GP

Chemical contamination of aquifers on Long Island, New York

August A. Guerrera

On Jun. 21, 1978, the US Environmental Protection Agency determined that the aquifer system underlying Nassau and Suffolk counties on Long Island, N.Y., is the principal source of drinking water for these counties and that if the aquifer system were contaminated, it would create a significant hazard to public health. This "sole source" designation made pursuant to Section 1424 (e) of the Safe Drinking Water Act (Public Law 93-523) requires that a federal agency may not commit funds (through a grant, loan guarantee, contract, or otherwise) to any project that may contaminate the aquifer system through a recharge zone. Although this designation has only rarely been utilized to influence the commitment of any federal funds on Long Island, it does emphasize the unique hydrologic situation there, where almost three million people are served exclusively with groundwater developed on an island surrounded by salty water.

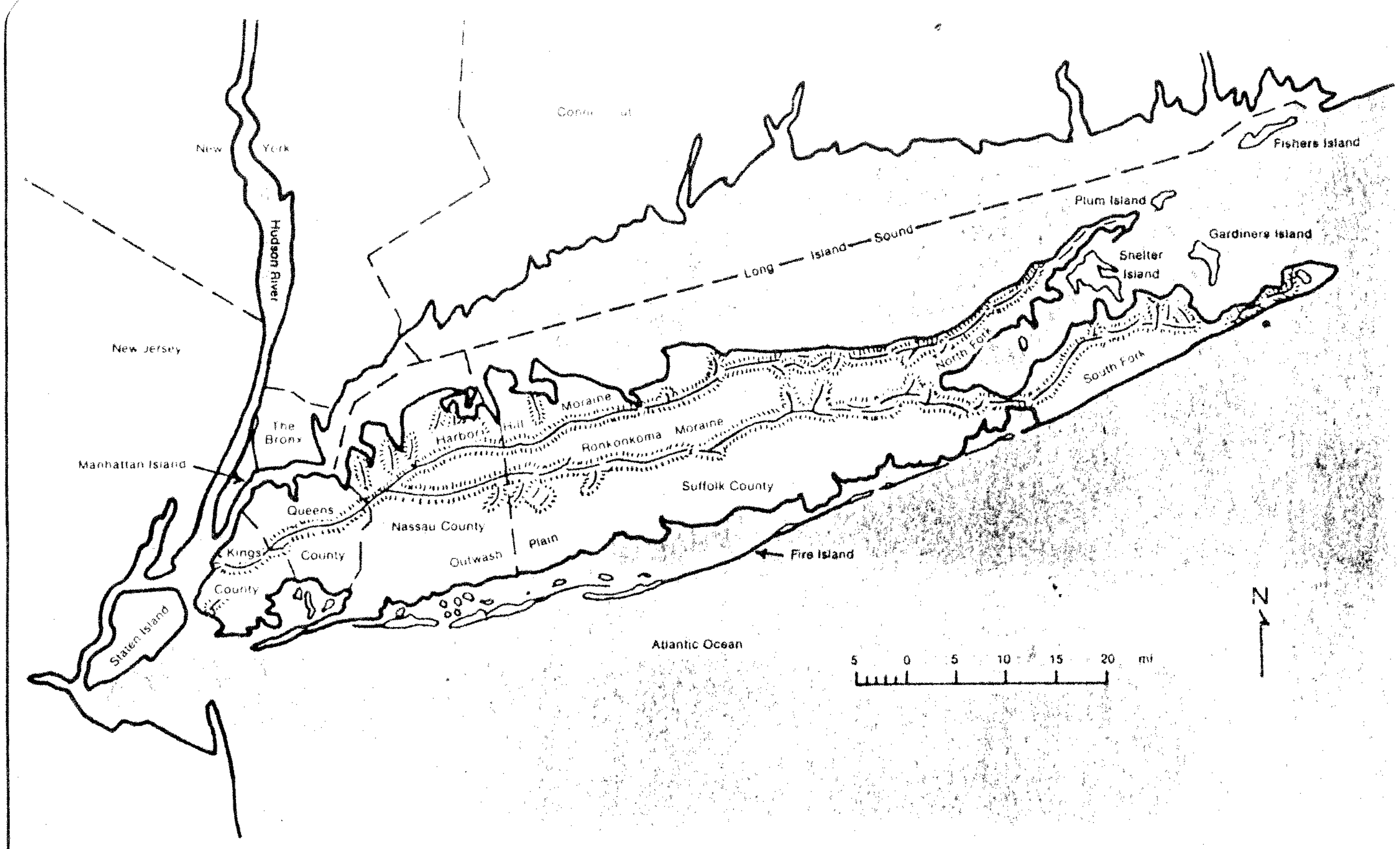

Figure 1. Physiographic features of Long Island N.Y.

Chemical contamination of aquifers on Long Island, New York

August A. Guerrera

On Jun. 21, 1978, the US Environmental Protection Agency determined that the aquifer system underlying Nassau and Suffolk counties on Long Island, N.Y., is the principal source of drinking water for these counties and that if the aquifer system were contaminated, it would create a significant hazard to public health. This "sole source" designation made pursuant to Section 1424 (e) of the Safe Drinking Water Act (Public Law 93-523) requires that a federal agency may not commit funds (through a grant, loan guarantee, contract, or otherwise) to any project that may contaminate the aquifer system through a recharge zone. Although this designation has only rarely been utilized to influence the commitment of any federal funds on Long Island, it does emphasize the unique hydrologic situation there, where almost three million people are served exclusively with groundwater developed on an island surrounded by salty water.

The Long Island, N.Y., area has experienced a dramatic increase in population since the end of World War II, but it is only in the past two decades that extensive sewerage projects have been advanced to protect groundwater quality. Although more than 568 ML (150 mil gal) of untreated domestic wastes are still discharged to the ground daily through on-site disposal systems, only recent experiences with contamination of these aquifers by chemicals introduced by other activities of man will be discussed in this paper. These chemicals include volatile halogenated hydrocarbon solvents and a carbamate pesticide extensively used by potato farmers. The detection of these chemicals at μg/L (ppb) levels and the response of local regulatory agencies to the uncertain health risks associated with them have had a dramatic and costly effect on the ability of local water suppliers to meet the needs of their consumers.

There is considerable information about the water resources of Long Island as a result of the 50 years activities of a renowned subdistrict office of the US Geological Survey (USGS) performing technical studies at the request of local governments and with their matching-funds support. The following synopsis of

0003-150X/81/040190-10$02.00

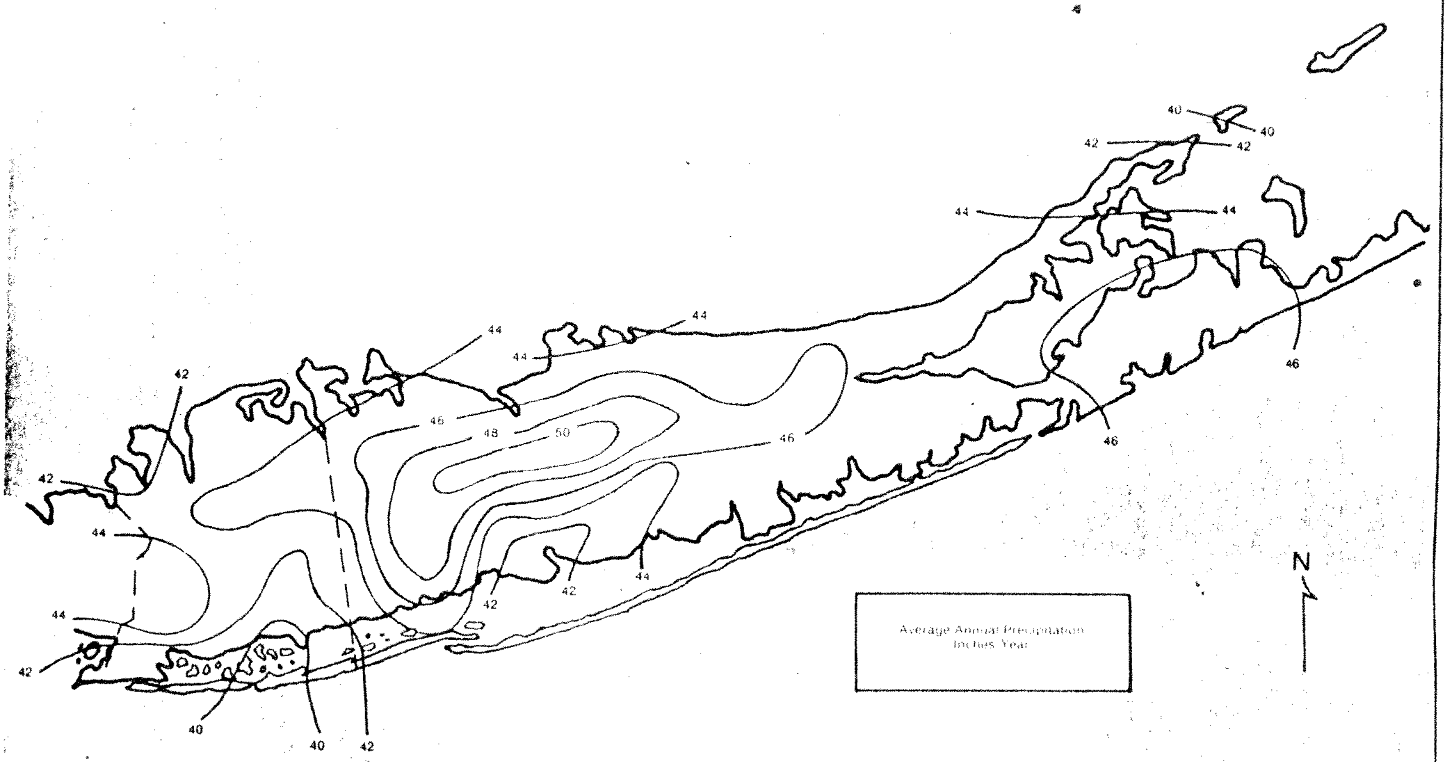

Figure 2. Annual precipitation on Long Island N.Y.

portions of these studies is presented to demonstrate the uniqueness of this resource and its vulnerability to contamination.

Location and extent of area

Long Island extends eastward from the mainland part of New York state, about 193 km (120 mi) into the Atlantic Ocean. Kings and Queens counties are part of New York City and derive most of their water supply from surface waters from central New York state. However, the three million people occupying the 3108 sq km (1200 sq mi) of Nassau and Suffolk counties derive their entire water supply from wells tapping the underlying groundwater reservoir. Fire Island is the longest of several barrier beaches that parallel the south shore of Long Island, where the major water supply sources are free-flowing artesian wells intercepting underflow from the main part of the island and discharging to the Atlantic Ocean. The two eastern peninsulas, known locally as the North and South Forks, are considered hydrologically separate from the main part of the island, as they are supplied from freshwater lenses which are several hundred feet thick and are underlain by salty water with chlorinity equal to that of the Atlantic Ocean.

Topographic and physiographic features

During the Pleistocene or Ice Age, great continental ice sheets developed and spread over Europe and North America. At least two glaciers of the Wisconsinan Age reached Long Island and began retreating 12 000 to 15 000 years ago. The southerly limits of the ice advances are marked by terminal moraines with lines of hills reaching a maximum altitude of 122 m (400 ft). The Ronkonkoma Moraine is the oldest of the southernmost line of hills and extends eastward to form the South Fork. The Harbor Hill Moraine, in the northern line of hills, extends eastward to form the North Fork (Figure 1). The moraines are composed of poorly sorted rock debris consisting of boulders, gravel, sand, and silt. This debris was pushed ahead of and incorporated within the continental ice sheets when they rode over New England and advanced onto the island, and it was deposited during the melting of the ice.

The moderate flat surface south of the Ronkonkoma Moraine (Figure 1) is a glacial outwash plain composed of sands and gravel deposited by streams that were fed by glacial-melt water draining into the ocean, whose level was then more than 61 m (200 ft) lower than at present. Along the north shore are eroded headlands composed of glacial deposits and harbors eroded by northward flowing streams. Wave erosion on Long Island Sound has steepened the northern slopes into nearly vertical bluffs some 30 m (100 ft) high in places.

Climatic conditions

Long Island is located between 40° and 42° north latitude in a temperate climate belt. The mean annual temperature of 11°C (51°F) is several degrees higher

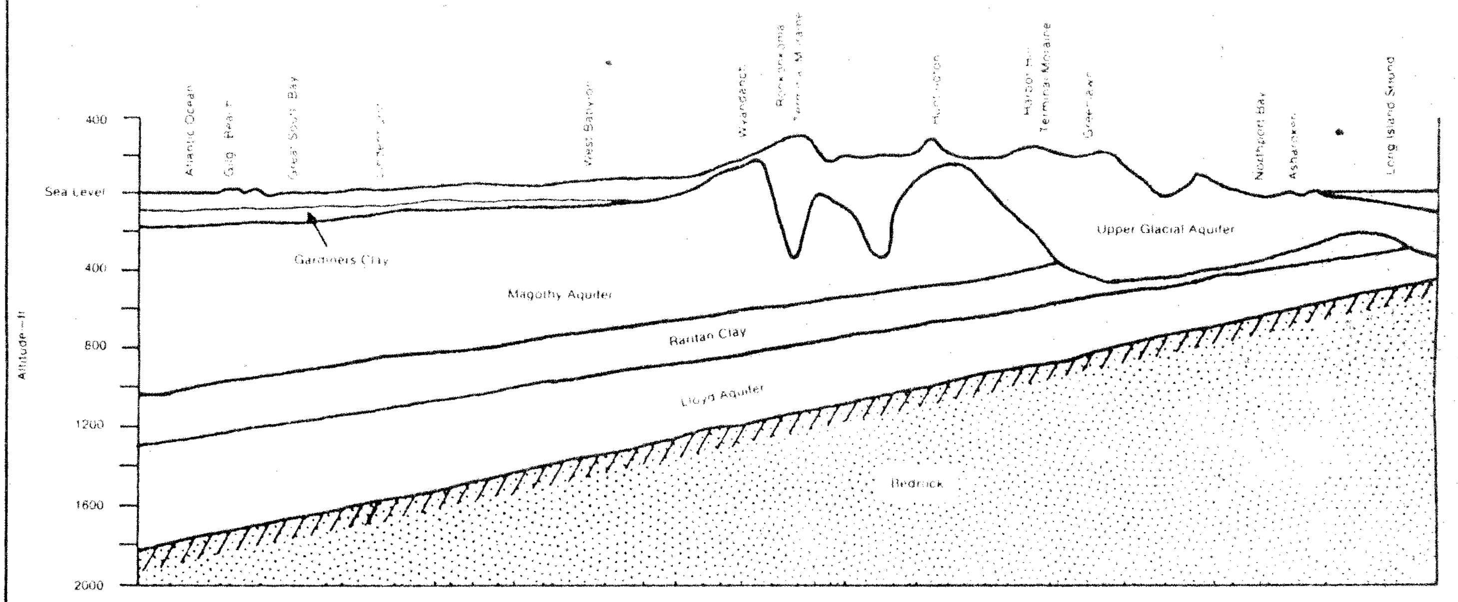

Figure 3. Geological cross section of Long Island N.Y.

than that of nearby New York state because of the influence of the Atlantic Ocean and Long Island Sound. The eastern end of the island is a popular vacation resort because temperatures are moderated by the ocean, with cooling on-shore breezes during the summer months when the prevailing winds are from the south and southwest. Precipitation averages about 112 cm (44 in.) per year and is fairly evenly distributed throughout the year (Figure 2). At depths of 30–122 m (100–400 ft) below the land surface, the groundwater temperature is also 10°C (50°F).

There are, therefore, in all four counties many wells withdrawing water for air-cooling purposes. In Nassau and Suffolk counties, state law requires recharge of that water to the same aquifer from which it was withdrawn.

Major hydrogeologic units

Long Island is geologically part of the Atlantic coastal plain and is more directly related to the coastal regions of New Jersey than New England. Long Island is composed of unconsolidated deposits of sand, gravel, and clay in more or less parallel beds on a hard bedrock surface. The crystalline bedrock, of schist or gneiss, appears at the surface in Manhattan and Queens counties and slopes to the southeast at 11–13 m/km (60–70 ft/mi). The unconsolidated rock materials that overlie the bedrock and that constitute the groundwater reservoir form a wedge-shaped mass ranging in thickness from about 200 m (650 ft) to more than 600 m (2000 ft). They consist primarily of a series of Pleistocene glacial deposits and fluvial deltaic deposits of the Cretaceous Age. The glacial deposits lie on an irregular surface and in some places fill valleys cut by preglacial streams.

Groundwater in the uppermost part of the zone of saturation is under water-table conditions, but artesian conditions predominate in most other parts. The hydraulic head in the confined or partially confined aquifers ranges from about 3 m (10 ft) below the water table, near the groundwater divide in the center of the island, to as high as 6 m (20 ft) above it along the north and south shores and on the barrier beaches (Figure 3).

The outwash deposits are moderately to highly permeable, with specific capacity of wells ranging from 3 to 13 L/s (40 to 200 gpm/ft) of drawdown. The Magothy Formation in Cretaceous material is poorly to moderately permeable with specific capacity of wells from 0.06 to 1.9 L/s (1 to 30 gpm/ft). Recharge to the water table occurs virtually all over the island, and the water table surface, therefore, represents a variable potential that is equal to the altitude of the water table at any point.

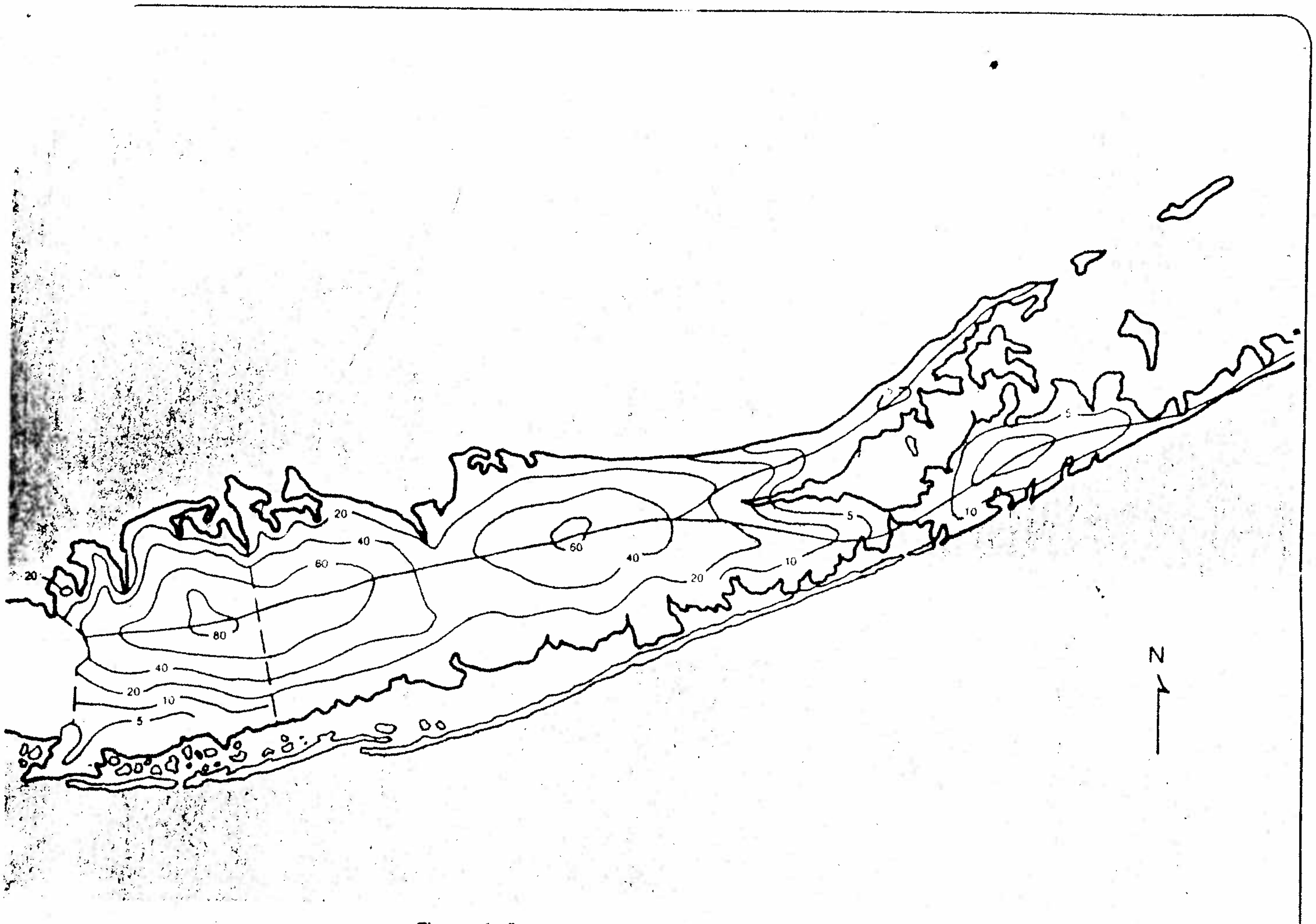

Figure 4. Groundwater contours on Long Island N.Y.

About half of the precipitation is lost because of surface water runoff and evapotranspiration; the remaining precipitation infiltrates the ground and recharges the aquifer. A map of the contours of the water table on Long Island indicates two prominent highs—one about 24 m (80 ft) above sea level in Nassau and one about 18 m (60 ft) above sea level in Suffolk (Figure 4). The horizontal component of the direction of groundwater movement is at right angles to the contours with velocities ranging from 9 to 61 cm/d (0.3 to 2 ft/d). Since the differences between vertical and horizontal permeability are substantial, vertical movements in the saturated zone may be as slow as 3 m/year (10 ft/year), even near the maximum elevation of the water table. The residence time of water in this system may, therefore, be extremely long, estimated by the USGS at many hundreds of years (Figure 5).

Water quality

Under predevelopment conditions, the natural freshwater of Long Island had a remarkably low dissolved solids content, primarily because of the relatively inert deposits within the groundwater reservoir and its replenishment exclusively by precipitation. Total dissolved solids are less than 50 mg/L and in some cases as low as 20 mg/L, with total hardness and alkalinity less than 10 mg/L. The pH of Long Island groundwater is generally low, commonly less than 6 and in the deeper aquifers less than 5. Some of the groundwater, especially the older, deeper waters near the south shoreline, has a high iron content considerably above the 0.3 limit with H_2S present.

Man's activities have affected the quality of the water on Long Island through a variety of mechanisms including

- Rainwater with sulfates and low pH;
- Discharge of cesspool effluents with increases in nitrogen, sulfate, and sodium;
- Discharge of industrial wastes through recharge basins or leaching pools, with increases in heavy metals, detergents, and solvents;
- Leachate from sanitary landfills with increases in metals, sodium, calcium, and chloride;
- Leaching of fertilizers and agricultural chemicals from farming and cultivation of turf; and
- Increases in chlorides, sodium, and calcium from the storage and application of roadway deicing salts.

Development of the groundwater supply

The amount of water stored within the groundwater reservoir is so vast (more than 227 trillion litres [60 trillion gallons]) that there is sufficient available

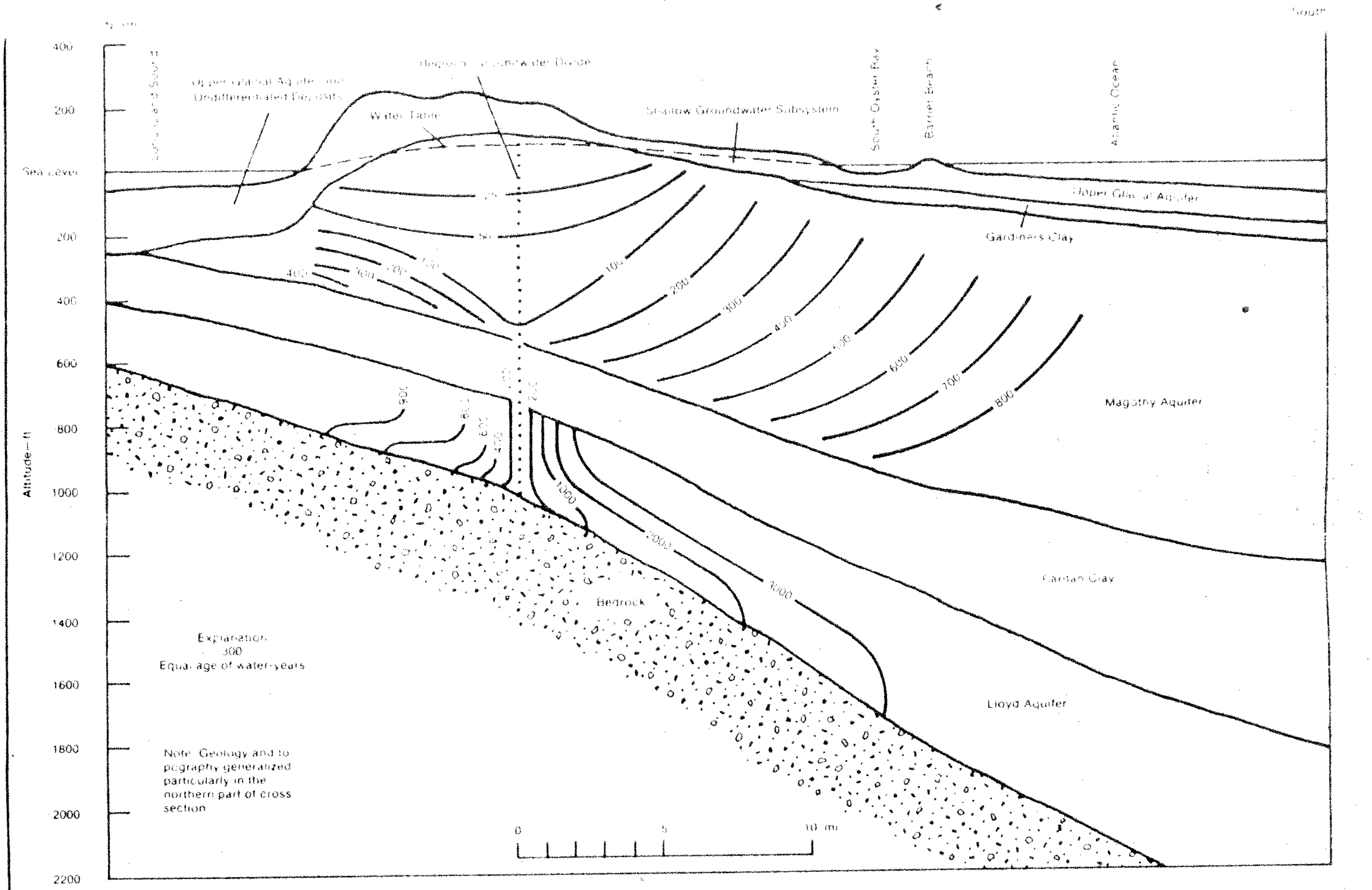

Figure 5. Time required for water movement within the regional groundwater system

groundwater to supply Long Island's future saturation population, provided that provisions are made for solving water quality problems in local areas and for adopting proper management techniques to alleviate production imbalances.

Major concentrations of pumpage have developed near areas of dense population, leaving other portions of the subsurface reservoir underutilized. This is partly due to the ability to install high-capacity wells nearly everywhere on the island, the cost effectiveness of well supplies compared to larger transmission and distribution systems, and to the multitude of agencies in the water supply field. In Nassau and Suffolk counties there are, at present, 128 community water supplies ranging from apartment complexes and trailer parks with less than 100 services to the Suffolk County Water Authority (SCWA) with 243 000 active services representing a population of 900 000. Some of these utilities are stockholder-owned, tax-paying corporations. Most are municipal or tax-collecting water districts, and the SCWA is a public benefit, tax-exempt utility financed by revenue bonds. Service areas are assigned by the state of New York and range from less than one to more than 1295 sq km (500 sq mi).

These utilities operate 935 wells with capacities from about 15 L/s (235 gpm) to 150 L/s (2380 gpm). The SCWA operates 350 wells located at 150 separate well fields and pumping stations (Figure 6). An attempt is made to maintain equilibrium groundwater levels by not withdrawing more water per square mile of recharge area than the estimated infiltration rate. Consumptive use in the bicounty area mainly consists of 416 ML/d (110 mgd) of sanitary wastes discharged through ocean outfalls and 57 ML/d (15 mgd) by farm irrigation, compared to average daily production of nearly 1514 ML/d (400 mgd).

Experiences with contamination

Volatile halogenated hydrocarbon solvents. In March 1975, the employees of a major aerospace facility in Nassau County reported objectionable tastes and odors in their drinking water. This facility then employed more than 10 000 people and produced its own potable and industrial water supply with nine wells having a capacity of 38 ML/d (10 mgd). Chemical analyses indicated satisfactory compliance with all the drinking water standards in effect at the time. More than a year had elapsed before the offending chemicals were identified as trichloroethylene, tetrachloroethylene, and, in one well, vinyl chloride. The metal-treating activities at this site included dipping product into a degreasing bath and then finishing in spray booths

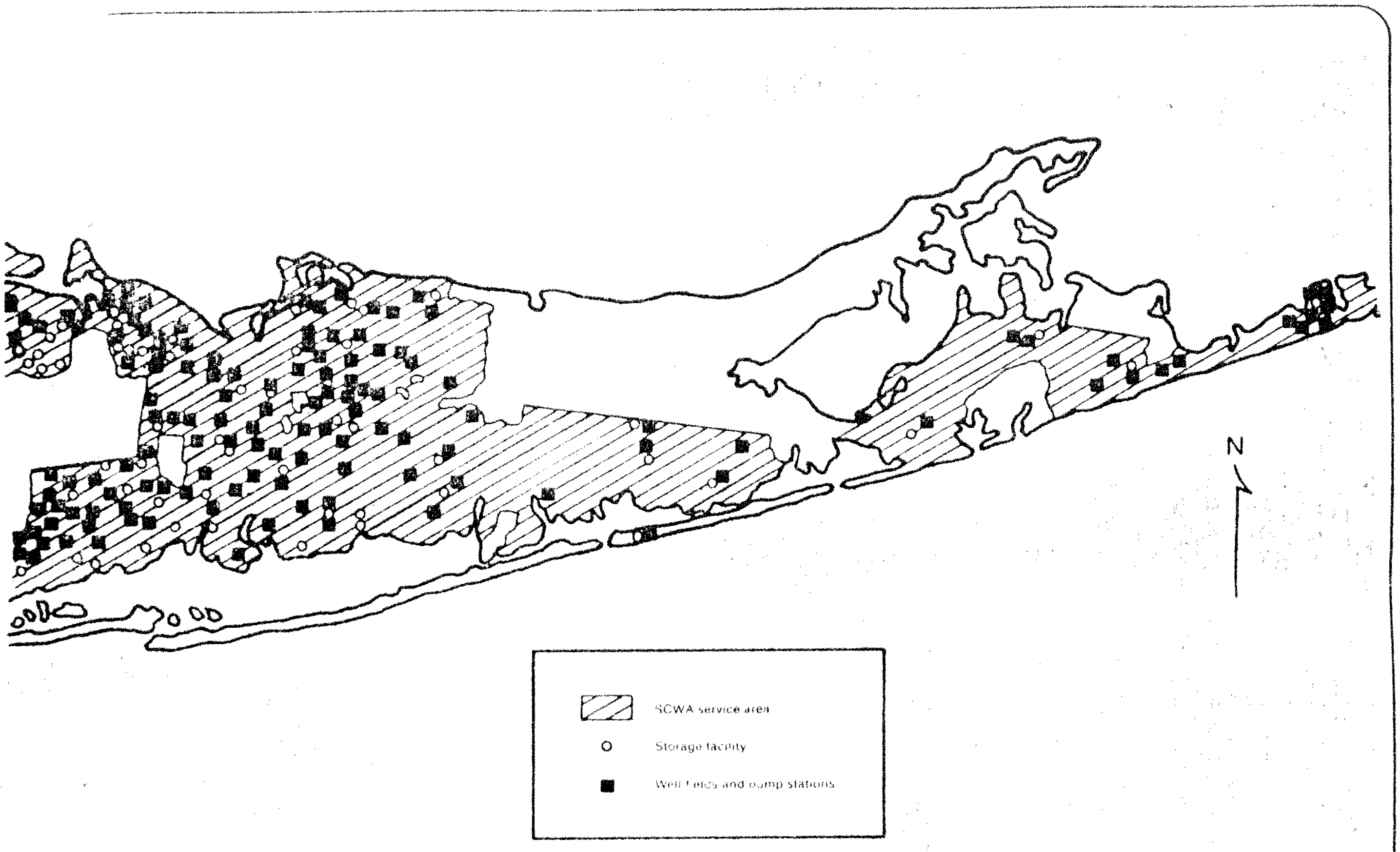

Figure 6. Map showing Suffolk County Water Authority service area

before curtains of water. In retrospect, there was no analytical capability to detect and quantify these compounds at $\mu g/L$ levels. Bellar and Lichtenberg had only just published in late 1974. The National Organics Reconnaisance Survey was just beginning but dealt with only six compounds in surface water supplies. The subsequent National Organics Monitoring Survey in 1976–1977 looked for 27 specific compounds, again concentrating on raw and finished surface waters. Only the trihalomethanes in finished waters exceeded 2 $\mu g/L$ in the four New York state supplies included in the survey. These studies emphasized the importance of the quality of the raw water, especially the presence or absence of precursor compounds. In the SCWA's gas chromatography laboratory, studies on total trihalomethane potential indicated low generation of these compounds even with chlorinating to very high residuals and at elevated pH (Figure 7). These results were obtained even with well waters already contaminated with degreasers such as trichloroethylene or with constituents of cesspool-leaching origin.

Intensive surveys were conducted and are continuing in both counties for the presence of volatile organic compounds. The extent of these surveys and the degree of contamination of the groundwater resource are demonstrated by the number of wells sampled and by the range of concentrations of the various compounds detected. The departments of health of the two counties requested assistance from the state and the USEPA in establishing threshold limits of maximum contaminant levels. There were not then, and there are not now, established limits for any organic compounds other than the six pesticides and herbicides in the SDWA primary drinking water regulations. The New York State Commissioner of Health in early 1977 recommended "actionable guidelines" of 10 $\mu g/L$ for vinyl chloride, 50 $\mu g/L$ for any other volatile halogenated organic compound, and 100 $\mu g/L$ for the sum of all organic compounds, based mainly on an extrapolation of the 95 percent confidence limit of the no-adverse-response dose in test animals, and for human risk levels of one excess cancer death per lifetime in 100 000 population, assuming an intake of 2 L of water per day, a 70-kg body weight, and a 68-year life span. This rationale was referenced to the 1977 National Academy of Sciences (NAS) report entitled *Drinking Water and Health*. These guidelines are enforced through the cooperative compliance of the water utilities, which is encouraged by the weekly press releases issued by the regulatory agencies involved.

The initial surveys concentrated on wells within or near industrial activities, and many samples were

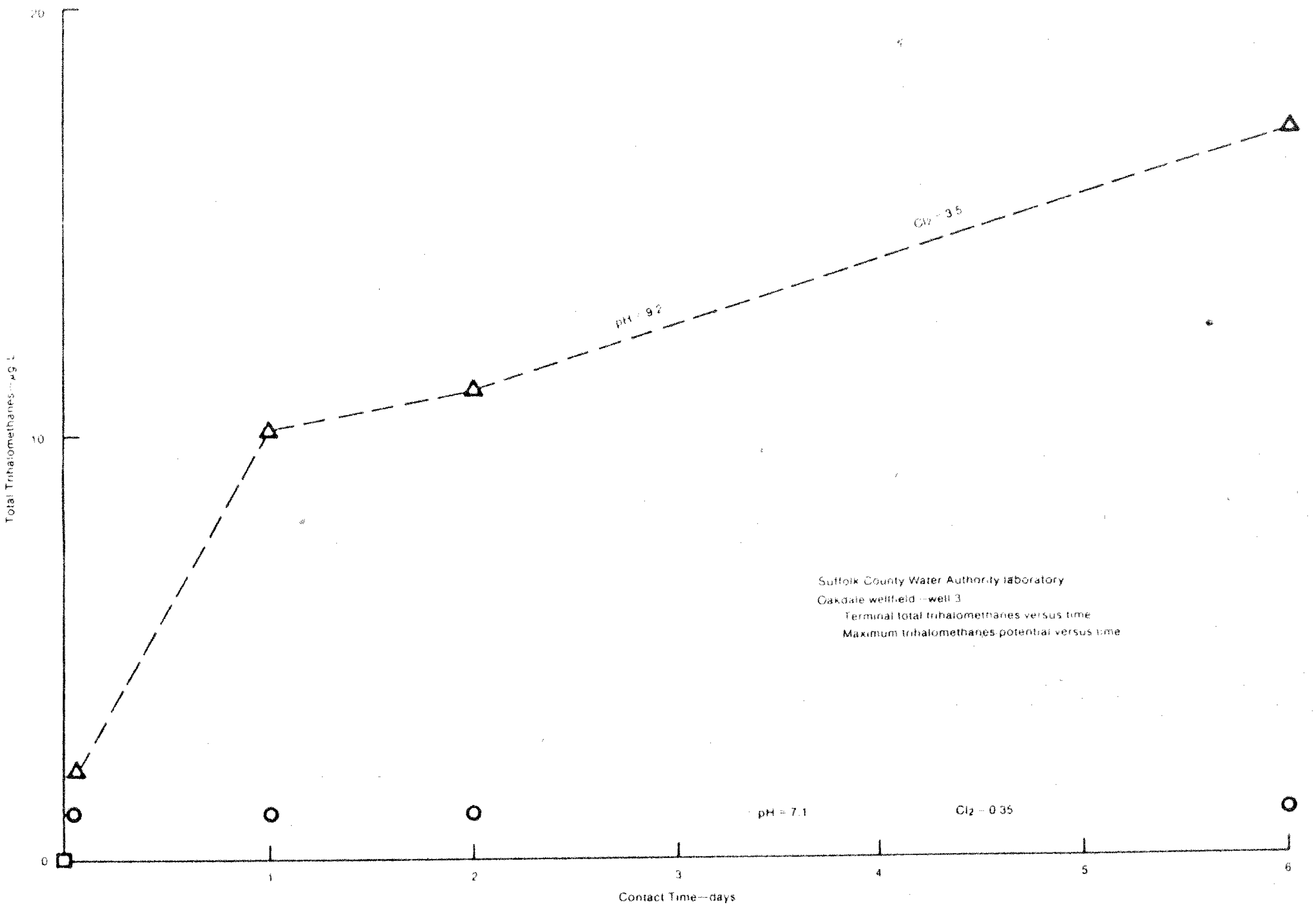

Figure 7. Suffolk County Water Authority's studies on total trihalomethane potential

reported to contain trichloroethylene and tetrachloroethylene. However, an even greater percentage contained 1,1,1-trichloroethane. This compound is a constituent of many household cleaning products, but it is also a major constituent of a popular and widely used product sold to open clogged cesspools and drains.

In Nassau County, where 389 public supply wells are utilized by 48 water suppliers to serve 1.5 million persons, 13 wells are at present restricted because of the presence of one or more of these three compounds in excess of 50 µg/L. However, of another 50 nonpotable water wells that also exceed the guidelines, 17 are screened in the Magothy Formation, the aquifer from which virtually all of the drinking water is produced. Many of these nonpotable wells are high-capacity air-conditioning wells that have companion diffusion wells to recharge this water to the same aquifer.

In Suffolk County, where 527 public water supply wells are utilized by 80 water utilities to serve 1.4 million persons, 16 wells are still restricted owing to the presence of these same three chemicals in amounts exceeding 50 µg/L. Ten of these are part of the 352 wells operated by the SCWA. One of the others also contains 1,2-dichloroethylene, benzene, toluene, and several of the xylenes. The difficulty in interpreting these results is apparent in Figure 8, which shows the location of only the restricted public water supply wells. Each of these wells may have its own point source, or the sources may be so diffuse (such as the 400 000 cesspools in the two counties) as to be considered nonpoint.

The uncertainties in the early analyses made evaluation of results and response to public reaction very difficult. Two examples are indicative. Early in 1976, a major governmental laboratory, which was requested to serve as a "referee" laboratory, reported at a press conference that analyses of eight wells at various locations and at varying depths showed that all contained the same 300 µg/L chloroform. The retraction two days later, explaining atmospheric contamination of the laboratory, received considerably less press space. In another case, results of more than 100 µg/L trichloroethane were reported in a well screened to 193 m (632 ft), where the USGS estimated the age of the water at hundreds of years. This well was closed despite the fact that another well 61 m (200 ft) away and screened at the same depth was shown to be free of contamination. It was subsequently determined that Suffolk County Water Authority mechanics and electricians routinely cleaned electrical connections and column pipe threads when installing pumps, by using wire brushes dipped in a commercial solvent. Pumping to waste cleared this particular problem, and the well

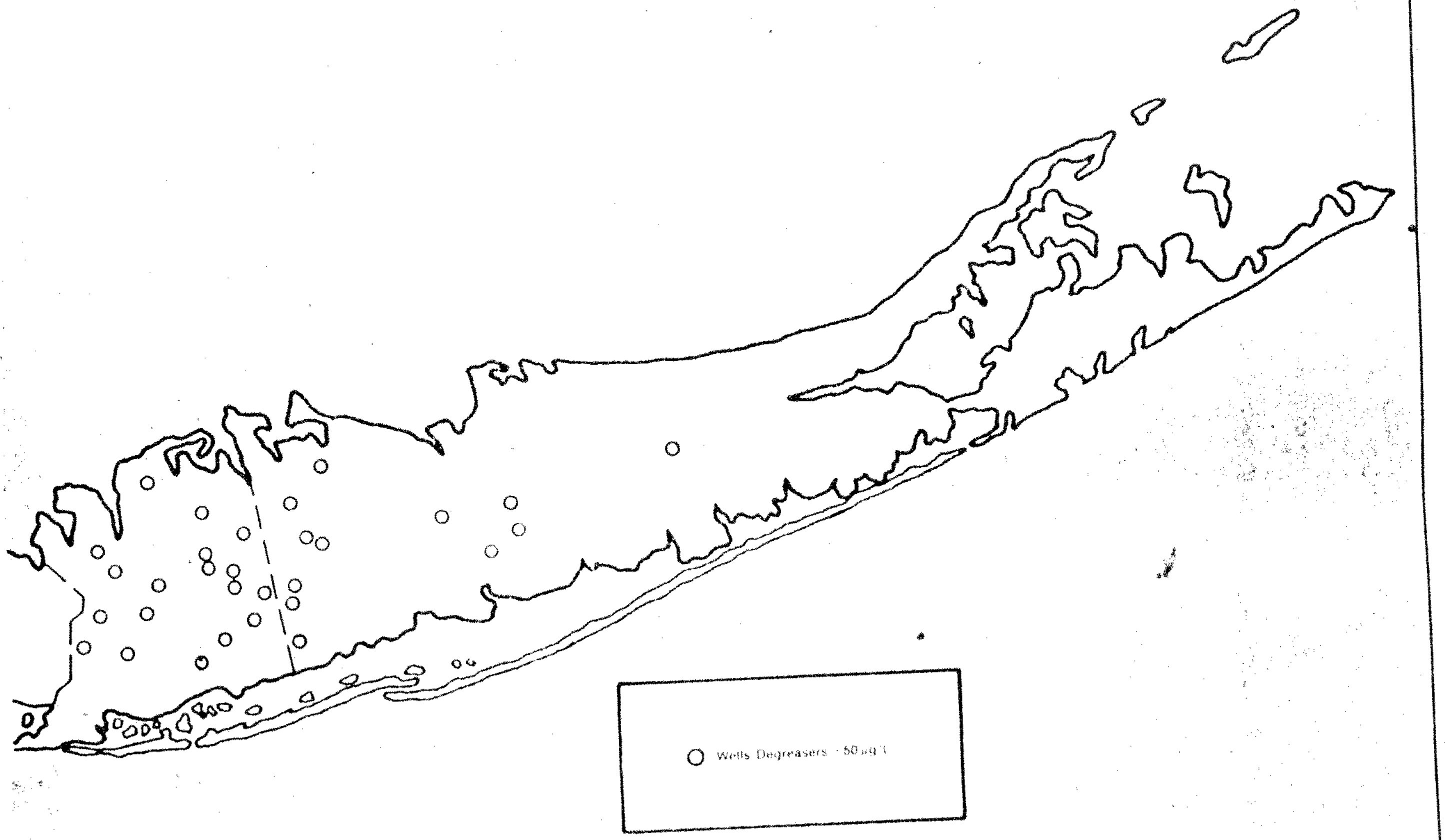

Figure 8. Location of restricted public water wells in Suffolk County

has since been returned to service.

The SCWA has already expended more than 1.5 million dollars to replace the lost capacity of the restricted wells. If a positive sample indicates a contaminated aquifer, production screens can no longer be deepened, as has been customary; rather, many new wells must be drilled at new locations. With wells of 152-m (500-ft) depth now being bid at nearly $150 000 and with attendant costs (for land, building, fencing, landscaping, and chemical treatment), the cost of a new 7.6-ML/d (2-mgd) facility has escalated to $0.05 million.

Pesticides including aldicarb. In December 1974, the Nassau-Suffolk regional planning board received a $5.2 million grant from the USEPA to conduct a regional wastewater management study under Section 208 of PL 92-500. One of the consultants retained by the technical advisory committee to investigate the role of agricultural chemicals on groundwater quality was the Cooperative Extension Association of Cornell University. Early in the study, the consultants reported their concern over the almost exclusive use by potato farmers of a broad spectrum pesticide that exhibits several chemical properties indicating potential hazard. Aldicarb* (Figure 9) is a highly toxic, oxime carbamate pesticide and is labeled for use on potatoes, cotton, peanuts, sugar beets, and some ornamental plants. Aldicarb and its metabolites are highly soluble in water. Its solubility of 0.6 percent is equivalent to 6 × 10^6 μg/L (ppb). It is persistent in soils under certain conditions, and it is so resistant to heat that it can survive long periods of boiling. Aldicarb is applied at the time of planting with the seed. It is taken up in the stem and leaves and becomes a systemic poison when the plant is eaten by pests. It acts by inhibiting cholinesterase, an enzyme required for nerve function. This pesticide has been found to be very effective against two pests that have long plagued Long Island potato farmers, the golden nematode and the Colorado potato bettle. Since 1975, it has been the principal chemical weapon used by the 200 Long Island farmers who grew 22 000 acres of potatoes in 1979 (Figure 10).

Because of studies reported at the time of USEPA registration, the pesticide was expected to break down in the soil and was not supposed to leach to the groundwater. In fact, some studies reported apparent volatilization of the product along with evaporation of capillary water from the soil.

When aldicarb was first registered for use on potatoes in 1974, the USEPA accepted a rate of three pounds

---

Temik aldicarb pesticide, Union Carbide Corp., New York

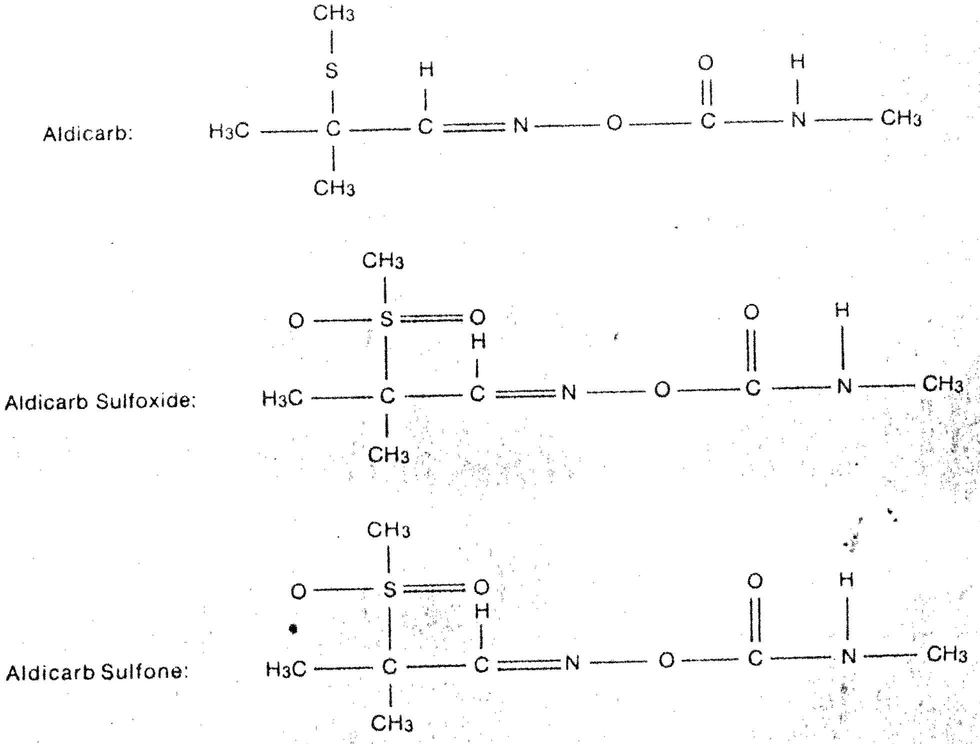

Figure 9. Aldicarb—chemical equations

of active aldicarb per acre for control of the potato beetle. In 1975, New York state approved the use of five pounds per acre for control of the golden nematode. In 1977, USEPA amended the aldicarb federal label to allow the use of five pounds per acre in Long Island, N.Y., only. In June 1978, New York state approved the use of postemergence side-dress application of two pounds of active aldicarb per acre in addition to the five pounds applied at planting. The USEPA countermanded New York state's recommendation until it was conclusively shown that aldicarb residues in potatoes were less than the established Food and Drug Administration tolerance of 1 mg/L (ppm). These data were procured in 1978, and New York state reinstituted the postemergence side-dress application in May 1979.

Research studies are routinely conducted by the staff of Cornell University's Long Island Horticultural Research Laboratory at Riverhead, Long Island. Samples were collected from shallow wells located within potato fields and were accepted by the manufacturer's laboratory for analysis. In August 1979, the Union Carbide Corp. notified the USEPA that aldicarb was detected in Long Island groundwater in a few areas. Over the next few months 145 samples were collected from wells on or near farms and analyzed by Union Carbide, USEPA, and New York state health department laboratories. In spite of the biased sampling procedure, where wells on or within 457 m (1500 ft) of active farms and as shallow as 9 m (30 ft) were tested, considerable publicity was given to the discovery that 26 wells exceeded the "actionable level" of 7 μg/L (ppb). Two of these wells were public water supply wells. One is owned by the SCWA and was reported to contain 6 μg/L aldicarb and, later, 3 μg/L of carbofuran, another carbamate. This well was removed from service. A subsequent split sample from this well was reported to contain 2, 4, and 6 μg/L by these three laboratories. Subsequent samples yielded results of 1 μg/L and "none detected," and the well has since been returned to service.

The toxicity of aldicarb in rats has been reported to be an LD$_{50}$ of 1 mg/kg. Instances of human exposure are rare, with symptoms being short term and reversible and with no systemic accumulation. Aldicarb and its metabolites are not carcinogenic, they are not mutagenic, and they are not teratogenic. Based on available data on rats and dogs, the highest no-adverse-effect level was determined to be 0.1 mg/kg per day. Dividing by an uncertainty factor of 100, an acceptable daily intake (ADI) of 0.001 mg/kg per day was recommended in the NAS study. The actionable level of 7 μg/L was calculated by using the assumptions of the ADI of 0.001 mg/kg per day, an average adult weight of 70 kg, an average consumption of 2 L of water per day, and that 20 percent of the total ingestion of that compound would be from the drinking water.

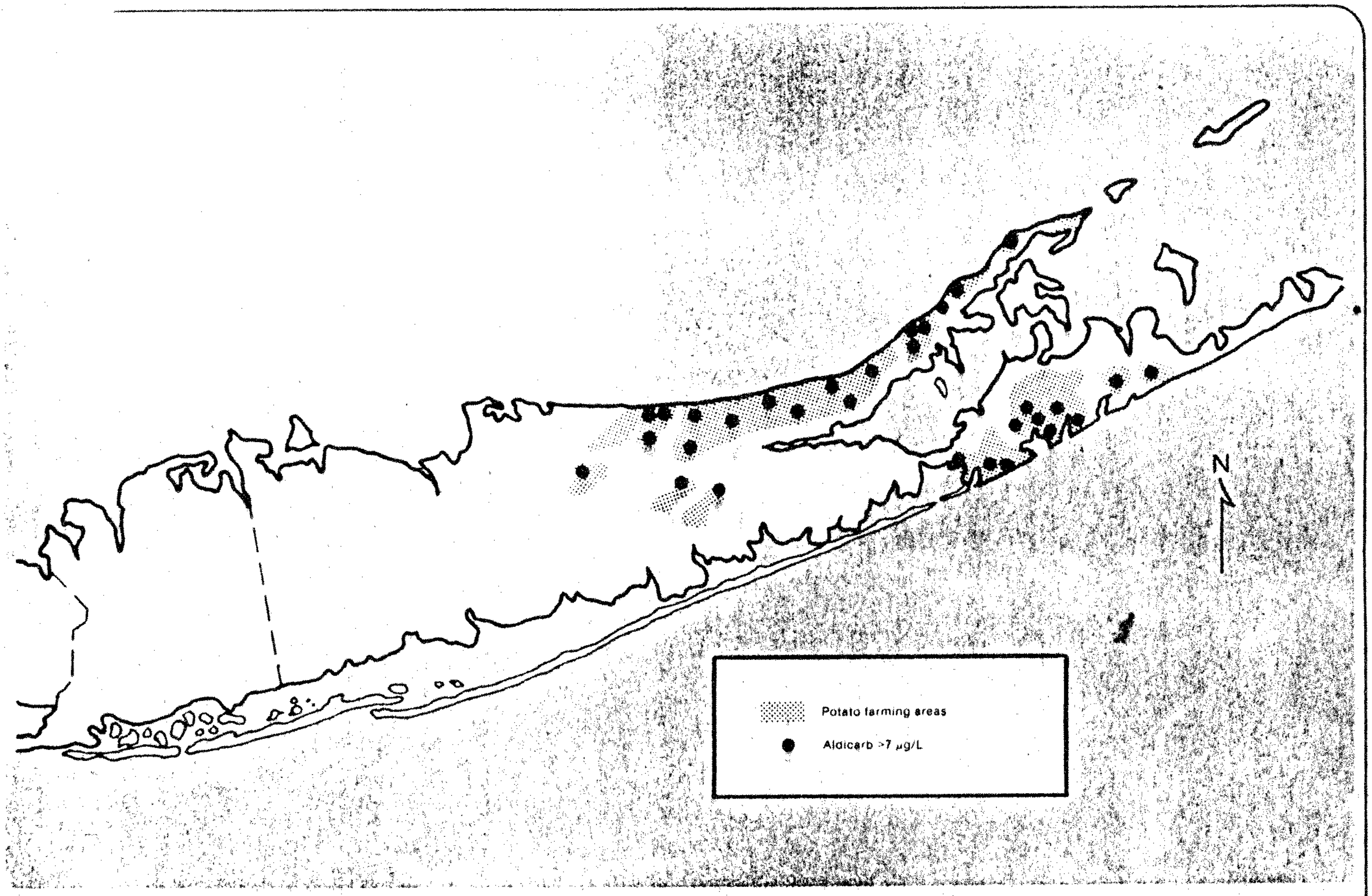

Figure 10. Map of Long Island, showing areas of potato farming and aldicarb concentrations exceeding 7 μg/L

Recognizing the effectiveness of aldicarb and its value to the farmers and local economy, the county commissioner of health requested in December 1979 that the state reduce the allowable application rate, especially at planting. However, in February 1980 the manufacturer* asked the USEPA to revoke its approval of aldicarb on Long Island. The removal is expected to be a severe blow to the farmers. In March 1980, the manufacturer agreed to undertake the analysis of 6000 samples from wells within 760 m (2500 ft) of all treated farms, as well as investigations of the effectiveness of carbon filters for treatment of some affected wells.

Conclusion

The water supply industry on Long Island has borne a disproportionate share of expense and loss of consumer confidence through the premature and incomplete release of findings of instances of contaminated samplings. The cost of replacing lost well capacity because of the rigidity of interpretation of laboratory data of uncertain precision has been substantial. The damage to public relations and the human costs in responding to near-hysterical consumers, who cannot accept the rationale involved in estimating risk factors based on lifetime exposures with uncertainty factors applied to no-adverse-effect levels, cannot be calculated. A local health officer even stated his preference for public water supplies over individual household supplies because the public water supplies were "manipulable." The water supply community must plead that future controls of environmental risks be evaluated in terms of total exposures.

Bibliography

Cohen, P.; Franke, O.L.; & Foxworthy, B.L. An Atlas of Long Island's Water Resources. *New York State Resources Commission Bull.* 62 (1968).

US Environmental Protection Agency. Environmental Impact Statement on Waste Water Treatment Facilities Construction on Grants for Nassau and Suffolk Counties, New York (1972).

Franke, O.L. & McClymonds, N.E. Summary of the Hydrologic Situation on Long Island, New York, as a Guide to Water-Management Alternatives. *US Geological Survey Professional Paper* 627-F (1972).

Greeley & Hansen, Engineers. Comprehensive Public Water Supply Study, Nassau County, New York (1971).

Holzmacher; McLendon; & Murrell, Engineers. Comprehensive Public Water Supply Study, Suffolk County, New York, Vol. II (1970).

Miller, D.W. Ground Water Conditions. The Long Island Comprehensive Waste Treatment Management Plan, 2:41 (1978). Summary Documentation, Nassau-Suffolk Regional Planning Board.

August A. Guerrera is director of laboratories, Suffolk County Water Authority, Oak Dale, N.Y. 11769.

---

*Union Carbide Corp., New York.