302	1,251.49	1,626	1,044	44,960	–	2,248	–	83	22
1940	192,000	26,543	15,988	1,390.93	1,277	671	31,414	288	145	–	246	115
1945	"	32,122	24,744	970.15	2,209	330	69,199	–	1,125	–	266	93
1950	"	27,000	14,580	–	1,400	400	36,400	–	200	–	400	–
1954	"	12,964	6,848	3,163.51	1,412	196	16,532	256	158	–	347	–
1959	"	7,406	4,268	8,570.13	343	122	6,814	–	29	–	129	–
1964	"	5,565	3,512	6,850.11	193	–	4,000	–	33	–	101	–
1969	"	2,437	–	7,262.00	–	–	–	–	–	–	–	–
1974	"	1,112	695	16,902.00	76	126	519	–	–	–	–	–
Suffolk												
Year												
1900	–	276,860	–	–	–	–	–	–	–	–	–	–
1910	–	178,063	–	–	–	–	–	–	–	–	–	–
1920	588,800	159,249	–	189.65	7,605	5,870	247,526	70,646	11,637	418	1,374	67
1925	"	111,762	67,446	351.98	5,732	4,609	322,945	–	3,305	–	435	26
1930	"	99,671	63,063	607.67	3,614	2,521	1,338,124	119,005	2,548	–	487	62
1935	"	123,251	64,556	410.28	5,335	3,178	297,159	–	3,405	48	491	35
1940	590,080	119,061	66,526	409.79	5,206	1,517	348,949	712,853	2,807	–	469	410
1945	"	120,837	74,893	450.44	4,808	618	361,786	–	4,234	–	484	570
1950	"	123,000	68,880	–	4,200	500	398,300	–	3,000	–	700	–
1954	"	99,752	64,967	837.37	4,218	194	286,757	4,800,822	1,661	–	428	–
1959	"	89,776	61,621	1,444.36	3,197	252	238,342	8,000,000	1,956	–	192	–
1964	"	74,308	53,215	1,867.00	2,443	–	165,000	–	2,895	–	154	–
1969	"	61,520	–	3,513.00	–	–	–	–	–	–	–	–
1974	"	55,397	41,007	4,840.00	959	321	56,774	4,200,000*	647	–	114	–

**CES estimate.*
Source: U.S. Bureau of the Census.

5.3.2 Domestic or On-Site Disposal Systems

On-lot systems conventionally rely on two phases of treatment. In the primary phase, sedimentation occurs with some digestion and liquefaction of solid materials. On Long Island, septic tanks or cesspools are generally used to provide this treatment. In the secondary phase, treatment is provided by the soil in the so-called absorption field to which the cesspools, or tile drains, discharge. Purification occurs through the agency of the soil and soil organisms, which filter, break down and absorb most of the pollutants contained in the sewage. These processes, however, do not function effectively if the disposal system is overloaded. The U.S. Environmental Protection Agency, in its recent comprehensive review (1977a), noted that numerous studies have shown soil to be an extremely efficient purifying medium under properly managed conditions. Removal rates of potential disease organisms and viruses may be very high as described by Vaughn and Landry (1977). Heavy metals and complex organic substances are also effectively removed from percolating wastewater by the soil (USEPA, 1977a). A critical exception is the highly soluble inorganic compound: nitrate.

In assessing the potential role of on-site disposal systems, this study sought answers to specific questions:

1. What is the average daily flow of wastewater generated per person?
2. What is an average concentration of organic and inorganic nitrogen in
   a. the influent to the disposal system?
   b. the effluent from the disposal system?
   c. the percolate in the leaching area, *i.e.,* what is the rate of attenuation in the concentration of nitrogen as it moves downward through the soil?
3. What are typical concentrations of nitrogen in groundwater immediately underlying the disposal systems?

A very large number of studies have considered wastewater flows and nitrogen loads to and from disposal systems, both on Long Island and elsewhere. There is substantial agreement between reported per capita flows, as can be seen from Table 5–2. The overall average is 44 gallons per person per day; the lowest value was reported in the *Long Island Groundwater Pollution Study* (NYSDH, 1969).

There is considerably more variability in reported nitrogen loadings. In addition, the strength of raw sewage is often not analyzed, or only inorganic nitrogen is measured. Such omissions render it almost impossible to assess the systems studied in terms of their effectiveness in treating nitrogen.

5.3.3 Holding Tanks

Concentrations of organic and inorganic nitrogen found in raw sewage prior to entry into disposal systems, and the corresponding strength of effluents, are shown in Tables 5–3 and 5–4, respectively. Although only three of the studies, (Hickey and Duncan, 1966; USEPA, 1977a; Andreoli, 1978) reported both influent and effluent concentrations, it appears that significant

Table 5–2

AVERAGE PER CAPITA FLOWS INTO DOMESTIC DISPOSAL SYSTEMS

Study cited		Average daily per capita flow (g/c/d)
Weibel *et al.*	(1949)	44
Watson *et al.*	(1967)	56
NYSDH	(1969)	40
Bouma	(1975)	42
Laak	(1972)	41
Bennett and Linstedt	(1975)	45
USEPA	(1977a)	43
Overall average		**44**

Table 5–3

LEVELS OF VARIOUS FORMS OF NITROGEN MEASURED IN RAW DOMESTIC SEWAGE (mg/l)

Form of Nitrogen	Source of data: Weibel et al. (1949)	Hickey & Duncan (1966)	Watson et al. (1967)	USEPA (1977a)	Andreoli (1978)
Organic	58	23	17	–	25
Ammonia	15	24	57	–	50
Total	**73**	**47**	**73**	**62**	**75**

reductions in concentrations of nitrogen may occur in the septic tank or cesspool. The overall mean reduction for the three studies was sixteen percent (see Table 5–5). This reduction may be due in part to storage in the tank or gaseous losses. Early studies of the composition of gases produced by septic tanks indicated significant percentages of nitrogen (Fuller, 1912; Metcalf and Eddy, 1916). More recently, Hickey and Duncan (1966) obtained the results shown in Table 5–6.

5.3.4 Absorption Fields

Complex processes govern the movement of nitrogen in absorption fields. Organic nitrogen and ammonia are readily retained by the soil (Walker *et al.,* 1973; Andreoli *et al.,* 1977). However, organic nitrogen is subject to mineralization, and the ammonia consequently produced, along with that already present, can be oxidized to nitrite and nitrate. Thus, in the long run, all the nitrogen, regardless of its initial form, may be subject to leaching as nitrate.

Table 5–4

LEVELS OF VARIOUS FORMS OF NITROGEN IN EFFLUENT FROM SEPTIC TANKS
(mg/l)

Form of Nitrogen	Source of data: Salvato (1955)	Preul (1964)	Hickey & Duncan (1966)	Corey et al. (1967)	Popkin & Bendixen (1968)	Polta (1969)	Boyle & Polkowski (1970)	Walker et al. (1973)	Otis & Boyle (1976)	USEPA (1977a)	Andreoli (1978)
Organic	12	10	5	10	6	10	16	14	16	16	20
Ammonia	24	25	34	34	25	25	14	66	35	39	41
Total	**36**	**35**	**39**	**44**	**31**	**35**	**30**	**80**	**51**	**55**	**61**

Table 5–5

AVERAGE LEVELS OF NITROGEN AND PERCENT REMOVED BY SEPTIC TANKS
(mg/l)

Total Nitrogen	Source of data: Hickey & Duncan (1966)	USEPA (1977a)	Andreoli et al. (1977)	Average of the three	Overall average Tables 5–3 & 5–4
Influent	47	62	75	61	65
Effluent	39	55	61	52	45
% removed	17	11	19	15.7	31

Table 5–6

COMPOSITION OF GASES PRODUCED BY SEPTIC TANKS AT VARIOUS TEMPERATURES
(percentages)

Gas	Septic Tank Temperature: 59 °F	40 °F	33 °F
CO_2	2.2 ± 0.3	0.3 ± 0.01	0.27 ± 0.05
O_2	4.0 ± 1.1	8.9 ± 2.8	5.2 ± 2.2
N_2	90.7 ± 1.3	90.6 ± 2.9	95.1 ± 1.8
CH_4	2.1 ± 0.7	–	–

Walker *et al.* (1973) found that both organic and ammoniacal nitrogen were retained within centimeters of the crust formed in seepage beds, and that the levels of nitrate-nitrogen in the leachate were significantly less than the level of the total nitrogen originally entering the absorption field. Salvato (1955) found that the level of total nitrogen in a subsurface sand filter was 42 percent lower than that in the effluent from a septic tank. Finally, results from an experimental system reported by Andreoli *et al.* (1977) indicate that similar reductions of total nitrogen occurred in a field-scale experimental system on Long Island.

It should be noted that these results are not consistent with those obtained by the *Long Island Groundwater Pollution Study* (NYSDH, 1969), which investigated individual home installations. Great variability was observed, and in some cases very little reduction in nitrogen was found to occur.

Without detailed measurements, it is very difficult to interpret levels of nitrogen measured in groundwater underlying absorption fields. The dilution afforded by groundwater may produce an apparent attenuation in concentrations of nitrate-nitrogen that is misleading. For example, work reported by Viraraghawan and Warnock (1976) showed that levels of nitrate fell to background levels within 50 feet of the end of a tile field. This result is in contrast to those obtained by Walker *et al.* (1973), who demonstrated that concentrations of nitrate-nitrogen could exceed 10 mg/l at more than twice that distance.

In a study of eleven septic tank systems on sandy soils (Dudley and Stephenson, 1973), the average nitrate concentration in groundwater was about 15 mg/l. At none of the eleven sites were concentrations found to be greater than 10 mg/l at distances more than 50 feet downgradient from the absorption fields. These results are in agreement with those obtained by Preul (1966).

Such results indicate the difficulty of establishing the maximum number of disposal units that would not produce nitrate levels in excess of 10 mg/l over a broad area.

5.3.5 Discussion

For the purposes of this study, it was assumed that the daily average domestic wastewater flow was 40 gallons per person (Weston, 1976). As can be seen from Table 5–2, this flow rate is in close agreement with other studies.

Estimates of average levels of nitrogen in the influent to, and effluent from, on-site disposal systems are more difficult to achieve. Loadings of nitrogen per person are therefore not easily determined. Even greater uncertainties arise in assessing the fate of the nitrogen in the primary and secondary phases of on-site systems.

A summary of the levels of nitrogen and the percent removed by the primary treatment phase of the on-site systems is shown in Table 5–5. If the assumed average influent concentration is 61 mg/l of total nitrogen (based on the average of values from Hickey and Duncan, USEPA, and Andreoli, see Table 5–3), and the per capita flow is 40 gallons per day, then the corresponding annual load of nitrogen would be just over seven pounds. If Andreoli's estimate of 75 mg/l total nitrogen for influents is used, then the annual per capita load is equal to just over nine pounds.

Andreoli also took detailed measurements of the leachate in the absorption field. Over a twelve month period, the average concentration of total nitrogen at a four foot depth in the leaching field was 38.2 mg/l. This compared with the average influent concentration of 75 mg/l. Thus, an overall reduction of about 50 percent was observed. Although the data were less complete, measurements at a greater depth indicated that the levels of nitrogen continued to decrease and approached an overall reduction of 60 percent relative to the original strength of the sewage. This result is consistent with other studies, which have shown that average levels of nitrogen directly underlying on-site disposal systems that are functioning properly are rarely above 30 mg/l (Dudley and Stephenson, 1973).

Concentrations above 30 mg/l would appear to be atypical on Long Island even in high density residential areas that are unsewered (Perlmutter and Koch, 1972; Katz, 1978; USGS, 1976). Exceptions to this generalization might be expected where the disposal systems malfunction and the soil is heavily overloaded.

Exceptionally high concentrations of total nitrogen were observed during the *Long Island Groundwater Pollution Study* (NYSDH, 1969). At one of six sites studied, average concentrations of ammonia in the groundwater were as high as 75 mg/l. The disposal system on the site consisted of a septic tank and tile drains. Despite the 25 feet depth to groundwater, and the sand and gravel content of the soil, there was little nitrification or adsorption of ammonia.

The *Long Island Groundwater Pollution Study* did not include measurements of organic nitrogen, so it is not possible to determine what the total nitrogen loadings to the systems were. Also, measurements were taken of the septage in the tanks themselves, rather than of the influent or effluent, so the construction of a nitrogen balance from the data is impossible.

Despite the uncertainties regarding the data obtained from the *Long Island Groundwater Pollution Study,* it appears prudent to recognize that the levels of nitrogen measured were substantially higher than generally reported elsewhere. Therefore, for the purposes of this study, it was conservatively assumed that the average annual per capita nitrogen load in wastewater is ten pounds, which corresponds to an average nitrogen concentration of 82 mg/l in 40 gallons per day of raw sewage. It was further assumed, for initial calculations, that 50 percent of the nitrogen in the raw sewage will reach the groundwater.

Wastewater flows are also generated by institutional, commercial and industrial sources. The nitrogen in wastewater from these land uses can be estimated by using a standard sewage BOD to nitrogen ratio, and the sewage BOD loadings for various land use categories previously estimated by the NSRPB (1975).

In areas that are totally sewered, wastewater flows can be assumed to equal the sum of all the flows from all land uses. Where there is only partial sewering, sewage flow figures can be divided between sewers and septic tanks according to the fraction of sewered land.

Studies by the U. S. Geological Survey (Franke and McClymonds, 1972) have indicated that about ten percent of the wastewater (and, therefore, ten percent of the nitrogen) transported in sewers leaks out to groundwater. Of the remaining 90 percent of the nitrogen load conveyed by sewers, some is discharged to groundwater after treatment; the remainder is discharged in the ocean after treatment, and the nitrogen it contains is lost.

5.4 NITROGEN FROM FERTILIZERS

5.4.1 Introduction

In assessing the potential impact of nitrogenous fertilizers on ground or surface waters, it is necessary to have reliable estimates of the quantities of fertilizers used and the fate of the nitrogen following application.

Rykbost (1973) undertook a survey of thirty-five Long Island sites in order to assess the effects of various fertilizer rates on turf. In their report of 1970, Holzmacher *et al.,* estimated that householders applied an average of 3 lbs. N/1000 sq. ft./year to their lawns.

The Suffolk County Department of Environmental Control also undertook a study of the Twelve Pines area, Medford, in 1974 (SCDEC, 1974). A total of 161 householders were interviewed during the summer of 1974. As a result, the Department estimated that 9,600 pounds were applied to 21 acres of turf, corresponding to an annual application rate of 2.2 pounds of nitrogen per 1000 square feet.

5.4.2 208 Household Fertilizer Use Survey Methodology

During this study, extensive field surveys were carried out to quantify the use of fertilizers by major types of users: home owners, farmers, and insti-

tutions. Field work was also undertaken at representative sites throughout the Bi-county Region to monitor the movement and fate of nitrogen in the soil throughout the growing season.

A household survey was conducted using a questionnaire designed to elicit information regarding the quantity of nitrogenous fertilizers used, the extent of watering, the variety and quality of turf, and the method of disposing of grass clippings. A preliminary survey was made in Riverhead to test the questionnaire. Seven additional sites in Nassau and Suffolk were selected for the survey. In selecting the sites, particular attention was given to population density and to average household income.

The density of housing can affect the amount of fertilizer used, since density and the extent of impervious areas are directly related, and are inversely related to the area available for vegetation. Household income was considered because it was surmised that the degree of lawn care would be related to the level of income. Although there is doubtless some relation between income level and housing density, both should be considered, since some high density areas are occupied by high income households (*e.g.*, central western Nassau).

Some consideration was also given to the topography and the age of existing development at potential survey sites, since these factors may also affect the care given to lawns and gardens. The age of a development may also affect the number of trees and size of those trees, which in turn affects the size of the lawn and variety of grass it contains. The maturity of the lawn is also important since well established lawns could behave differently in relation to fertilizer uptake than recently seeded lawns.

Seven areas were selected on the basis of the above considerations. The locations of the areas are shown in Figure 5–1. Within each area, the individual households to be surveyed were randomly selected. A sample size of sixty households was chosen based on information obtained during a SCDEC survey in the Twelve Pines area of Medford. From the Medford study results, the mean fertilizer use and standard deviation were estimated:

Mean = 1.52 lbs N/1000 sq. feet; Standard deviation = 1.4

A desirable sample size was then calculated using the argument of Snedecor and Cochran (1956). Using a permitted error of up to 25 percent of the mean, at the 95 percent level of confidence, the sample size required was as follows:

$$n = 4 \frac{(\text{standard deviation})^2}{(0.25\ (\text{mean})^2)} = 54$$

Hence it was decided to administer 50 or more surveys per area. Two persons conducted the entire survey, and an effort was made to sustain uniformity in the way the questionnaires were administered. The Riverhead trial survey indicated that households at which responses could not be obtained on the initial visit should be replaced with alternate households. To avoid introducing a possible bias by making surveys only during working hours, the surveys were made from approximately 2:00 to 8:00 p.m.

In those cases where households used contract service for lawn and garden maintenance, the firm providing the service was questioned. Since the surveys were made during the summer, the results obtained had to be adjusted to provide estimates for the whole year. It is common practice to make

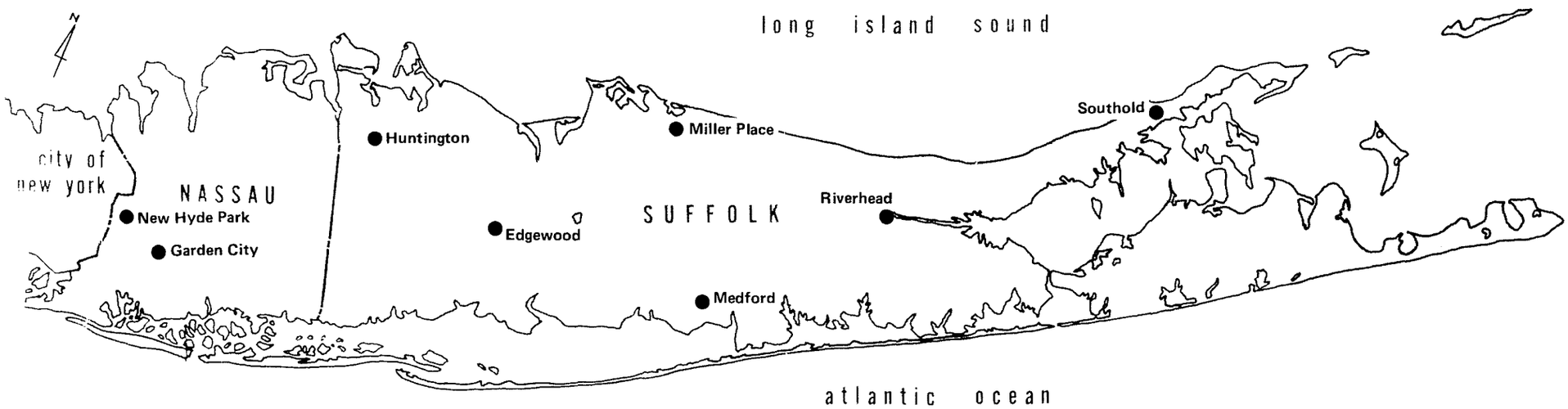


FIGURE 5–1 *208 Field Survey Areas: Household Fertilizer Use.*

one or more fertilizer applications to turf in the fall, and indeed such applications are recommended. (See the publication: *Cornell Recommendations for Turf.)* A further questionnaire was mailed to all the houses visited in order to obtain additional information with which to adjust the estimates. As happens with many surveys conducted by mail, the response was poor. However, it was possible to estimate that about 50 percent more fertilizer was applied in the fall by the householders who used fertilizers. This conclusion is consistent with recommendations for fertilizer use on turf.

5.4.3 208 Household Fertilizer Use Survey Results

Use of fertilizer was characterized by extremes, *i.e.,* was either nonexistent or exceeded recommended rates. There are a variety of reasons why homeowners do not fertilize at all, among them being lack of income; the presence of a large number of trees on the property, and therefore little grass to fertilize or a deeply shaded lawn; or the fact that the residence is temporary housing, either a rental or summer occupancy. The behavior of a majority of homeowners represented one of these two extremes; only a minority followed the application instructions on the package. For this reason, care should be exercised in interpreting nitrogen application rates for an area. If 4 lbs N/1,000 ft.^{2} is applied to one lot and none to another, the average input will be 2 lbs/1,000 ft.^{2}, which does not appear to be excessive. However, a large fraction of the fertilizer may leach through the soil on the first plot, while a much smaller amount would leach were two pounds applied to the entire area.

Some householders fertilize various parts of the yard differently. Sometimes the front lawn is fertilized and the back lawn is not. This gives validity to the idea that appearance and social value are important factors in maintaining a high quality lawn. Householders who kept their clippings often used them as a garden mulch or attempted to compost them along with other materials.

During the survey, an attempt was made to quantify the use of water for irrigating the lawns. Irrigation may induce higher rates of leaching of nitrogen than would otherwise occur. Initially, householders were requested to place a can on their lawns to catch the water, in an attempt to make crude estimates of the amount of water used. The results were erratic. Householders were then asked how frequently they watered. Although the information obtained does not permit good estimates to be made of the volumes of water applied, it does appear that some individuals apply water excessively.

The veracity of the responses to the questionnaire must also be considered. It was perceived that there was some unwillingness to respond to questions frankly, especially in the higher income areas of Nassau. Efforts were made to assure the respondents that responses would be kept confidential. Frequent explanations were made of the study being conducted and when requested, informative booklets were provided. However, quite a few homeowners appeared wary of the survey and some were very uncooperative. Where there was reserve in replying to questions, it appeared that respondents were inclined to give underestimates of their use of fertilizers. (A similar observation applies to pesticide use.)

Finally, time was the most limiting factor in this study. Although a large number of surveys were completed, the degree of confidence in extrapolating the results would have increased had more areas been surveyed. The Nassau-Suffolk Region is large and extremely diverse. Hence, the results of the survey must be accepted with caution. A summary of the results is given in Table 5–7.

Table 5–7

SUMMARY OF RESULTS FROM THE 208 HOUSEHOLD FERTILIZER USE SURVEY

Survey Area	Number of Questionnaires Completed	1969 Average Family Income[1] (Dollars)	Average Lot Size (square feet)	Fertilizer N Application lbs/1000 sq. ft. turf/year[2]	Fertilizer N Application Tons/acre turf/year
Edgewood	60	8,662	5,000	1.74	0.0379
Southold	63	10,376	27,000	1.73	0.0377
Miller Place	50	10,673	29,000	1.70	0.0370
Medford	109	13,000[3]	13,000	2.19	0.0477
Huntington	52	14,713	15,000	3.32	0.0723
New Hyde Park	65	15,008	5,000	3.00	0.0653
Garden City	61	21,805	7,000	3.75	0.0817

[1] *Calculated from 1969 income data as reported in the 1970 Census of Population.*

[2] *Based on CES Survey responses, multiplied by 1.5 to account fertilizer applied after survey was taken.*

[3] *CES estimate for area surveyed.*

As can be seen from Table 5–7, rates of fertilizer application by householders appear to be closely related to the level of household income. A graph showing the data and a line "fitted" to them by linear regression is depicted in Figure 5–2. The equation of the line accounts for about 85 percent of the variance.

FIGURE 5–2 *Relationship Between 1969 Family Income and 1976 Turf Fertilizer Use.*

The equation was used to estimate the total quantities of nitrogen applied in Nassau and Suffolk. The grid cells defined by the NSRPB were the units of computation used for the calculation. (See Section 5.6.2, Figure 5–12.) Unfortunately, income levels were not available for each cell. To make the estimation, grid cells were individually tabulated by listing the numbers of the 1970 census lying within their boundaries. The median family income for each tract for 1969 was obtained from the 1970 U.S. Census. An estimated average income level, for the households within each grid cell, was then estimated by computing the arithmetic mean of the median income levels of the tracts lying within the cell. (See Table 5–7.)

To complete the estimation for the entire region, it was necessary to calculate the total area of household lawns within each grid cell. During the survey, it was found to be impractical to use direct measurement in all areas in order to estimate the portion of the lots that were turfed. Direct measurements were made in a medium-density residential area. The average turfed area was found to comprise at least 40 percent of the entire lot. Table 5–8 presents estimates of turfed area based upon observations made during the survey, and the assumption that a specified fraction of the previous area of each lot is turfed.

Using the derived percentages of turfed areas, it is possible to calculate the total number of acres devoted to turf in each cell by multiplying the fractions corresponding to each category of residential area with the net acreage used for that category. Finally, by combining this result with an estimated rate of application related to income level, the total amount of nitrogenous fertilizer applied to residential lawns can be estimated. (See Section 5.7.1.)

Table 5–8

ESTIMATED IMPERVIOUS AND TURFED AREAS OF LOTS, BY RESIDENTIAL CATEGORY

NSRPB Residential Categories	% Impervious Area*	% of Area Turfed and Fertilized*
Low density	25	30
0–1 Dwelling units/acre	35	39
2–4 Dwelling units/acre	45	40
5–10 Dwelling units/acre	55	36
High density	65	28

**Percentage of gross acre.*

5.4.4 Use of Fertilizers on Turf Other Than Household Lawns

CES investigated the use of nitrogen on recreational and ornamental turf, such as golf courses, highways, playing fields and parks. A summary of the average annual rates of application is shown in Table 5–9.

Throughout 1976, extensive and intensive monitoring of nitrogen applied to turf was carried out. (See Figure 5–3 for monitoring locations.) A total of fourteen areas were sampled for soil nitrogen and soil water levels every two to three weeks. Samples were taken at several depths to determine profiles of nitrogen and water within and below the root zone. It was assumed that the greater part of the inorganic nitrogen detected below the root zone would eventually leach to groundwater. Some of the sites were subdivided and fertilized at different rates. Detailed measurements were made on a mature lawn at the Long Island Horticultural Research Station, where fertilizer and water were applied under controlled conditions. A listing of the basic data is available at the Suffolk County Cooperative Extension Service office in Riverhead.

Although sod farms were included in the survey, they more properly fall into the category of agricultural production, and were so regarded in this study. A key factor in normal turf culture is that it is not cropped in an agricultural sense. Although after cutting the grass the clippings may be re-

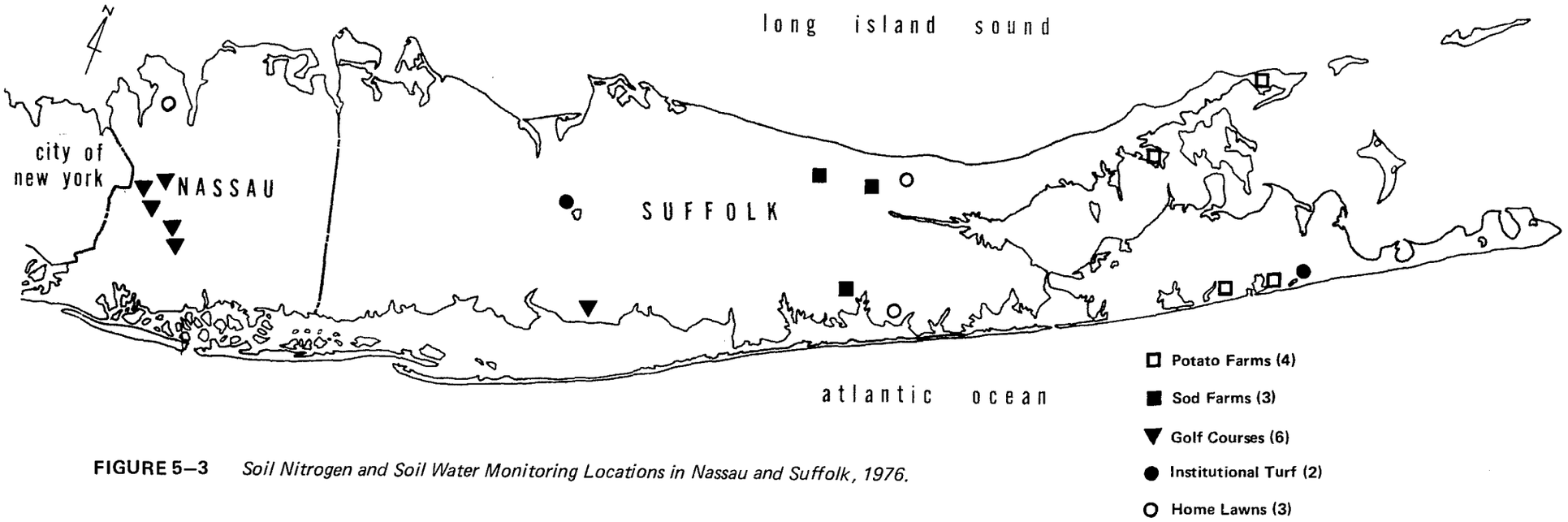


FIGURE 5–3 *Soil Nitrogen and Soil Water Monitoring Locations in Nassau and Suffolk, 1976.*

Table 5–9

ESTIMATED AVERAGE ANNUAL USE OF NITROGENOUS FERTILIZERS APPLIED TO RECREATIONAL AND ORNAMENTAL TURF

Use	Annual rate lbs N/1000 sq. ft.
Golf courses	
Greens	7
Tees	5
Fairways	3
Weighted average*	3.5
Playing fields	3
Parks**	2
Highways	0–1

**Weighted according to relative areas based on County of Nassau golf courses:*
Greens = 4.4%
Tees = 3.3%
Fairways = 92.3%

***As a rule only 10% of the turfed area in parks is fertilized.*

moved, the nitrogen is not deliberately removed entirely as is normally the case with an agricultural crop. This is a key factor in the nitrogen balance for turf. A simplified representation of the nitrogen balance for turf is shown in Figure 5–4. Evidence suggests that under mature grass, soil organic nitrogen is in equilibrium with the soil, *i.e.,* the curve representing organic nitrogen is asymptotic as shown in Figure 5–4. In this case, losses of nitrogen will approximately equal gains. Thus, on Long Island, if volatilization, denitrification and runoff are minimal, then virtually all the nitrogen in fertilizer supplied to mature grass will be leached. This may even be true if the grass is cropped and the clippings removed, because the clippings presumably remain in the area. There is, however, a possibility that there would be some volatilization of ammonia from the clippings, especially if they are composted, in which case the area may sustain an actual loss of nitrogen.

The interpretation of many field studies is not straightforward, as can be seen from Figure 5–4. If the grass were immature, and the soil initially poor in organic nitrogen, there could be a net accumulation for an indefinite period. In such a case, the quantity of organic nitrogen being mineralized (D) will be less than the inorganic nitrogen being utilized by plants (B) and hence losses of nitrogen (E) will be less than gains (A) in the short run.

An investigation was made to determine the levels of losses of nitrogen due to volatilization that may be expected in freshly cut clippings. Replicated samples of grass clippings were taken and treated four ways, as indicated in Table 5–10. The highest average loss, which was only 12.8 percent, occurred

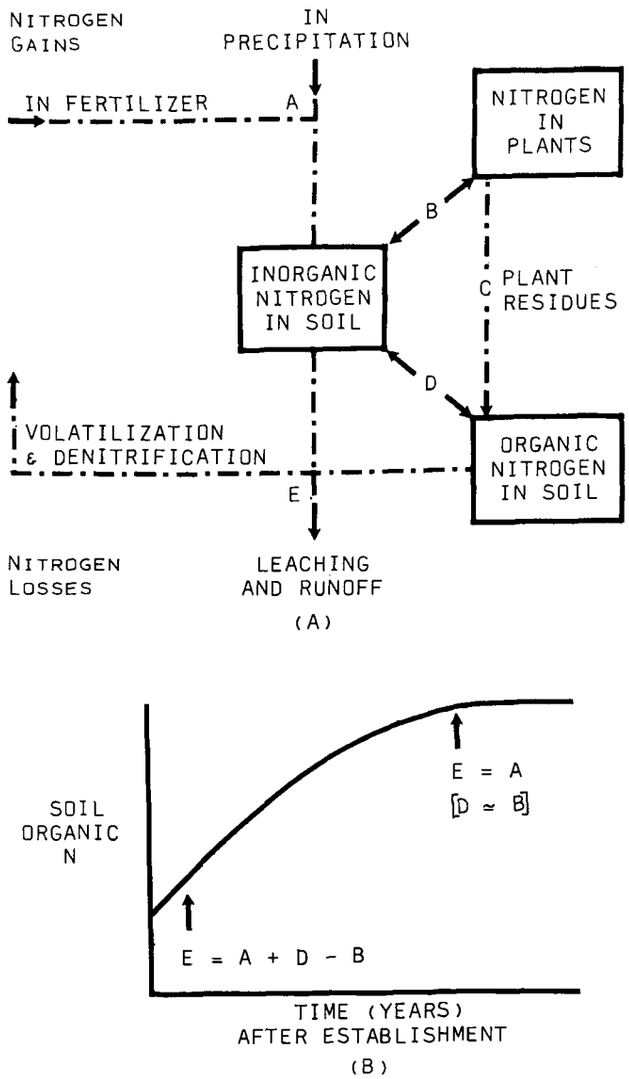


FIGURE 5–4 *Nitrogen Balance for Soil Under Turf.*

Table 5–10

LOSS OF NITROGEN FROM FRESHLY CUT GRASS CLIPPINGS

Treatment	% nitrogen in clippings after treatment	% reduction in nitrogen
Original clippings	4.68	–
Oven dried immediately	4.08	12.8
Air dried after three days	4.25	8.8

when freshly cut clippings were immediately dried in an oven. It does not, therefore, appear from these results that this gaseous loss of nitrogen from turf is likely to be significant.

As already indicated, the primary aim of the study was to measure the movement of inorganic nitrogen below the root zone. Such movement was found to occur on all plots, although to varying degrees. (See Figures 5–5 through 5–10.) As expected, the extent of downward movement of the nitrogen depended on soil conditions and the amount of nitrogen applied. The greatest losses occurred when nitrogen was applied immediately preceding irrigation or rainfall. For example, Figure 5–10 represents the measurements taken on mature turf at the Long Island Horticultural Research Station. The intent of the work was to determine the movement of nitrogen, after application, when the turf was irrigated following application.

The plots were ten feet by ten feet in area. Bulk densities, infiltration capacities, and field capacities were measured. In the first experiment, water was applied at the rate of one inch, twice a day for three days, following an application of 4 lbs. KNO_3 – N/1000 sq. ft. In the second experiment 2 lbs. of $NaNO_3$ –N/1000 sq. ft. was applied, and water was applied at the rate of one inch per day for seven days. As may be seen from the figure, the soil nitrogen profiles are very similar.

In addition to the intensive field experiments on turf already described, another experiment was conducted over a longer period of time. The intent of the experiment was to monitor the movement of inorganic nitrogen induced by rainfall and natural soil water percolation.

Eight plots, each measuring ten feet by ten feet, were marked out on good quality mature turf consisting of a mixture of bluegrass and fescue. Four treatments were applied to the plots: 0, 1, 2, and 3 lbs/1000 sq. ft. of ammonium nitrate-nitrogen. Two plots were utilized for each treatment.

Measurements for soil nitrogen were taken on October 4, 1976 at five equal depths, from zero to twenty inches. As can be seen from Figure 5–11, all the plots had similar initial background levels of inorganic nitrogen. Following the measurements, the fertilizer was applied. The data represent the averages of the results for each pair of replicates. A comparison of the

graphs clearly shows the direct relation between the amounts of nitrogen applied and the levels actually observed. Movement of inorganic nitrogen down through the soil may be seen from the graphs, especially in the cases of the treatments involving higher rates of application. Measurements were taken every few days up until mid-December; a further set of measurements was made in mid-March. By that time, virtually all signs of the added inorganic nitrogen had disappeared from the soil profile.

5.4.5 The Impact of Turf Fertilization

Traditionally, studies of turf fertilization have been directed towards achieving the highest quality of turf. Only recently has there been considerable interest in the possible environmental effects of turf fertilization (Ricke and Ellis, 1974). In the past five years, several studies have explicitly examined the movement of nitrogen in the soil. English *et al.* (1974) found that both ammonia and nitrate-nitrogen were leached from soil columns seeded with creeping bentgrass. Losses of nitrogen in the columns were found to occur in all treatments studied, although to varying degrees. This conclusion was supported by subsequent work of Waddington *et al.* (1976) in which it was found that all but one fertilizer application of turfgrass produced higher levels of nitrogen in the soil.

Ricke and Ellis (1974) studied several treatments of nitrogen applied to 'Merion' Kentucky bluegrass. The authors concluded that the leaching of nitrate-nitrogen is greatest when (a) high annual rates of nitrogen are applied, (b) infrequent and heavy applications of soluble inorganic nitrogen are made, (c) irrigation or rainfall is heavy and (d) the soil is light and sandy. As has been noted on Long Island, virtually no nitrate-nitrogen was left in the top twenty inches of soil after the winter months.

Finally, Brown *et al.* (1977) obtained results similar to those above, *i.e.,* losses of nitrogen and concentrations of nitrate in leachate were directly related to the amount of nitrogen and water applied. As in the case of the previous studies, the authors found that losses could be greatly reduced by irrigating at a rate commensurate with evapotranspiration, and by applying organic and slow release fertilizers. The authors concluded that, under careful management, losses of nitrogen from fertilized turf could be reduced to low levels.

There have also been several recent studies on Long Island. In 1973, Rykbost undertook a short term survey of thirty-five sites, including a variety of grass species, soil types and levels of fertilization. The sites included golf courses, institutions and household lawns in the Nassau-Suffolk Region. Each site was visited twice during the summer of 1973. Levels of inorganic nitrogen were determined from soil samples taken at three depths: 0–2, 2–9 and 9–16 inches. The results are summarized in Table 5–11. The table lists average levels of inorganic nitrogen measured in the top twenty inches of soil under turf at thirty-five sites. The turf at each site was fertilized at one of the four rates indicated in the table. Total nitrogen was not measured, so the

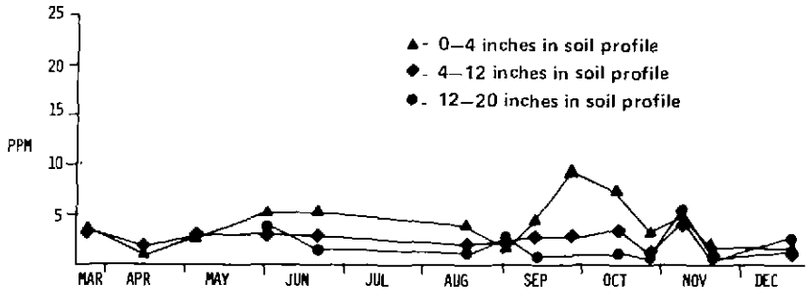


FIGURE 5–5 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under a Neglected Household Lawn, 1976.*

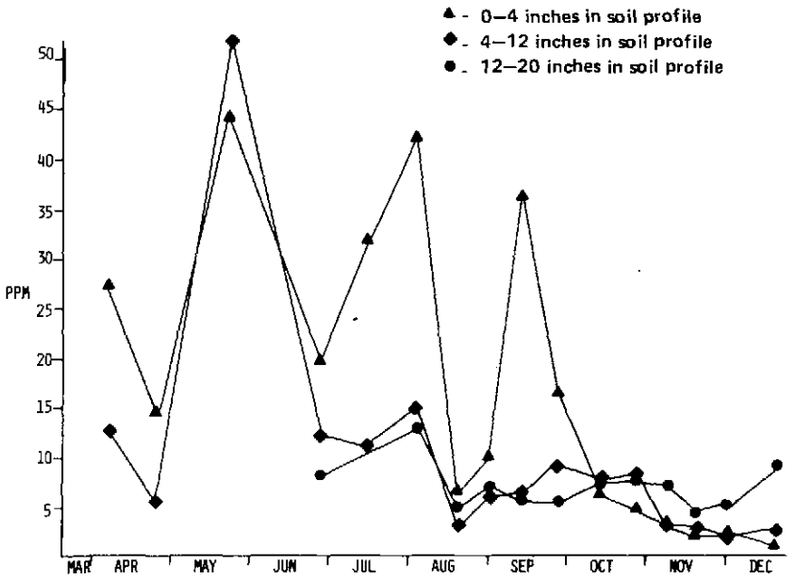


FIGURE 5–6 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under a Well-Kept Household Lawn, 1976.*

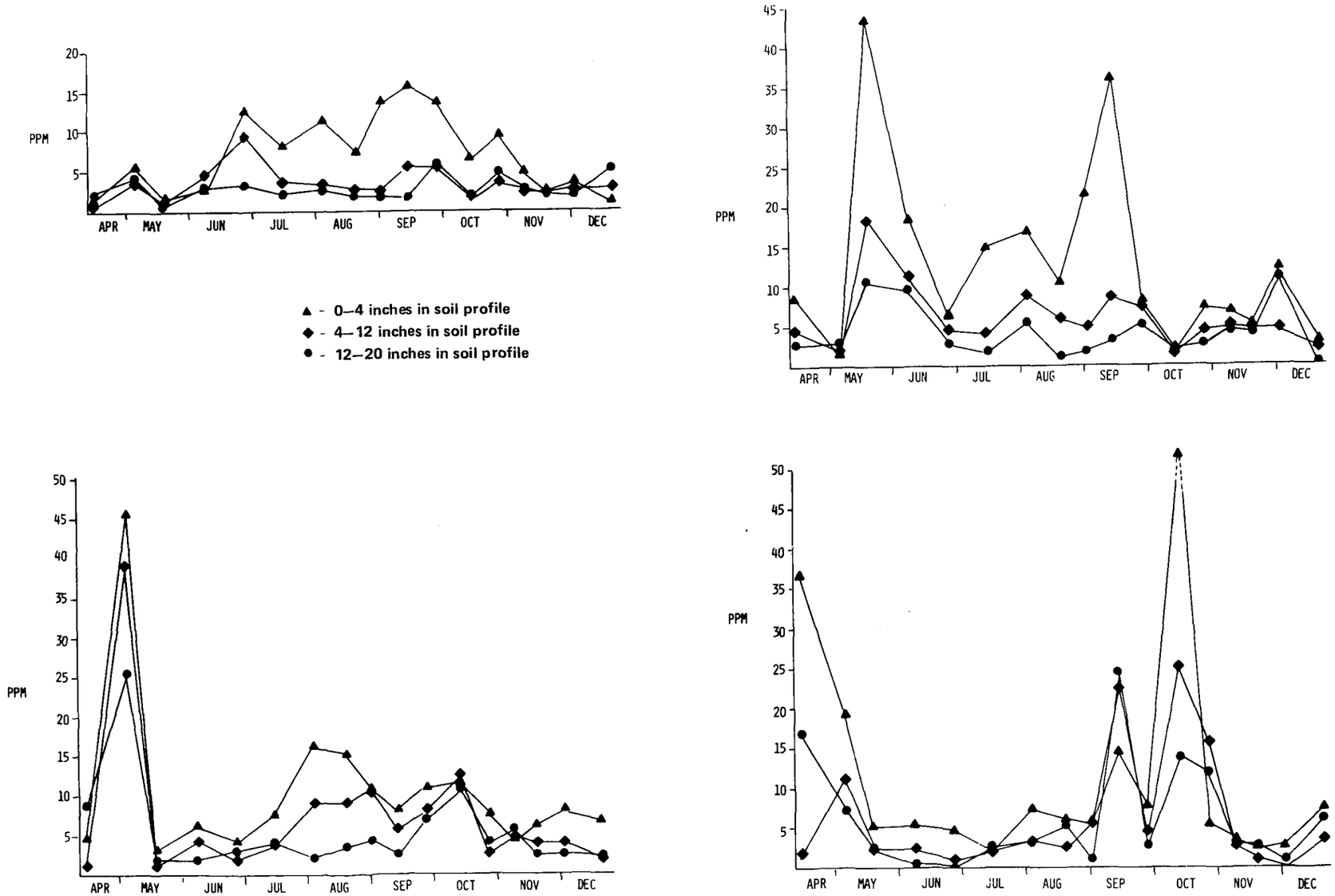


FIGURE 5–7 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under Golf Course Greens, 1976.*

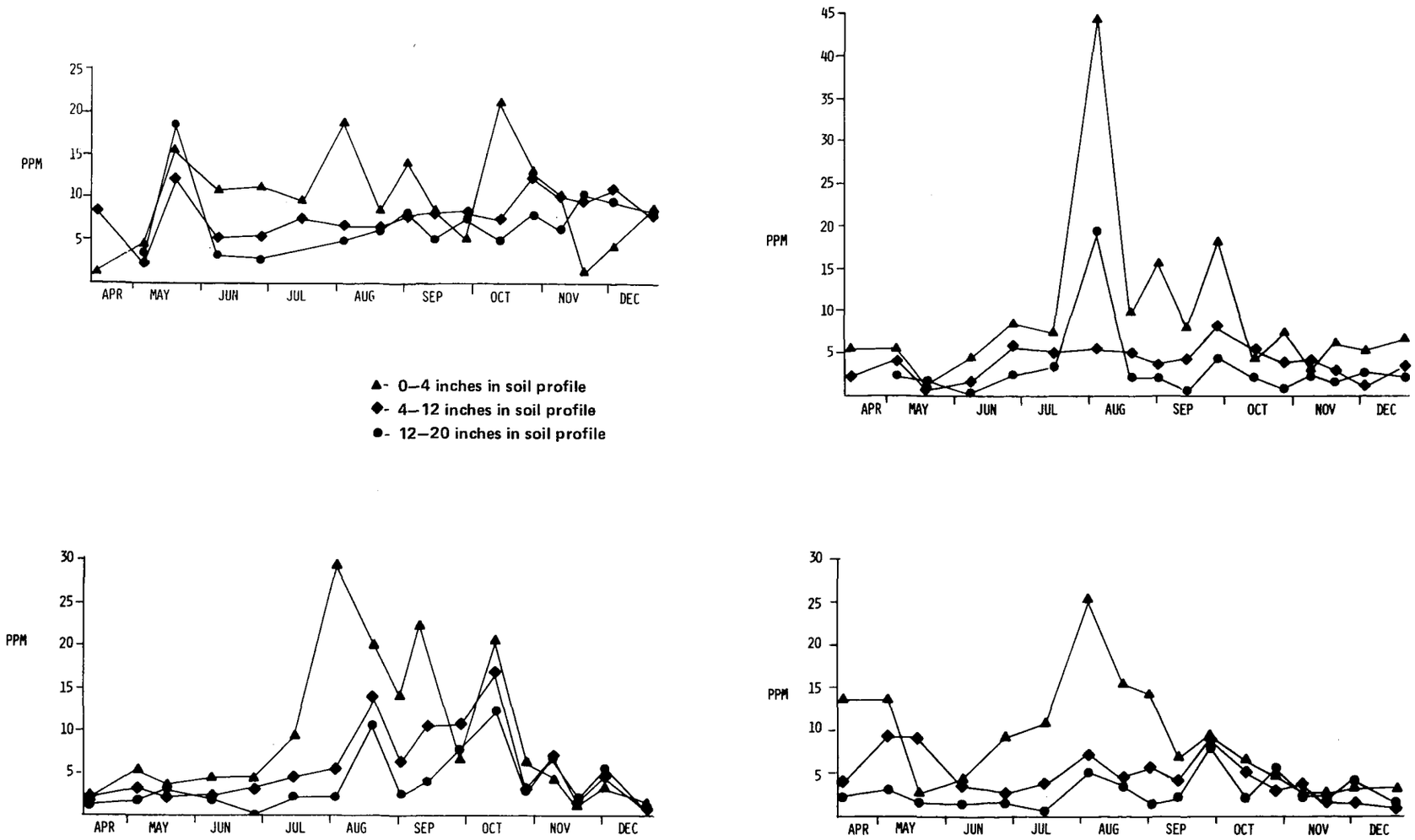


FIGURE 5–8 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under Golf Course Fairways, 1976.*

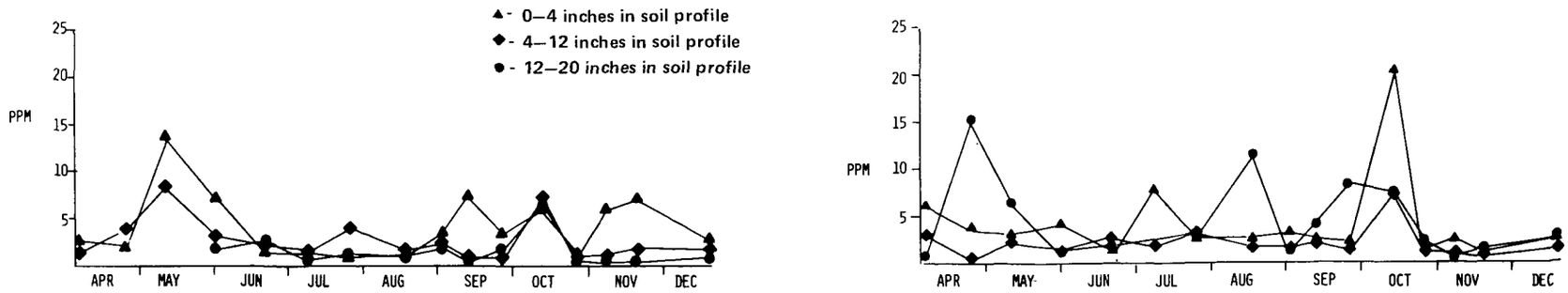


FIGURE 5–9 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under Sod Farms, 1976.*

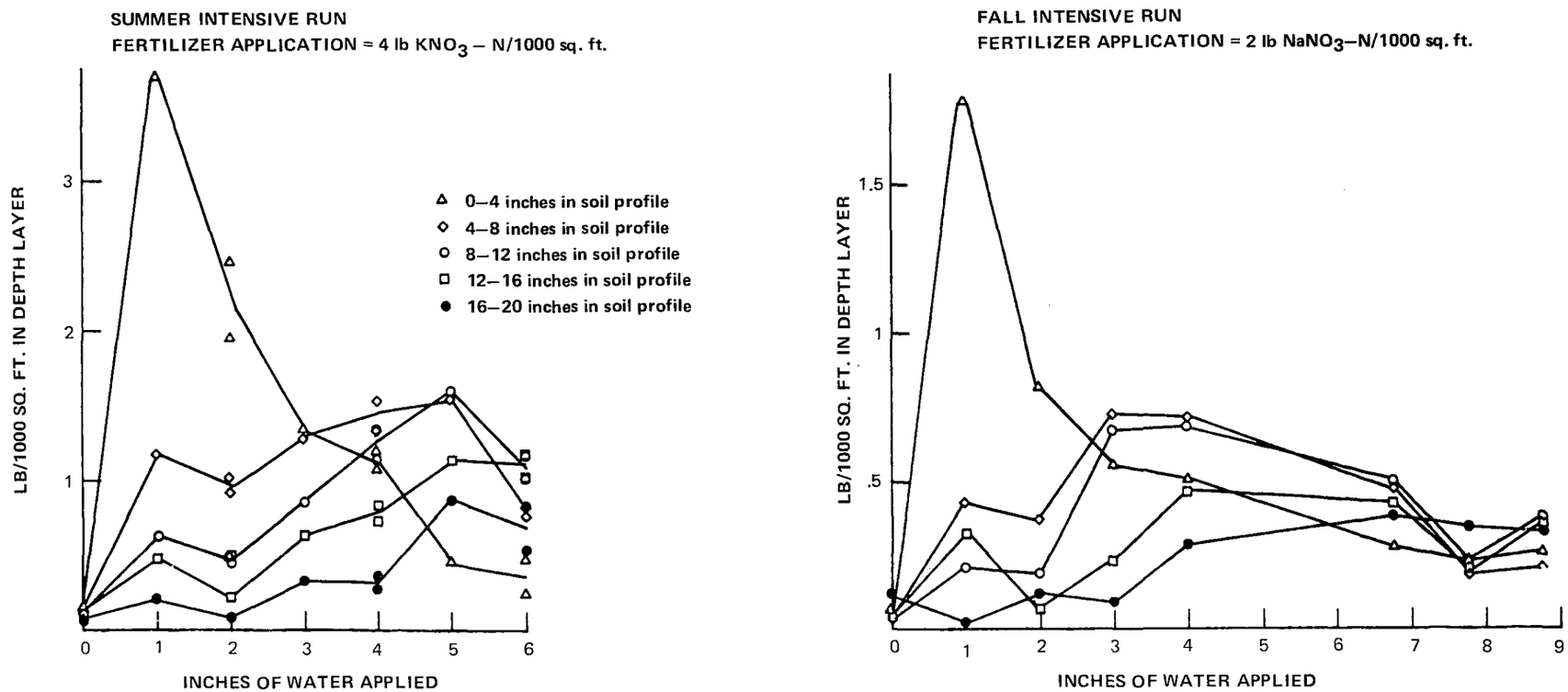


FIGURE 5–10 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under Mature Turf as a Function of the Amount of Water Applied.*

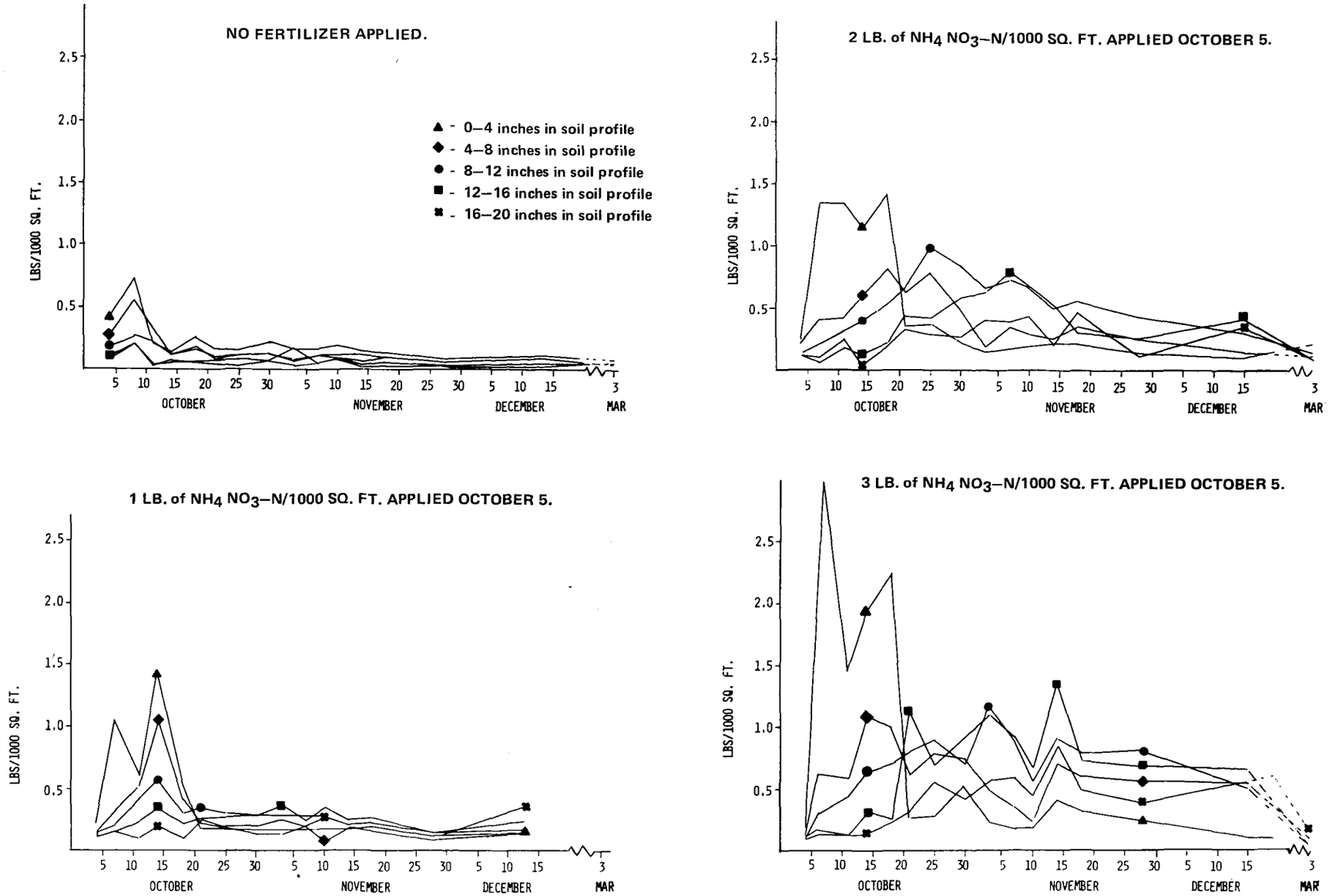


FIGURE 5–11 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under Turf Plots as a Function of the Amount of Fertilizer Nitrogen Applied, October 4, 1976 to March 3, 1977.*

Table 5–11

AVERAGE INORGANIC NITROGEN CONTENT OF TURFED SOILS RANKED ACCORDING TO THE LEVEL OF NITROGEN APPLICATION*

Soil Depth	Level of N application** Zero	Low	Medium	High
0–2"	9.8	13.2	22.5	16.7
2–9"	3.9	4.6	9.5	7.7
9–16"	2.1	4.6	5.8	6.1

**ppm on a dry soil weight basis*
***Definition of levels:*
Zero = No regular fertilization
Low = About 2 lbs/1000 ft.
Medium = About 2.5–4.5 lbs/1000 ft.
High = More than 4.5 lbs/1000 ft.
Source: Rykbost, 1973.

concentrations of inorganic nitrogen only serve as rough guides to the potential leaching of nitrogen associated with various levels of fertilization. As can be seen from the table, higher levels of inorganic nitrogen tend to be associated with higher application rates. It follows, therefore, that the higher application rates are likely to be associated with greater rates of leaching. On Long Island, turf roots rarely extend beyond nine inches into the soil; hence, soil inorganic nitrogen below nine inches is subject to leaching to groundwater.

Snow (1976) studied the effects of different rates of fertilizer applications on Kentucky bluegrasses. In particular, Snow attempted to account for the nitrogen applied by measuring the nitrogen recovered in clippings and the turf biomass. As a result of this work, Snow concluded "that large quantities of N may be leached from turfgrass areas."

The Cooperative Extension Service has estimated that the total nitrogen load in fertilizer applied to all types of turf on Long Island is about 9,300 tons per year, of which approximately 5,600 tons per year may leach to groundwater. (See Section 5.7.1.)

5.4.6 Fertilizers Applied to Potatoes

About half the total cropland in Suffolk County is devoted to potato production. Thus, it was decided that this study should also be concerned with fertilizers applied to potatoes.

Potatoes require an ample supply of nutrients, and, traditionally, large amounts have been supplied. Recent work completed by Meisinger (1976a), however, indicated convincingly that yields of potatoes could be sustained with applications of nitrogenous fertilizers as low as 150 lbs/acre. Normal applications were generally higher than this, and it is known that in some cases double that amount was applied annually. Surveys conducted by Rykbost (1976) indicated that the average rates have now fallen, in part in response to the work done by Meisinger and the Cornell Horticultural Research Station. Rykbost concluded that average annual rates were about 220 pounds.

A detailed survey of eight representative farm operations was made for this study in cooperation with the Cornell University Cost Accounts Program. The average rate of application of nitrogen by the farmers, in 1976, was about 200 pounds, an estimate close to that obtained by Rykbost.

The staff of the Cornell Long Island Research Farm has been conducting research on the variations in yield obtained in response to different types of fertilizer, amounts of fertilizer, methods of fertilizer application, and timing of application. A major part of the recent work was funded by the Suffolk County Department of Environmental Control. Results indicated that equivalent yields could be obtained with less nitrogen fertilizer than the amounts used in current fertilizer programs (Meisinger, 1976a). It was found that split applications could provide fertilizer more effectively than a single application at the time of planting. Split applications decrease the total amount of fertilizer required, and also decrease the amount of fertilizer potentially available for leaching. In January 1975, the research farm commenced a project to test these results under commercial conditions.

Four commercial farmers agreed to participate in the study. On each of the farms, the field was divided in half; half to be fertilized according to the farmer's current management practices, and half according to an experimental management program. Skimming wells were installed in each half field to monitor the groundwater nitrate-nitrogen concentrations. Yields were measured for comparative productivity. In 1976, monitoring wells were installed upgradient of the fields to determine background nitrogen levels.

The objectives of this part of the study were to determine the potential losses and gains of nitrate-nitrogen and ammonium-nitrogen within the soil under the potato crop. Core samples were taken every two weeks from March 1976 through December 1976, when preplanting, post harvest, and cover crop establishment and growth took place. A one inch diameter soil probe was used to extract samples to a twenty inch depth. The samples were divided into units of 0–12 inches and 12–20 inches. An assumption was made that the root zone was completely contained within the uppermost twelve inches. Therefore, any nitrates or ammonium measured in the 12–20 inch unit were assumed to be available for leaching into the groundwater. Each sample was taken two inches to either side of the seed through the fertilizer band.

Three random samples were taken from each half of the field, composited, placed in airtight containers, and stored at 35° F until chemical analyses were made. Storage time varied from zero to two weeks. The effects of the storage time were considered negligible.

The chemical analyses consisted of two measurements: gravimetric measurement and a micro-Kjeldahl steam distillation determination for nitrate-nitrogen and ammonium-nitrogen. Gravimetric measurements were made of twenty (20) gram samples of sifted soil. (The sifting process elimin-

ated gravels which would affect the gravimetric measurement.) The twenty gram samples were oven dried at 100°F for no less than twelve hours. The dried samples were reweighed, and the soil water content determined. Micro-Kjeldahl steam distillation required a preparation of potassium chloride (KCl) saturated soil samples. The twenty gram soil samples were extracted with 100 ml KCl. Magnesium oxide (MgO) and Devardo's alloy were used as reducing agents.

Well water samples were taken every two weeks by the staff of the Long Island Horticultural Research Station. These were also analyzed by micro-Kjeldahl steam distillation. Only nitrate-nitrogen (NO_3–N) was measured, since the concentration of ammonium-nitrogen (NH_4–N) was insignificant. The depth of the static water level was determined when the wells were installed. The depth indicated the potential time interval between the application of fertilizer and possible leaching through the soil profile to the groundwater. It was important to determine this relationship in order to derive a complete correlation between fertilizer management and the groundwater concentrations of nitrate-nitrogen.

Soil characteristics were determined for each of the demonstration potato farm sites. Soils were generally slightly acid, sandy loams, with low organic matter content and poor water holding capacities (high infiltration and permeability rates).

The results of the study showed low NO_3–N and NH_4–N concentrations in the early spring, prior to planting, indicating that the background soil nitrogen levels are low. Observed levels of nitrogen at various depths indicated a downward movement of the NO_3–N. The immediate and obvious response to fertilization application at planting was an increase in soil NO_3–N and NH_4–N concentrations. Leaching was apparent from the concentrations measured in the twelve to twenty inch layer, where it is unavailable to plant uptake. Decreasing concentrations in the surface layer for the two samples taken after fertilization were primarily due to plant uptake and/or leaching.

Sidedressing applications increased nitrogen concentrations in the surface layer but did not tend to influence the subsurface layer. This suggests that the sidedress applications coincided with the times of high plant uptake requirements. Post harvest application of fertilizer for the winter cover crop of rye showed increased concentrations of NO_3–N in both the surface and subsurface layers. The observed presence of NH_4–N in subsurface soil layers indicated a tendency for the NH_4–N to leach.

The well water nitrate-nitrogen concentration data indicated several important points. During the first year, the well water samples from the experimental fertilizer management program fields registered higher NO_3–N concentrations than those from the current management program fields. This probably reflected antecedent management practices, and seemed to imply a considerable transit time between the surface and the groundwater. At each farm, current management program field well samples having greater NO_3–N concentrations than the experimental management program field well samples began to show up early in the second year (1976). This suggests that the experimental fertilizer management program may have been effective in reducing the NO_3–N concentrations leaching to the groundwater. (For further details see reports of the Cornell Horticultural Research Station, L.I.)

The experimental management program consistently used 160 lbs N/acre. The rate applied by the current management programs ranged between 190–270 lbs N/acre. The significance of this comparison is that the lower rates of fertilization were able to produce comparable yields. The premise of the experimental management program was that effective fertilizer applications must coincide with plant nutrient requirements. The peak of the nitrogen uptake occurs approximately six weeks after planting; therefore, the heaviest application should occur at this time. The experimental fertilization program applied 60 lbs N/acre at planting, and followed approximately six weeks later with a sidedress of 100 lbs N/acre.
six weeks

The current fertilizer management programs apply the bulk of the fertilizer at planting, with a light sidedressing later in the season. If heavy rainfall occurs in the interval, and on Eastern Long Island this is more than likely, then the bulk of the fertilizer will be leached out of the root zone. Thus in the experimental fertilization program, the fertilizer is made more available to the plants and less susceptible to leaching to the groundwater.

The soil sampling program monitored nitrogen fertilizer movement during the potato season. A comparison of the fertilizer management programs indicates that there is approximately 40 to 70 percent more nitrogen available for leaching under the current management practices. The Long Island Horticultural Research Station calculated that, with efficient fertilizer management, 175 lbs N/acre/year would yield 125 lbs N in tubers/acre/year, and approximately 50 lbs N/year would be available for leaching. This leached nitrogen would produce a groundwater nitrate-nitrogen concentration of 10 mg/l if the annual recharge rate from precipitation is assumed to be 550 millimeters. This concentration is presently the maximum acceptable level for drinking water set by the USEPA. Therefore, it may be concluded that the previous rates of fertilization resulted in groundwater recharge concentrations that exceeded desired levels. Reductions in the rate of fertilization, in combination with the practice of timed fertilizer applications, have the potential to reduce nitrogen losses, while maintaining yields.

5.5 DOMESTIC ANIMALS AS A SOURCE OF NITROGEN

5.5.1 Dogs and Cats

As part of the 208 Program, the Soil Conservation Service (SCS) conducted a survey of households in five selected areas and found that "between 33% and 40% of the homeowners interviewed in the study of the sampled areas reported dog ownership" (Soil Conservation Service, 1977). The results of the survey were extrapolated to the whole Bi-county Region to produce an estimated total of between 300,000 and 360,000 (or 425,000 if strays are

included). This range corresponds closely to the estimate of 385,000 dogs, based on license data of the New York State Bureau of Dog Licensing. In order to avoid overestimating the canine nitrogen contribution, the following analysis uses a more conservative population estimate of 350,000.

From the same field survey, the Soil Conservation Service concluded that there are two cats to every three dogs in the region, or 233,000 in all. Assuming a human population of 2.735 million persons in the region, it follows that there is one cat to every twelve persons and one dog to every eight persons. Estimates of the total nitrogen load per dog per day were not readily available. For the purposes of the study, it was assumed that the *nitrogen/BOD_5 ratio for humans could be applied to the animals. Hence:*

$$\text{Nitrogen load per dog} = 0.08 \text{ lb } BOD_5 \times 0.147 \text{ lb N/lb } BOD_5\text{/day} = 4.29 \text{ lb N/dog/year}$$

Similarly, for cats, Loehr (1974) states that the BOD_5 load per cat per day = 0.06 lb. Therefore:

$$\text{Nitrogen load per cat} = 0.06 \text{ lb } BOD_5 \times 0.147 \text{ lb N/lb } BOD_5\text{/day} = 3.22 \text{ lb N/cat/year}$$

It is thereby possible to estimate the annual load of nitrogen from the pets per person as follows:

$$\text{lb N from pets/person/year} = \frac{233{,}000 \text{ cats} \times 3.22 \text{ lb N/cat/year} + 350{,}000 \text{ dogs} \times 4.29 \text{ lb N/dog/year}}{2{,}736{,}000 \text{ persons}} = 0.82 \text{ lb N/person/year.}$$

A surprisingly large fraction of the nitrogen in freshly defecated matter is rapidly volatilized. In fact, data supports the hypothesis that approximately half the nitrogen in fresh animal waste is lost by volatilization as ammonia (Porter *et al.,* 1975). For the purposes of this study, it was accordingly assumed that 50 percent of the nitrogen in pet waste would be lost in a gaseous form. It was also assumed that the remainder is deposited onto the soil surface, where it is available for removal by runoff or subsurface percolation. Thus, the actual nitrogen load from pets that may ultimately pollute ground and surface waters is equal to about 0.41 lb N/person/year.

5.5.2 Horses

It has been estimated by the Soil Conservation Service (SCS, 1977) that "there may be 30,000 or more horses in the bi-county planning area". If it is assumed that the average nitrogen content in a horse's daily waste is 0.3 pounds (Loehr, 1974) then the daily nitrogen loading from this source would be equivalent to over 300,000 persons, or about ten percent of the population. The magnitude of this equine source is therefore potentially highly significant.

The estimate of 30,000 horses, which has had wide circulation, appears to have originated in a feature article, written by Barbara Delatiner, printed in the Brooklyn, Queens and Long Island section of the *New York Times,* Sunday, July 28, 1974. In the article, the president of the Nassau-Suffolk Horseman's Association claimed that despite the decline of Long Island as a horse center, "it is estimated that some 30,000 horses still remain on the Island". The president did not indicate what fraction of this number applied to Nassau and Suffolk County, nor does other data apparently support the estimate.

In 1973, a SCS Survey of veterinarians identified 4,000 horses located in concentrations of ten or more animals. Since most horses are stabled in groups, this figure may account for a major portion of the horses, exclusive of race horses, in the Nassau-Suffolk Region.

It may be noted that in the 1974 Census of Agriculture, 34 farms were listed for Suffolk County as containing 321 horses. Even prior to the universal adoption of motor tractors on and off the farm, less than 15,000 farm and domestic horses and mules were reported for both Nassau and Suffolk Counties (1920 census).

It may further be noted that a significant part of the feed for the region's horses may be provided by the region itself, especially those animals which are pastured. Thus, the net addition to the region's nitrogen economy would be correspondingly reduced. To pasture the 4,000 horses enumerated by the Soil Conservation Service would take about 1,000 acres. It is not known how much land is devoted to pasture in the Bi-county Region, although that on farms is negligible.

Finally, according to the SCS (1977), about 2,000 race horses may be housed in the region during the racing season. However, since the waste they produce is shipped daily to mushroom farms in Pennsylvania, these animals may be virtually ignored in the region's nitrogen budget.

In summary, two conclusions are apparent. The total number of horses, and their distribution in the region are unknown, and their net contribution to the region's nitrogen budget cannot be quantified. However, it would appear there are probably substantially fewer animals then the 30,000 that have been estimated. With existing data, it appears that the 5,000 non-*racehorses is a reasonable estimate, and that these regionally would not* represent a significant input to the nitrogen budget.

5.6 ASSESSMENT OF NITROGEN SOURCE EFFECTS ON GROUNDWATER QUALITY

5.6.1 Introduction

Several recent studies have examined groundwater data from Long Island in an attempt to gain a greater understanding of the main causes of contamination. Sulam and Ku (1977) examined long term records of groundwater quality in an unsewered area of southeast Nassau County, and concluded that the maximum concentration of contaminants had occurred during the most recent period, "when the effluents from thousands of cesspools and septic tanks were being discharged". The authors also concluded that

fertilizers used before and during urbanization may have contributed large quantities of contaminants to the groundwater.

Katz (1978) made a very comprehensive study of data obtained from the southern half of Nassau County over the last twenty-five years, which showed that an improvement in the quality of groundwater with respect to nitrogen had occurred in the sewered part of the study area; improvement had also occurred in the unsewered area, but to a lesser degree. In another study of water samples from shallow wells, Katz (1978) examined short term variations in quality, and concluded that the fluctuation in quality appeared to be related to variations in non-point source pollution inputs. A preliminary analysis of trends in data from individual wells in Nassau County was made in an attempt to correlate urbanization and the extension of sewer service with groundwater quality. Unfortunately, the analysis failed to reveal a clear trend (see below).

Groundwater quality depends upon many factors, some of which may be markedly intermittent. For example, variations in the levels of inorganic nitrogen reaching groundwater may be governed by seasonal or meteorological factors, as suggested by Katz. Therefore, to adequately estimate an average concentration for a given year, a representative set of observations must be made. One observation per month appears to be a minimum number required.

Analyses for annual trends will be misleading if good estimates of annual mean concentrations are lacking. Furthermore, a period of several years must be covered by the observations. When such factors as long term cyclical patterns in the weather are taken into account, a minimum period of at least ten years is needed. Since no wells in Nassau County have a sufficient number of observations within each year, or a continuous observation record lasting at least a decade, the trend analyses undertaken by Katz and others were inconclusive.

5.6.2 Soil Conservation Service Analysis

The SCS was able to overcome some of the problems discussed in the previous section by grouping observations from different wells located in the same vicinity and aquifer. An example of such a grouping is shown in Tables 5–12 and 5–13. Wells screened in the Upper Glacial aquifer in Nassau County were grouped according to the NSRPB land use grid cells. (See Figure 5–12.)

The median concentrations of wells in each cell, as estimated by the USGS, were averaged over the period 1972 to 1976. All grid cells that were entirely sewered, or those that were without sewers, and for which observations were available, are listed in Table 5–12 and 5–13, respectively. The corresponding estimated population densities which were derived by dividing the estimated 1975 population in each grid cell by the number of acres of land (usually 1,440) in each grid cell, are also shown. As can be seen, there appear to be significantly lower nitrate-nitrogen concentrations in the sewered areas. The overall unweighted average population density in the sewered area is 12.7 persons per acre, with a corresponding average nitrate-nitrogen concentration of 4.5 mg/l. This compares with a lower overall population density of 5.8 persons per acre in the unsewered area, and a higher average median concentration of 5.8 mg/l. It should be noted that this comparison must be accepted with caution, since the histories of the areas within the two sets of grid cells differ.

After examination, the estimated average of the medians for two of the grid cells in Table 5–13, grid cells 81 and 123, were considered to be unreliable. Grid cell 81 is located in Bayville, on the North Shore of Nassau County. Measurements were available from only one well, which was screened

Table 5–12

POPULATION DENSITIES AND THE AVERAGE OF THE MEDIAN NITRATE-NITROGEN CONCENTRATIONS IN WATER FROM WELLS SCREENED IN THE UPPER GLACIAL AQUIFER IN AREAS THAT ARE ENTIRELY SEWERED

Grid Cell No.	Persons/Gross Acre	Average Median* (Mg/l)
18	6.4	5.6
19	12.2	5.9
29	9.1	4.4
30	13.7	1.4
31	11.8	7.2
33	14.1	3.9
34	12.2	5.8
43	10.2	6.8
44	11.0	4.2
46	13.0	4.8
48	14.5	2.6
59	10.7	3.6
60	16.8	2.7
61	9.6	2.0
63	12.4	1.6
75	27.2	7.0
76	12.5	6.7
93	16.5	3.2
94	13.2	1.4
143	9.0	4.9
159	11.2	9.4
Overall Average	**12.7**	**4.5**

**Medians based on observations made during 1972–76 from 49 wells.*

Source: USGS Open-file report 76–845

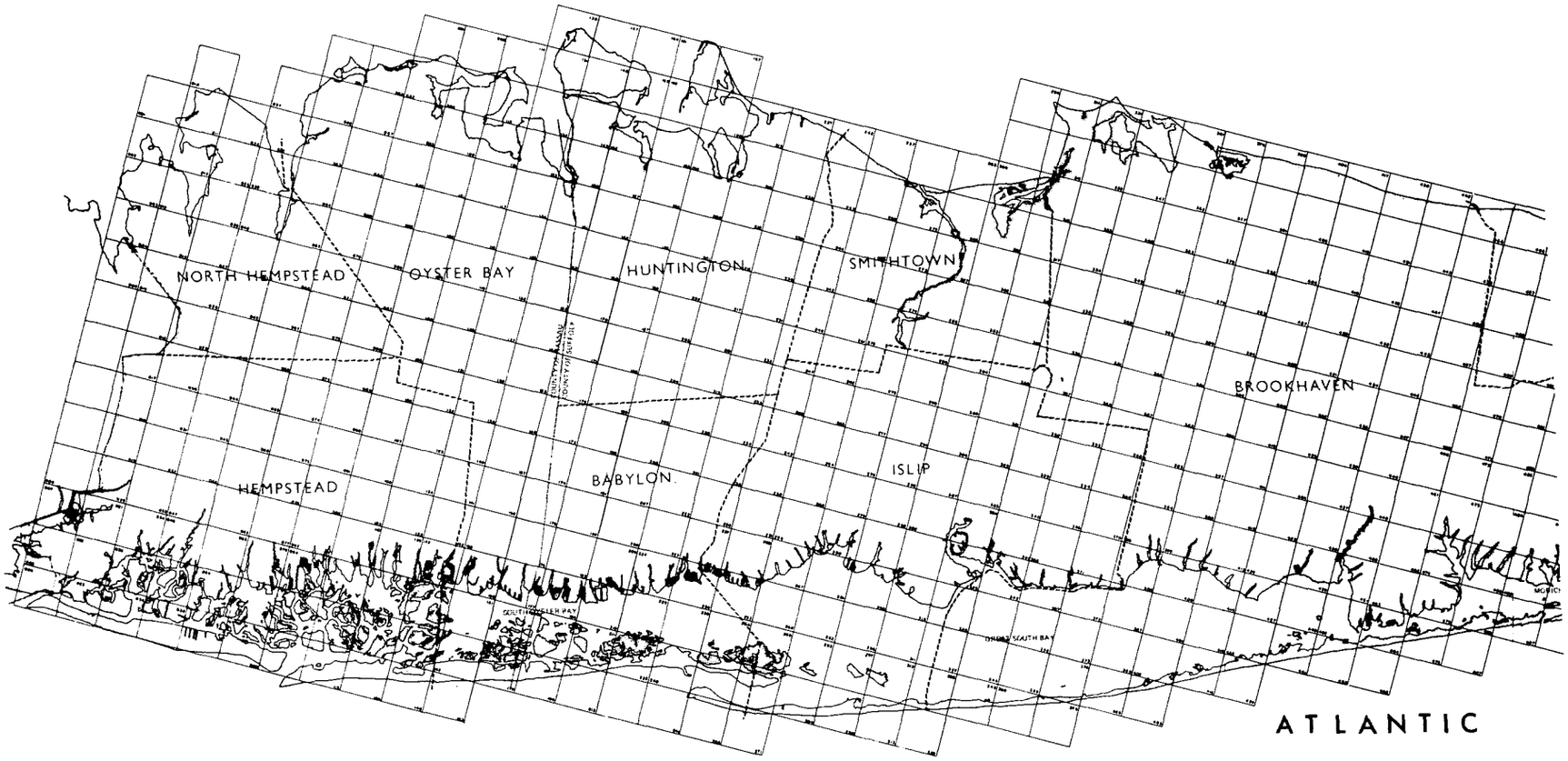


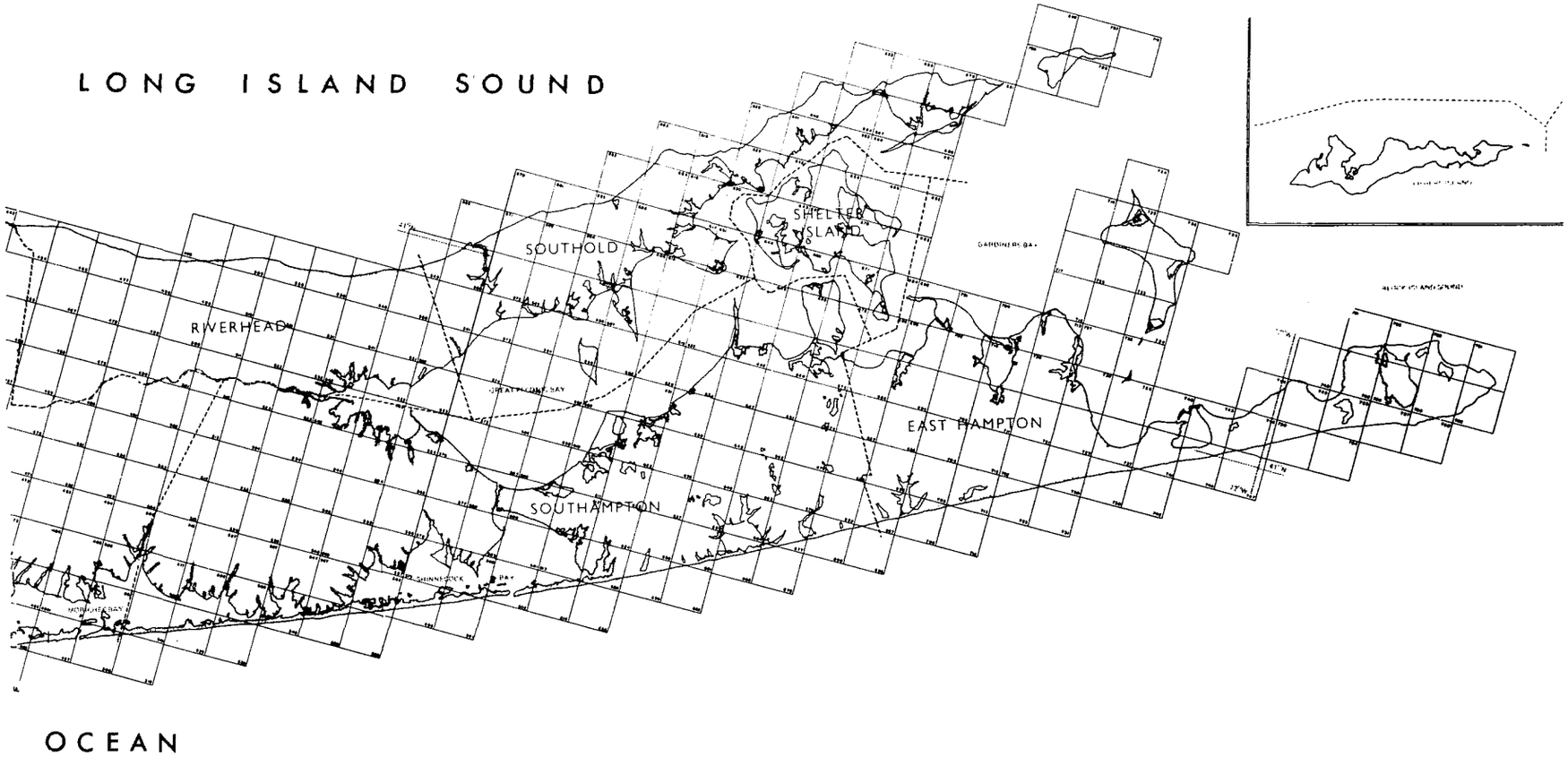
FIGURE 5–12 *NSRPB Land Use Grid Cells.*

at about 160 feet. Therefore, data from grid cell 81 were omitted from further analyses. Grid cell 123, which is in Levittown, had the largest number of wells and observations. Land use within grid cell 123 is primarily residential, with a population density of 10.5 persons per gross acre. Despite the uniformity of land use, concentrations of nitrate-nitrogen varied from less than 1 mg/l to about 16 mg/l (see Table 5–14), and the range is even larger if the individual observations, rather than the averages, are considered.

Table 5–14 shows that long term averages can be misleading, since, after 1965, samples were no longer collected from the two wells with the highest average concentrations. Abandoning wells producing poor quality water and replacing them with new wells is a common procedure. As a result, aggregate long term averages of well data may be biased in that they tend to understate pollutant concentrations.

A linear regression analysis was made relating population densities to the average of the median concentrations in the other grid cells. The result is shown in Figure 5–13. The relation obtained was based on observations over the period 1972–1976 for all wells, with the two exceptions noted, located in the Upper Glacial aquifer in unsewered areas (see Table 5–13).

Another analysis was performed independently using observations from wells that were carefully selected according to location and depth (Weston, 1977). Although this analysis mainly considered southeast Nassau County, the results obtained were very similar.



5.6.3 Groundwater Quality, Population Density, and the Drinking Water Standard for Nitrate

The variability of nitrate-nitrogen concentrations measured at public water supply wells makes it difficult to interpret these data in relation to the drinking water standard of 10 mg NO_3–N/l (applicable to water at the tap). An average (mean) value of 10 mg/l at the wellhead implies that the measured nitrate-nitrogen concentrations will exceed this level an unspecified percentage of the time. In order to assess the health implications of wellhead nitrate-nitrogen concentrations, the relationship between mean nitrate values and the percentage of measurements violating the 10 mg/l standard must be determined. An evaluation of this relationship for Nassau County wells was made by Porter (1977).

Porter's statistical analysis required the calculation of 90th, 80th, 70th, 60th, and 50th percentile values (the nitrogen concentration values below which the various percentages of measured concentrations occurred). Wells were grouped according to NSRPB land use grid cells so that the calculation of 90th percentile values, which requires at least 30 well measurements, could be made. A total of seventeen Nassau County grid cells, with a combined total of 865 observations from 54 wells, were utilized by Porter (see Table 5–15). Linear regression analyses were made for each set of percentile values and associated means in each grid cell (see Figure 5–14).

Figure 5–14 indicates the relationship between the average (mean) con-

Table 5—13

POPULATION DENSITIES AND THE AVERAGE OF THE MEDIAN NITRATE-NITROGEN CONCENTRATIONS IN WATER FROM WELLS SCREENED IN THE UPPER GLACIAL AQUIFER IN AREAS WITHOUT SEWERS

Grid Cell No.	Persons/Gross Acre	Average Median* (Mg/l)
2	1.5	2.5
55	3.3	6.6
66	0.9	1.9
71	1.5	1.5
81	9.5	19.0
82	4.2	3.1
84	0.7	1.5
104	4.4	2.3
105	10.9	9.6
119	1.6	5.0
120	6.3	9.8
123	11.9	2.3**
133	1.3	1.2
140	12.8	13.0
154	2.1	3.2
157	16.6	8.4
174	8.5	7.5
Overall Average	5.8	5.8

**Medians based on observations made during 1972—76 from 27 wells.*
***This estimate appears to be highly biased. See text for discussion.*
Source: USGS Open file report 76—845.

centration of nitrate-nitrogen measured at a particular well and the percentage of the measurements for that well that will be less than a specified concentration (in particular, the 10mg NO_3—N/l concentration used as the standard for drinking water). For example, if the average value of nitrate measurements for a well is 6mg/l, then 90% of the measurements from that well will be less than 10 mg/l (or conversely, 10% of the measurements will be greater than 10 mg/l). Similarly, if the average value of nitrate measurements is 7.1 mg/l, then only 80% of the measurements will be less than 10 mg/l (see Table 5—16).

Figure 5—14 can also be used to determine the average (mean) concentration of nitrate-nitrogen measured at a well that would correspond to a specified percentage of compliance with the 10 mg/l drinking water standard (or some other standard). For example, if it is desired that 90% of the samples from a well have concentrations below 10 mg/l (*i.e.*, meet the drink-

Table 5—14

NITRATE-NITROGEN CONCENTRATIONS IN WELLS IN GRID CELL 123 (Levittown)

Well No.	Depth (ft.)	No. of Observ.	Mean (Mg/l)	Standard Deviation	Last Year of Observation
2581	55—81	12	15.62	11.74	1965
2403	59—84	12	15.02	3.95	1965
7702	25—28	8	0.99	1.23	1968
2402	164—206	20	7.33	3.23	1968
7703	—	6	3.32	3.49	1970
7698	23—26	13	0.60	0.93	1972
7699	27—30	14	0.89	1.80	1972
7696	28—31	14	5.64	1.67	1972
7701	—	8	1.24	1.02	1972
7700	—	9	2.17	1.28	1972
7687	26—29	14	1.75	.91	1972
		130	**5.02**	**5.25**	

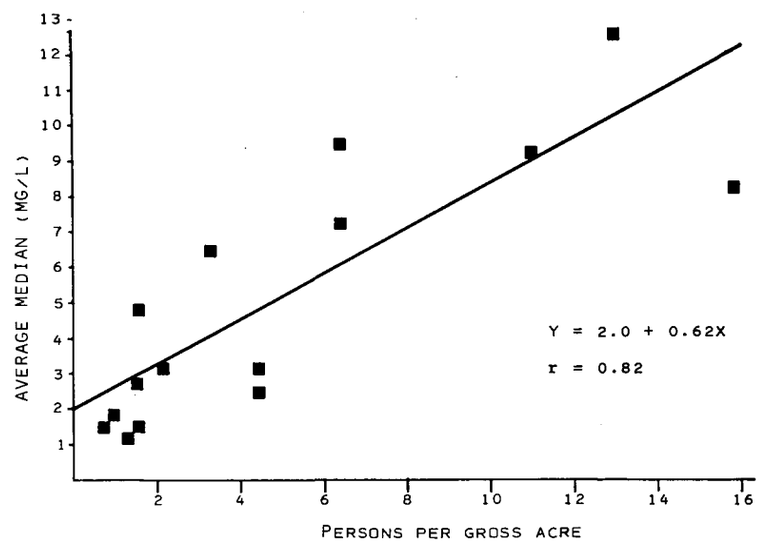


FIGURE 5—13 *Population Density and Related Nitrate-Nitrogen Concentrations in Underlying Groundwater.*

ing water standard 90% of the time), then the average (mean) concentration for water from the well would have to be less than or equal to 6 mg/l. Similarly, if compliance with the 10 mg/l standard is desired for only 50% of the samples (*i.e.,* 50% of the time), then the average concentration in the well water could be as high as 10.3 mg/l (see Table 5–16).

The relationships between population density and groundwater nitrate-nitrogen concentrations (see Figure 5–13), and between groundwater nitrate-nitrogen concentrations and the percentage of violations of the drinking

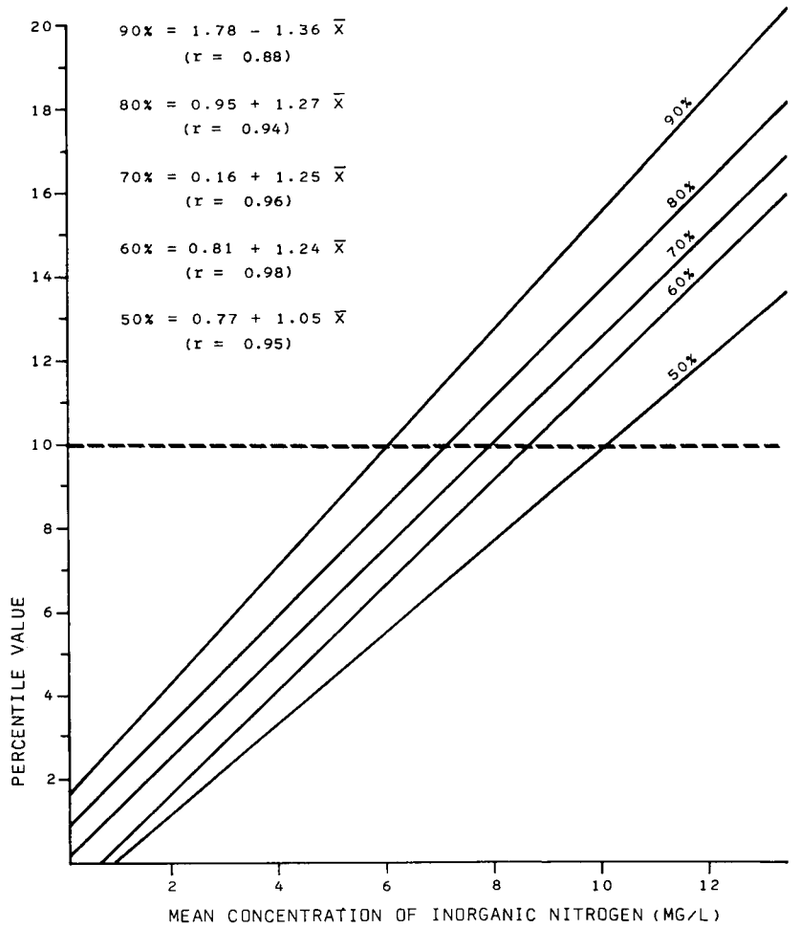


FIGURE 5–14 *Relationship Between Mean Groundwater Nitrogen Concentrations and Percentile Values.*

water standard (see Figure 5–14) can be compared to relate population density to percent violations (see Table 5–16). The statistical analysis relating population densities to variation in groundwater concentrations, as specified by percentage violation of the standard, is justified as a planning tool in the absence of reasonably convenient alternatives. The following three reservations should be noted:

1. The analysis is more empirical than statistical.
2. It would be an error to interpret the analysis as demonstrating a relation between population density *per se* and groundwater quality. Population density, as a statistical variable, is correlated with many other variables, including highways, animals and lawns (Weston, 1977). Cross correlations between such variables have been discussed by Haith (1975).
3. The groundwater data used for the analysis itself may be misleading. On purely theoretical grounds, the concentrations of nitrate-nitrogen appear too low. When all the sources of nitrogen associated with human settlements are considered, it appears remarkable that a population of ten persons per acre, with all the associated sources of nitrogen, would correspond to an average concentration of about 8 mg/l of nitrogen in the underlying groundwater. At normally assumed values of recharge (about twenty inches per year) a concentration of 8 mg/l would result from a per capita loading of about four pounds of nitrogen per year. Such a value is remarkably low, since the quantity of original nitrogen associated with an individual is close to four times that value.

That the observed groundwater concentrations are frequently unexpectedly low has been remarked by others. This may also be seen when the gross estimates of the nitrogen loads originating from the major sources are tabulated (see Section 5.7).

From a management standpoint, it is important to recognize the limitations in relying exclusively on existing groundwater data to guide management decisions. Since sources of groundwater contamination are subject to management, rather than the groundwater itself, it appears prudent, when deriving management policies, to quantify the actual sources themselves.

5.7 NITROGEN BUDGET FOR NASSAU AND SUFFOLK COUNTIES

5.7.1 Nitrogen Budget Formulation

In order to construct a comprehensive nitrogen budget for Nassau and Suffolk Counties, a computer program was developed at Cornell University that considers the relationships shown schematically in Figure 5–15. Computations were made for areas defined by the NSRPB land use grid cells (see Figure 5–12). The hydrological computations required for the program were based on the Bi-county Regional Water Budget Model described by Baskin (1977). By using the water budget model in combination with the nitrogen balance calculated for each grid cell, it was possible to estimate nitrogen loads in surface runoff to marine waters, and the loads and corresponding concentrations of inorganic nitrogen that leach to groundwater.

Table 5—15

SUMMARY OF WELL DATA USED TO DERIVE MEAN PERCENTILE RELATIONSHIPS

Grid Cell No.	Number Wells	Number Observ.	Median	Average	Standard Deviat.	Percentiles 90%	80%	70%	60%	50%
18	1	39	12.4	12.3	2.0	14.3	14.0	13.6	13.0	12.4
19	2	39	7.6	6.4	2.9	9.8	9.1	8.5	7.9	7.6
25	2	48	3.0	2.9	0.9	4.1	3.7	3.5	3.3	3.0
26	3	63	0.8	1.9	2.0	5.1	4.0	3.5	1.0	0.8
29	2	45	6.2	7.3	3.4	13.0	10.2	7.8	6.9	6.2
30	2	47	7.1	7.2	4.7	13.5	11.3	10.8	9.6	7.1
31	2	32	7.8	7.6	1.9	9.7	9.0	8.8	8.5	7.8
52	2	36	4.8	4.4	1.0	5.5	5.3	5.1	5.0	4.7
61	3	54	1.6	2.3	2.7	5.9	5.1	3.4	2.6	1.5
75	5	55	9.7	9.7	3.0	13.0	12.0	11.0	11.0	9.7
76	3	55	6.7	6.9	1.6	8.9	8.4	7.6	7.2	6.7
77	4	37	4.4	4.8	2.0	8.7	6.2	5.5	4.7	4.4
82	2	53	4.5	8.3	6.5	16.9	15.2	13.3	8.9	4.5
100	4	63	1.8	1.7	0.5	2.4	2.1	1.9	1.8	1.8
123	11	130	2.7	5.0	5.3	13.9	9.7	7.3	4.8	2.7
141	3	38	15.0	13.7	7.1	23.1	20.0	19.0	18.0	14.5
142	3	31	8.7	8.1	4.7	14.2	11.0	10.0	9.0	8.7

Table 5—16

RELATIONSHIP BETWEEN PERCENT VIOLATIONS OF THE 10 mg/l STANDARD FOR DRINKING WATER, MEAN GROUNDWATER NITRATE CONCENTRATIONS AND POPULATION DENSITIES

Percent violations	mean concentrations mg/l	population densities persons/gross acre
10%	6.0	6.7
20%	7.1	8.6
30%	7.9	9.8
40%	8.7	11.2
50%	10.3	13.7

Figure 5—16 shows the computed range of average inorganic nitrogen concentrations in percolating water in unsaturated soil for Nassau and Suffolk Counties. Table 5—17 lists the estimates of gross nitrogen loadings to the marine bays. For comparison, the estimates made by Tetra Tech (NSRPB, 1978) are included. Agreement between the two sets of results is reasonable for the North Shore bays and Peconic River, but less so for the South Shore bays. It should be noted that the methods of estimation used are different. Tetra Tech's estimates were largely based on the field measurements made during the 208 Program. The Cornell estimates are derived from water and nitrogen budgets.

A nitrogen budget for the region is presented in Table 5—18. As shown in the table, the estimated annual load of nitrogen carried down to groundwater by regional recharge is over 16,000 tons. This nitrogen is primarily in the nitrate form, and about 30 percent of it originates from human wastes discharged to the ground. The 16,000 tons that appears in the groundwater is only about 50 percent of the original load. Runoff accounts for very little of

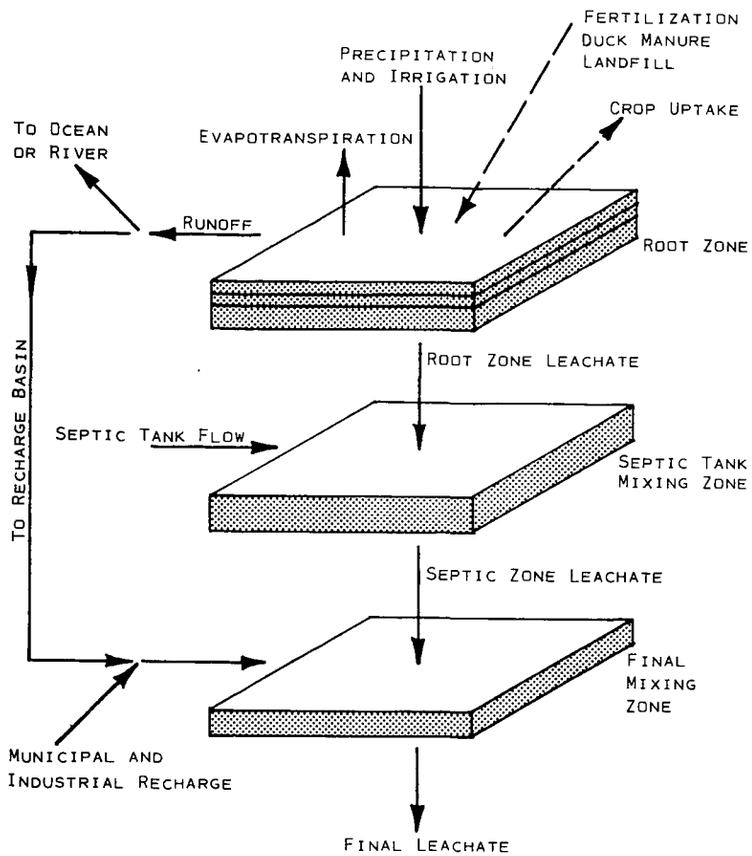


FIGURE 5–15 *Macromodel of Nitrogen Leaching.*

the difference, and it is believed that denitrification in the soil is a major factor. A very large portion of the nitrogen input to the Long Island system is believed to escape to the atmosphere in the gaseous form.

The figures given in Table 5–18 represent gross averages for the entire Bi-county Region. It must be recognized that a great deal of variability will be encountered under specific conditions. Also, the relative average magnitudes of the various components will change from locality to locality within the region. Table 5–19 shows gross estimates of nitrogen produced in a residential area with medium density housing (three houses per acre). A comparison

Table 5–17

COMPARISON OF ESTIMATES OF RUNOFF TO NASSAU-SUFFOLK MARINE BAYS

Marine Bay	Method of deriving estimates: Stormwater sampling[1] (lbs. N/yr)	Water and nitrogen budgets[2] (lbs. N/yr)
Manhasset Bay	62,050	86,000
Hempstead Harbor	80,300	110,000
Oyster Bay	105,850	101,000
Huntington Bay	135,050	129,500
Port Jefferson Harbor	73,000	70,400
Flanders Bay	10,950	10,600
Peconic River	20,000	23,800
Mecox Bay	21,900	8,820
Shinnecock Bay	21,900	38,000
Moriches Bay	69,350	76,420
Great South Bay	405,150	581,200
South Oyster Bay	98,550	154,400
Nassau Bays[3]	233,600	327,000
Totals	**1,337,650**	**1,717,140**

(1) Estimated by Tetra Tech (NSRPB, 1978)
(2) Estimated by CES
(3) East, Middle and Hempstead Bays

with the estimates in Table 5–18 shows that the relative magnitudes of the loads from the various sources for medium density residential land use differ from those for the region as a whole. The original total load of nitrogen for the acre would produce a concentration of inorganic nitrogen of about 30 mg/l, if it all leached. On the basis of work done during the 208 program, it has been estimated that reductions in nitrogen levels during, or prior to, leaching to groundwater, would produce an actual concentration closer to 15 mg/l. This compares with 10 mg/l that would be predicted by empirical relations based on groundwater data presented in Section 5.6.

The variability in the relative magnitudes of major nitrogen sources—domestic waste (population), fertilizers, precipitation, domestic pets—as a function of population density, is shown in Figure 5–17. The estimates depicted in the figure were derived from the nitrogen budget applied to unsewered areas (the grid cells listed in Table 5–13) with various land use mixes and household income levels (see Sections 5.4 and 5.6). Clearly, the variation in potential nitrogen loads from area to area is an important consideration when developing wastewater management policies for specific areas.

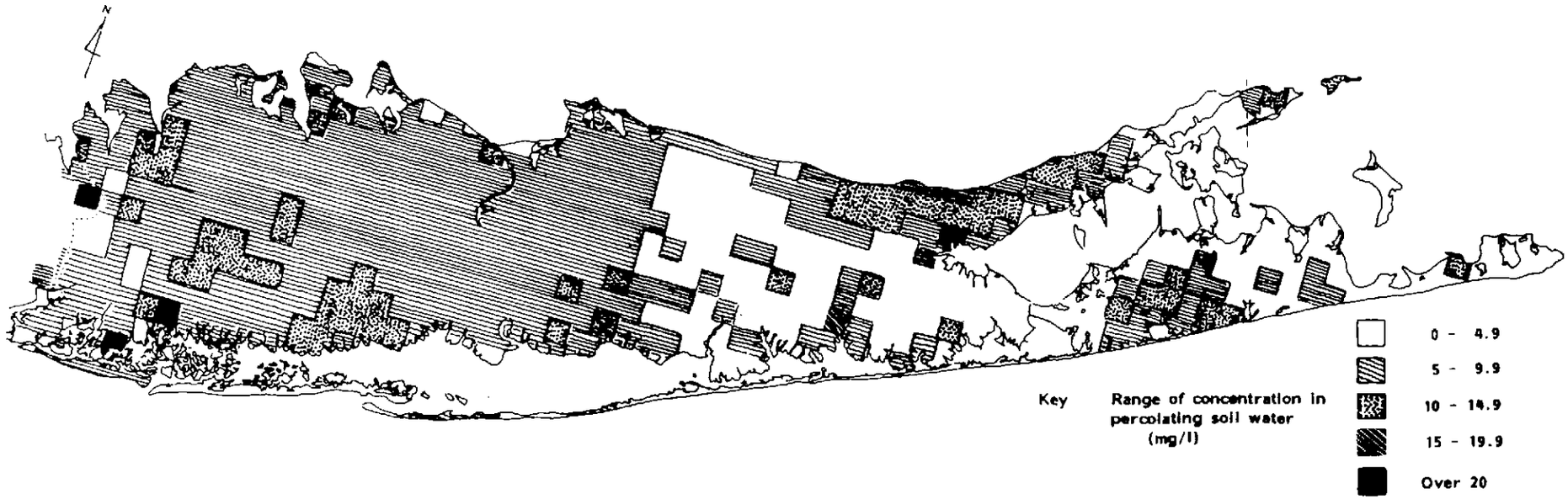


FIGURE 5–16 *Computed Range of Average Inorganic Nitrogen Concentrations in Percolating Water in Unsaturated Soil: Nassau and Suffolk Counties.*

5.7.2 Summary and Conclusions

The amount of nitrogen released into the Long Island environment by major sources of nitrogen was estimated. The estimation was made utilizing field data for fertilizer obtained during the period of the study, and a review of the literature on other sources.

Extensive and intensive monitoring of nitrogen was also performed to determine the downward movement of nitrogen from fertilizer through the upper soil profiles under different conditions. This, combined with other data obtained during the recent 208 Study, provided a comprehensive means of estimating the transport of nitrogen, from its sources, down to groundwater and overland to surface waters.

A computer program was constructed to provide a convenient means of identifying water and nitrogen budgets for each of the grid cells defined by the Nassau-Suffolk Regional Planning Board. Components in the budgets were related to land use characteristics.

The following conclusions were reached:

1. The major sources of nitrogen are human waste and fertilizers, which annually contribute approximately 14,000 and 13,000 tons, respectively.

2. Available data indicates that there are large (*e.g.*, 50%) reductions of nitrogen in on-site disposal systems, although variations in removal capability may vary significantly.

3. Available data indicates that most of the nitrogen applied to turf is lost to ground and surface waters, except in those cases where clippings are removed and taken to landfills.

4. It is estimated that about 75 percent of nitrogen applied to agricultural crops such as potatoes is removed by the crop.

Table 5–18

SUMMARY OF GROSS ESTIMATES OF SOURCES AND FATE OF NITROGEN IN THE BI-COUNTY REGION
(based on 1975 and 1976 data)

Source	Initial Nitrogen Load (tons/yr)	Load to Groundwater (tons/yr)	Comment on Sink
Wastewater			
On-site systems	8,500	4,300	(Denitrification, etc.)
Sewers & sewage treatment Sewer leakage	500	200	(Denitrification, etc.)
Effluent discharge to ground	200	100	(Denitrification, etc.)
Effluent discharge to marine bays	4,200	—	(Discharge to sea)
Sub-total	**13,400**	**4,600**	
Fertilizers and Animals			
Farm (Incl. sod farms)	4,000	1,000	(Crop removal)
Turf (Incl. households, golf courses, etc.)	9,300	5,600	(Volatilization & Denit.)
Animals (primarily dogs & cats)	1,600	800	(Volatilization & Denit.)
Ducks	600	300	(Volatilization & Denit.)
Sub-total	**15,500**	**7,700**	
Precipitation	4,000	3,700	(By difference from totals)
Total	**32,900**	**16,000***	**(Totals estimated by water/nitrogen model)**

**Assuming an annual recharge of about 500 billion gallons, the resulting concentrations in the leachate equals about 6.8 mg/l.*

Table 5–19

ESTIMATED ANNUAL LOADS ORIGINATING ON AN ACRE OF RESIDENTIAL LAND WITH THREE HOUSES

Source	Lbs. of Nitrogen Initial Load	Lbs. of Nitrogen Approx. load to Groundwater	Assumption
10 Persons	100	50	(10 lbs. N/person)
15,000 sq. ft. of turf	45	25	(average household income $16,000)
Pets	10	5	(0.82 lbs/person approx.)
Precipitation	10	6	(1 mg/l)

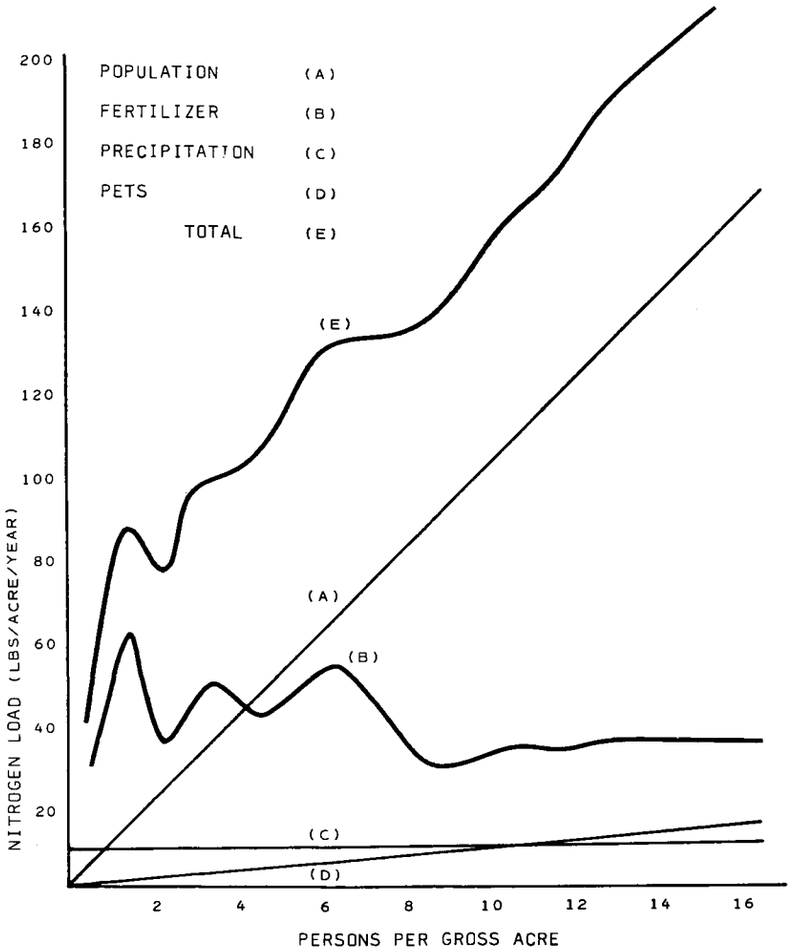


FIGURE 5–17 *Relationships Between Population Density and Nitrogen Loadings to Groundwater from Major Pollution Sources.*

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