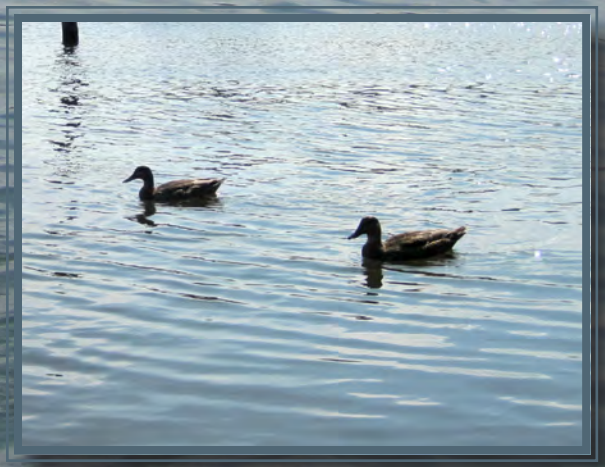
USGS
science for a changing world

Prepared in cooperation with the
Village of Patchogue, New York Department of State, and
Suffolk County Department of Health Services

Shallow Groundwater Quality in the Village of Patchogue, Suffolk County, New York



Scientific Investigations Report 2010–5132

U.S. Department of the Interior
U.S. Geological Survey

Cover. Patchogue River, Village of Patchogue, Suffolk County, New York.

Shallow Groundwater Quality in the Village of Patchogue, Suffolk County, New York

By Irene J. Abbene

Prepared in cooperation with the
Village of Patchogue, New York Department of State, and
Suffolk County Department of Health Services

Scientific Investigations Report 2010–5132

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2010

Suggested citation:
Abbene, I.J., 2010, Shallow groundwater quality in the Village of Patchogue, Suffolk County, New York: U.S. Geological Survey Scientific Investigations Report 2010–5132, 19 p., at http://pubs.usgs.gov/sir/2010/5132/.

Contents

Figures

Tables

Conversion Factors, Datum, and Acronyms

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Elevation, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Acronyms used in this report

LRL	Laboratory Reporting Level
MCL	Maximum Contamination Level
NWQL	USGS National Water Quality Laboratory
NYSDOH	New York State Department of Health
SSER	South Shore Estuary Reserve
SCDHS	Suffolk County Department of Health Services
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

This page has been left blank intentionally.

Shallow Groundwater Quality in the Village of Patchogue, Suffolk County, New York

By Irene J. Abbene

Abstract

The onsite disposal of wastewater within the Patchogue River Basin—a riverine estuary that discharges into Great South Bay, Suffolk County, Long Island, N.Y. —has adversely affected water quality and aquatic habitats within both the tidal and non-tidal portions of the river. In response to increased development within the approximately 14 square mile basin, the Village of Patchogue has expanded efforts to manage and protect the local groundwater resources, which sustain freshwater base flow and aquatic habitats. Water-quality samples from 10 shallow wells within the Village were collected in March 2009, before the start of seasonal fertilizer application, to document the effects of onsite wastewater disposal on groundwater discharging into the Patchogue River. Each sample was analyzed for physical properties (pH, dissolved oxygen, specific conductance, and temperature), nutrients, organic carbon, major ions, and trace elements. Water samples from eight wells were analyzed for stable isotopes of nitrogen. The nitrate concentration in one well was 40 milligrams per liter (mg/L), which exceeded the U.S. Environmental Protection Agency (USEPA) and New York State Department of Health (NYSDOH) maximum contamination level in drinking water of 10 mg/L. Sodium concentrations at nine wells exceeded the USEPA Drinking Water Advisory Taste Threshold of 60 mg/L. Dissolved iron concentrations at three wells exceeded the NYSDOH and USEPA Secondary Drinking Water Standard of 300 micrograms per liter (µg/L). Nitrogen isotope signatures ($\delta^{15}N$) were determined and compared with those reported from previous studies in Nassau and Suffolk Counties to identify possible sources of the nitrate. Local variations in measured ammonia, nitrate, total nitrogen, phosphorus, and organic carbon concentrations and $\delta^{15}N$ signatures indicate that nitrate enters the surficial aquifer from several sources (fertilizer, septic waste, and animal waste) and reflects biogeochemical processes such as denitrification.

Introduction

The Village of Patchogue is a residential community that encompasses an area of about 2.5 mi^2 (6.5 km^2) with a population of approximately 12,000 (Long Island Power Authority, 2008) on the south shore of eastern Long Island (fig. 1), Suffolk County, N.Y. The Village lies along Great South Bay and is bordered by Tuthills Creek to the west, Bay Avenue to the east, and N.Y. State Route 27 (Sunrise Highway) to the north. Great South Bay is part of the South Shore Estuary Reserve (SSER), which includes several small, shallow embayments. Great South Bay is protected from the Atlantic Ocean by a series of barrier islands but is connected to it through several inlets between the barrier islands. The SSER extends about 80 mi (129 km) eastward from Reynolds Channel in Nassau County to the eastern end of Shinnecock Bay in Suffolk County (fig. 1).

Long Island is underlain by permeable glacial sediments of Pleistocene age which are, in turn, underlain by unconsolidated Atlantic Coastal Plain sediments; these sediments comprise a sole-source regional aquifer system. Precipitation is the principle source of freshwater recharge to the aquifer system; water recharged near the groundwater divide flows vertically into deeper parts of the system, whereas water recharged nearer the coast, including the Village of Patchogue, flows through shallow parts of the aquifer system (mainly the upper glacial aquifer) and discharges into coastal streams and estuaries. Shallow-groundwater discharge represents about 78 percent (63,000 Mgal/yr) of the total groundwater discharged from the south shore of Long Island to the SSER (Monti and Scorca, 2003). A generalized hydrogeologic section of Long Island is given in figure 2. The Patchogue River system includes both tidal and non-tidal reaches, both of which receive groundwater discharge; freshwater inputs into the brackish, tidal portions of the river include direct groundwater discharge and freshwater streamflow.

Shallow groundwater that discharges to the Patchogue River and Great South Bay may include elevated concentrations of nutrients (mainly nitrate from fertilizers and septic effluent from onsite wastewater-disposal systems), pathogens, organic compounds, and other substances related to human activities. At present (2010), little is known about the site-specific effects of onsite wastewater-disposal systems on shallow groundwater near the Patchogue River; however, previous studies have shown that onsite disposal of wastewater

Base from U.S. Geological Survey digital data, 2000, 1:24,000
Universal Transverse Mercator projection, Zone 18

Figure 1. Location of wells installed within the Village of Patchogue, Suffolk County, N.Y., for groundwater-quality sampling, 2009.

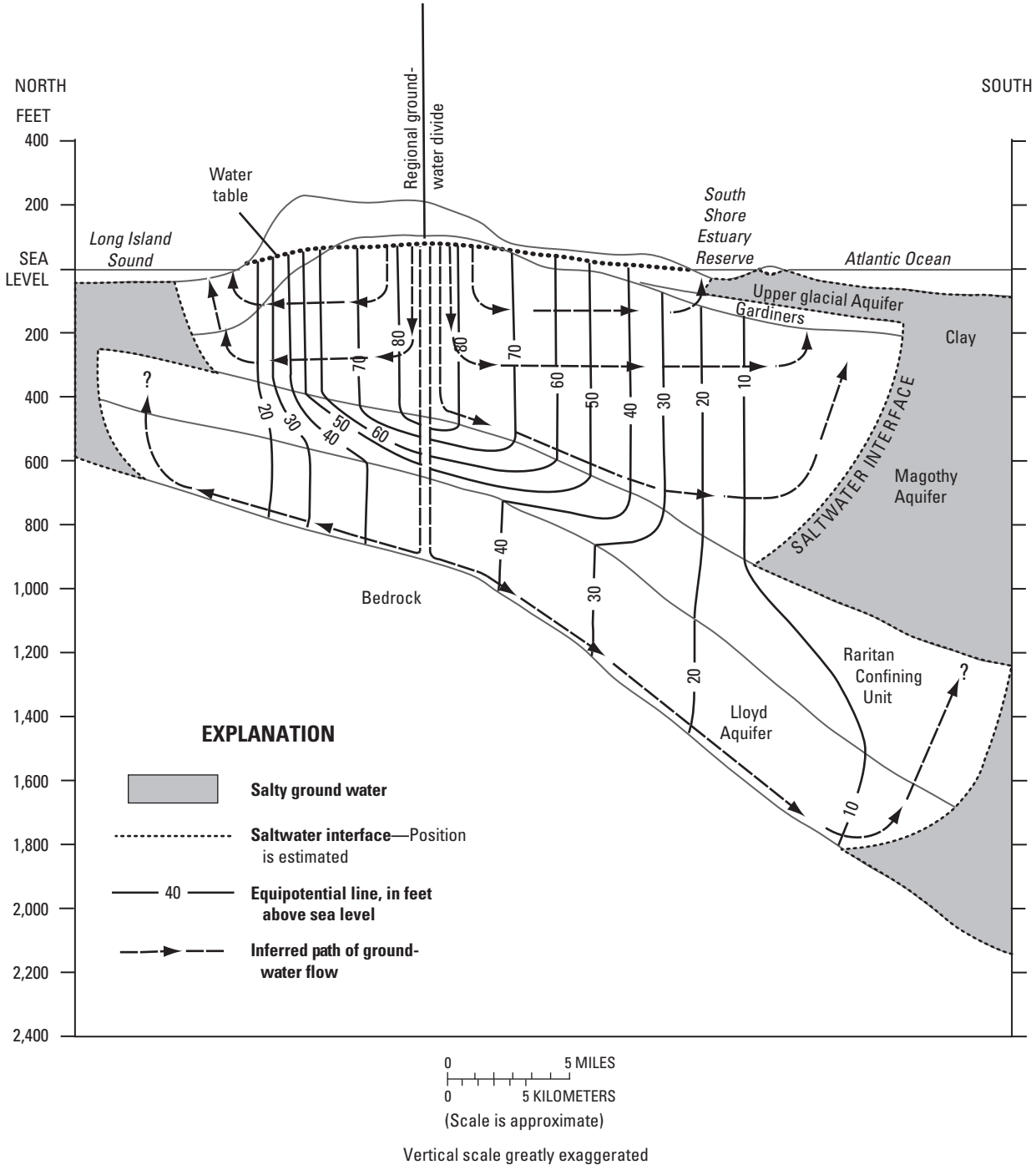


Figure 2. Generalized section showing hydrogeologic units and generalized directions of groundwater flow on the north and south shores of Long Island, N.Y. (Adopted from Monti and Scorca, 2003, fig. 3.).

generally leads to increased concentrations of nitrate and other anthropogenic compounds (Katz and others, 1980; Flipse and others, 1984; Leblanc, 1984; and Eckhardt and others, 1989). Recent suburban development within the Patchogue River watershed could pose a threat to the quality of river water and aquatic habitats. The Village of Patchogue, which encompasses about 18 percent of the Patchogue River Basin, has expanded efforts to manage and protect groundwater resources that sustain freshwater flow and aquatic habitats. Of particular concern are increases in nutrient concentrations (nitrate, nitrite, ammonia, and phosphorus), which can lead to eutrophication in receiving waters. Among the undesirable effects of eutrophication are an increase in water turbidity, odors at low tide, algal blooms, and a decrease in dissolved oxygen concentration, which can result in fish and shellfish mortality (Massachusetts Department of Environmental Protection and University of Massachusetts, 2010; Howarth and Marino, 2006). The Village has begun to develop a Local Waterfront Revitalization Plan (Patchogue Village, 2008) that will guide efforts to improve water quality of the Patchogue River and the adjacent Great South Bay estuary; information on the effects of onsite wastewater disposal on groundwater quality and on water quality of the Patchogue River is central to this effort. The particular area of concern is in the south-central section of the Village of Patchogue (fig. 1). The study area is bounded by the Patchogue River to the west, Amity and Carman Streets to the north, Rider Avenue to the east, and the Great South Bay to the south (fig. 3).

An assessment of the possible sources of elevated concentrations of nutrients in the Patchogue River requires a characterization of the chemical quality of the groundwater that discharges into the river. Monti and Scorca (2003) noted an overall decrease in nitrogen concentrations in shallow (<125 ft deep) groundwater eastward from Nassau County to Shinnecock Bay within 1 mi of the SSER. The elevated nitrogen concentrations in the west (Nassau County) were attributed to increased human activity (septic waste and (or) fertilized turf); therefore, any observed eastward increase trend in nitrogen concentrations may be attributed to development. Some studies analyzed the isotope signatures of nitrogen ($\delta^{15}N$) in groundwater to identify the probable source(s) of nitrate. Nitrate from septic waste has a typical $\delta^{15}N$ signature between 7 and 12 parts per thousand (‰), whereas nitrate from chemical fertilizer has a range between 1 and 7 ‰ (Kreitler and others, 1978; Flipse and others, 1984; and Hinkle and others, 2007). At the present time (2010), the Village of Patchogue does offer the option for some residents to connect to the Village's sewer system; however, not all residents have chosen to connect to the sewer system.

In 2008, the U.S. Geological Survey (USGS), in cooperation with the Village of Patchogue, New York Department of State, and Suffolk County Department of Health Services, began a 15-month study to (1) collect and analyze water samples from 10 newly installed shallow wells within the nearshore (south-central region) section of the Village of Patchogue, and (2) compare these data with published records from nearby (sewered and unsewered) areas that have similar land uses in an effort to identify the principal sources of nitrate that are discharging into the Patchogue River and SSER through groundwater transport.

Purpose and Scope

This report (1) describes the methods used in this study, (2) presents a discussion of the water-quality data collected during March 2009 in relation to State and Federal standards, (3) presents nitrogen-isotope data to give an indication of the probable source of nitrate detected in groundwater, and (4) presents a comparison of the collected sample data with records from areas with land use similar to that of Village of Patchogue (high- and medium-density residential) in sewered and unsewered parts of Nassau and Suffolk County. The data are summarized in tables and graphs; observation well data, water levels, and concentrations of all constituents are listed in appendices 1 and 2 and are available on the National Water Information System (NWIS) webpage (U.S. Geological Survey, http://waterdata.usgs.gov/usa/nwis).

Methods and Approach

Fifteen observation wells cased in polyvinyl chloride (PVC) were installed within the Village of Patchogue in 2008 (fig 1). Criteria for the observation well locations were (1) proximity to known locations of onsite wastewater-disposal systems; (2) adequate distance from other features that could affect groundwater quality, such as contaminant plumes, point discharges, and stormwater recharge basins; and (3) shallow depth to water (the water table is no more than 10 ft below land surface). Wellhead (or top of casing) elevations for all observation wells were surveyed in reference to North American Vertical Datum of 1988 (NAVD 88) and were based on a differential Global Positioning System (GPS) benchmark set at one well location.

The 15 new wells were drilled under the auspices of the Suffolk County Department of Health Services (SCDHS); USGS technicians documented the hydrogeologic conditions and recorded well-construction data. Wells were drilled to a depth of about 2 ft below the observed water table, and a 2-ft screen extending from the top of the saturated zone was installed in each well to ensure that the water sample would reflect any potential human contamination that was present. Of the 15 wells, 10 wells were installed to be sampled and 5 were to be used as alternates in case some wells were unsuitable for sampling. Also, the alternates could be used for future research.

Groundwater that discharges into the river channel near its banks originates near the river, follows short flow paths, and has a short residence time (Modica and others, 1998). Therefore, the residential area located near the river could be a potential source of contaminants entering the Patchogue River. Wells were placed near the river within the residential area of

Base from U.S. Geological Survey, 2000, 1:6,500
Universal Transverse Mercator projection, Zone 18

Figure 3. Locations of wells sampled for δ^{15}N (nitrogen) signatures and nitrate concentrations in the Village of Patchogue, Suffolk County, N.Y., in March 2009.

concern to determine the potential amount of contaminants discharging into the Patchogue River.

Water levels were measured in each well prior to sampling. Water samples were collected during March 18–25, 2009, for chemical analysis from 10 wells in accordance with standard USGS methods as described in the USGS National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated). The physical properties monitored at each well were water temperature, pH, dissolved oxygen concentration, specific conductance, and turbidity. Samples were analyzed at the USGS National Water Quality Laboratory (NWQL) in Denver, Colo., for nutrients (filtered and unfiltered samples), organic carbon, major ions, and trace elements. Additional samples were analyzed for $\delta^{15}N$ signatures at the USGS Stable Isotope Laboratory in Reston, Va. Samples were collected once at all 10 sites for comparison with quality-assurance/quality-control (QA/QC) samples (1 equipment blank and 1 field blank) to confirm uniform sample collection and handling.

Water samples were collected in March 2009, shortly before the professional application of lawn fertilizer is permitted for the growing season (April 1 to October 31) in Suffolk County, to minimize the potential effect of fertilizer application on nitrate concentrations. At the time of sampling, 5 of the 10 sampling sites were in areas where residents were offered the option to connect to the Village's sewer system, but not all of the residents had chosen to connect to the sewer system.

Shallow Groundwater Quality in the Village of Patchogue

The chemical signature of effluent plumes from onsite wastewater-disposal systems in sandy glacial aquifers has been studied in detail and is typified by elevated concentrations of most major ions, nitrate, and possibly phosphorus, depending on the age of the septic system (Kreitler and others, 1978; Ragone and others, 1981; Flipse and others, 1984; LeBlanc, 1984; Robertson and other, 1991; Robertson and others, 1996; Heisig, 1999; Hinkle and others, 2007). Detection of this signature in groundwater discharging to the Patchogue River indicates a septic-system source, although these nitrogen compounds may have other origins; therefore, interpretation of the results requires caution.

Local Variations in Groundwater Quality

The samples collected from 10 observation wells were analyzed for physical properties, isotope signatures, and concentrations of 25 water-quality constituents. All water-quality results are presented in appendix 2 and are available on the NWIS webpage. Most constituents were present in measureable concentrations, and few had concentrations that were less than the laboratory reporting limit (LRL). The only constituent reported as not having a measurable concentration was carbonate (CO_3) (see appendix 2). Concentrations reported as "estimated" are given where the detected concentration was less than the LRL or less than the lowest calibration standard (Childress and others, 1999). Some constituent concentrations are discussed below in relation to maximum contaminant levels (MCLs) or secondary drinking-water standards established by the U.S. Environmental Protection Agency (USEPA) or the New York State Department of Health (NYSDOH).

Physical Properties

The standard USGS procedure is to monitor the physical properties pH, specific conductance, dissolved oxygen, turbidity, and water temperature while purging water from observations wells. Sequential measurements of these parameters are used to help determine when water withdrawn from the well is representative of water flowing through the aquifer and when purging should end and sampling is to begin. Values reported are the median values of the last five sequential measurements once all parameters have stabilized (USGS, variously dated).

pH and Specific Conductance

The pH values of the 10 samples ranged from 4.3 to 6.5 and had a median of 6.2 (appendix 2). The range for specific conductance was from 165 µS/cm at 25°C to 1,930 µS/cm at 25°C, and the median value was 757 µS/cm at 25°C. The highest specific conductance value (1,930 µS/cm at 25°C) was measured at well S128335 (fig. 1), as was the greatest concentration of residue on evaporation (ROE) (1,060 mg/L) (appendix 2). The lowest specific conductance value (165 µS/cm at 25°C) and the lowest ROE (107 mg/L) were measured at well S128334.

Dissolved Oxygen

The median concentration of dissolved oxygen (DO) in the 10 samples was 2.6 mg/L. The concentrations ranged from less than 1.0 mg/L to 7.5 mg/L (appendix 2). The lowest concentration (<1 mg/L) was measured at well S128335 (fig. 1).

Turbidity

The MCL for turbidity, as set by the NYSDOH, is 1 nephelometric turbidity unit (NTU). The recorded unfiltered-sample values for turbidity ranged from 2 NTU to 180 NTU.

Water Temperature

The median water temperature during the March 2009 sampling period was 8.1 °C. Local variations in the temperature of the groundwater sample can be attributed to several factors, for example, direct sunlight on the measuring instrument, irregularities in the pumping rate, or water-temperature alteration by recent recharge from precipitation or operation of a sprinkler system.

Nutrients and Organic Carbon

An assessment of nutrient concentrations within the study area (fig. 1) of the Village of Patchogue (the area of recent residential development and closest to potential receiving waters) can give some indication of geochemical processes that occur in shallow groundwater before it discharges to the Patchogue River and Great South Bay. Nitrite concentrations in the groundwater samples either were less than the LRL or undetected. Nitrite in undisturbed systems is ultimately converted to nitrate through nitrification. In this report, therefore, nitrate concentrations refer to nitrate plus nitrite.

Nitrate

Nitrate concentrations ranged from less than the reporting limit of 0.04 mg/L to 40 mg/L (appendix 2). The wide range indicates that several sources and geochemical factors are affecting the local groundwater. Some residents, where sewer mains are in place, have the option to hook up to the Village sewer district. Only 5 of the 10 sampled wells were along the present sewer main (fig. 3). The Mann-Whitney Rank Sum Test (Helsel and Hirsch, 2002) was used to test for a statistically significant difference between nitrate concentrations from wells in sewered and unsewered areas. The resulting T value of 23.5 is between the lower and upper critical values of 19 and 36, respectively, indicating that there is no statistically significant difference between nitrate concentrations in sewered areas and unsewered areas at a 95-percent confidence interval.

The only well at which the reported nitrate concentration exceeded the NYSDOH and USEPA drinking-water standard of 10 mg/L was S128337 (fig. 3). This well also was reported to have the highest concentrations of nitrate (40 mg/L as N), ammonia (16.2 mg/L as N), phosphorus in filtered water (1.91 mg/L as P), and orthophosphate (1.84 mg/L as P) (fig. 4, table 1). The total nitrogen concentration in filtered water from this well was 61.3 mg/L, the highest concentration observed during the study.

Nitrate concentrations at two wells (S128334 and S128335, fig. 3) were less than the LRL of 0.04 mg/L (fig 4); nitrogen was present in these wells in the form of ammonia (0.325 mg/L and 2.87 mg/L, respectively). The ammonia concentrations for this study ranged from less than the reporting limit of 0.02 mg/L to 16.2 mg/L (appendix 2).

Organic Carbon

The highest concentration of organic carbon (18.2 mg/L) was measured in a sample from well S128335, and the median concentration for all 10 wells was 4.2 mg/L (fig. 4, table 1).

Major Ions and Trace Elements

Measured concentrations of major ions and trace elements can give an indication of possible sources of contamination present in the groundwater. The measured constituents are presented in table 1 and appendix 2.

Chloride and Sodium

The NYSDOH MCL of 250 mg/L for chloride was exceeded at two wells— S128335 (504 mg/L) and S128392 (252 mg/L). The median chloride concentration was 170 mg/L (table 1); the median sodium concentration was 82 mg/L (table 1). The USEPA Drinking Water Advisory Taste Threshold for sodium (60 mg/L) was exceeded at all but one well (S128334).

Calcium and Magnesium

Calcium concentrations ranged from 12.6 mg/L to 47.9 mg/L. The lowest calcium concentration (12.6 mg/L) was at well S128334; the median was 36.9 mg/L (table 1). Magnesium concentrations ranged from 2.48 mg/L to 15.8 mg/L; the median was 4.71 mg/L (table 1). The wells with the highest concentrations were S128335 and S128336 (15.8 mg/L and 14.7 mg/L, respectively), and the well with the lowest concentration (2.48 mg/L) was S128334 (appendix 2).

Sulfate

Sulfate concentrations ranged from 5.43 mg/L to 32.8 mg/L, with a median of 18.6 mg/L (table 1). The wells with the highest concentrations were S128336 and S128332 (32.8 mg/L and 26 mg/L, respectively); the wells with the lowest sulfate concentrations were S128334 and S128335 (5.43 mg/L and 6.50 mg/L, respectively) (appendix 2).

Potassium, Silica, and Alkalinity

The sample from well S128337 contained higher concentrations of potassium (15.7 mg/L) and silica (16.1 mg/L) than the other samples (appendix 2). This well also had the lowest measurement of alkalinity (3 mg/L as calcium carbonate ($CaCO_3$)).

Fluoride and Boron

Fluoride was detected at well S128334 at a concentration of 0.20 mg/L (appendix 2); this concentration is well below the NYSDOH MCL of 2.2 mg/L for fluoride. Boron was the only constituent that was uniformly present throughout the

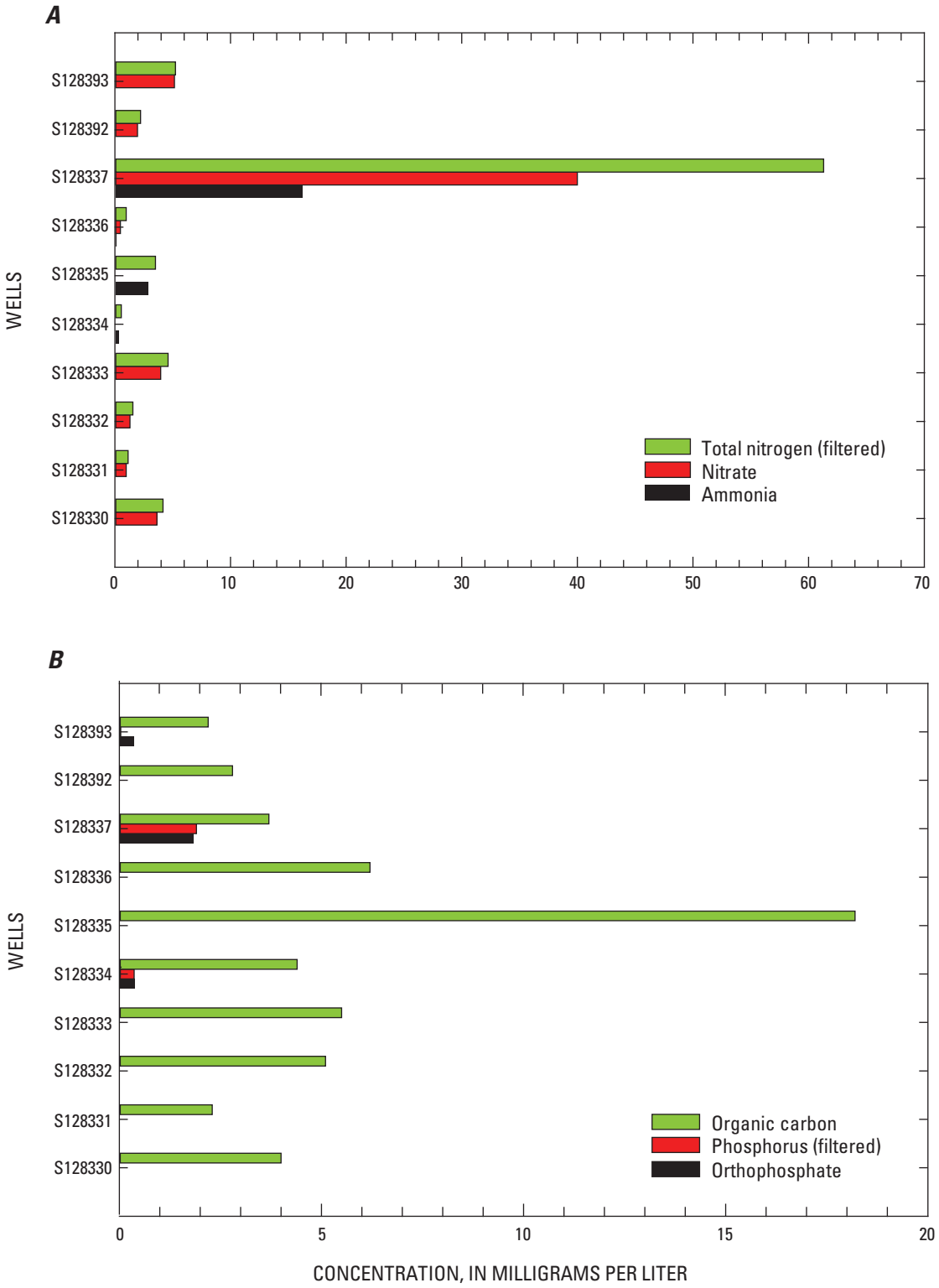


Figure 4. Concentrations of A, nitrate, ammonia, and total nitrogen (filtered) and B, orthophosphate, phosphorus (filtered), and organic carbon in water samples collected from the 10 wells in the Village of Patchogue, Suffolk County, N.Y., March 2009. (Well locations are shown in fig. 1).

Table 1. Minimum, median, and maximum concentrations of selected constituents detected in shallow groundwater samples collected in the Village of Patchogue, N.Y., March 2009.

[All values are in milligrams per liter unless specified. µg/L, micrograms per liter; <, less than; E, estimated; µS/cm, microsiemens per centimeter; NTU, nephelometric turbitity units; °C, degrees Celsius; $CaCO_3$, calcium carbonate]

	Constituent	Minimum	Median	Maximum
Nutrients	Ammonia	E 0.019	0.101	16.2
	Nitrate	< 0.04	1.64	40.0
	Nitrite	E 0.001	< 0.002	0.055
	Orthophosphate	E 0.005	< 0.008	1.84
	Phosphorus, filtered	E 0.003	0.007	1.91
	Phosphorus, unfiltered	E 0.006	0.045	2.55
	Total nitrogen, filtered	0.56	2.87	61.3
	Total nitrogen, unfiltered	0.60	2.83	61.2
	Organic carbon	2.2	4.2	18.2
Major ions and trace elements	Acid neutralizing capacity (mg/L as $CaCO_3$)	< 8	51	112
	Alkalinity (mg/L as $CaCO_3$)	3	55	143
	Bicarbonate (mg/L as $CaCO_3$)	6	67	174
	Calcium	12.6	36.9	47.9
	Magnesium	2.48	4.71	15.8
	Potassium	1.70	2.67	15.7
	Sodium	11	82	270
	Chloride	12.4	170	504
	Fluoride	E 0.06	<0.08	0.20
	Silica	3.9	6.6	16.1
	Sulfate	5.43	18.6	32.8
	Iron (µg/L)	E 3	15	30,600
	Boron (µg/L)	20	26	68
Physical properties	pH (standard units)	4.3	6.2	6.5
	Specific conductance (µS/cm at 25°C)	165	757	1930
	Dissolved oxygen	<1.0	2.6	7.5
	Turbidity (NTU)	2.0	6.3	180
	Temperature (°C)	6.8	8.1	10.2

study area; concentrations ranged from 20 µg/L to 68 µg/L (appendix 2). The median concentration was 26 µg/L (table 1).

Dissolved Iron

Dissolved iron concentrations exceeded the NYSDOH and USEPA secondary drinking-water standard of 300 µg/L at three wells—S128336 (554 µg/L), S128335 (30,600 µg/L), and S128334 (4,140 µg/L) (appendix 2).

$\delta^{15}N$ signatures

The isotope signature of nitrogen ($\delta^{15}N$) is a ratio of the stable isotopes of nitrogen (N^{15}/N^{14}) of a sample to the N^{15}/N^{14} of standard atmospheric N_2 and is expressed as

$$\frac{\delta^{15}(‰) = (N^{15}/N^{14})\ sample - (N^{15}/N^{14}\ )\ standard)}{N^{15}/N^{14}\ standard} \times 1000$$

Variations in N^{15}/N^{14} ratios in a sample are the result of fractionation that occurs during biogeochemical processes. The relative abundance of N^{15} in groundwater nitrate can be used to distinguish potential sources of nitrate in the surficial aquifer. For this study in particular, enriched (positive) $\delta^{15}N$ values (a greater proportion of N^{15}/N^{14}) denote a septic source, whereas as depleted (less positive or negative) $\delta^{15}N$ values (a lower proportion of N^{15}/N^{14}) denote a fertilizer source. The units are given in parts per thousand (denoted as ‰ or per mil).

Concentrations of nitrate in samples from two wells (S128334 and S128335) were not high enough to yield isotope data, but the $\delta^{15}N$ signatures from samples at the remaining eight wells ranged from 0.37 ‰ to 27.86 ‰. The most highly enriched $\delta^{15}N$ signature was at S128332, whereas the most depleted $\delta^{15}N$ signature was at well S128337 (fig. 3; appendix 2).

Results of the 2009 Study in Relation to those from Previous Studies

The data set from this study represents a one-week period (March 18–25, 2009) but nevertheless allows for comparison with data from previous studies in nearby areas to reveal possible trends in the concentrations of certain groundwater constituents.

Eckhardt and Others Study

Eckhardt and others (1989) analyzed groundwater quality within selected land-use categories in Nassau and Suffolk Counties. All wells used in that analysis were screened in the upper glacial aquifer and had a median screened depth of 31 ft below the water table. Land use in the Patchogue study area is best described as medium- to high-density residential, according to the land-use definitions (based on number of dwellings) of Eckhardt and others (1989). The median chloride, calcium, and alkalinity concentration values obtained in this (2009) study were higher than those reported by Eckhardt and others (1989) (table 2). The higher chloride concentrations and higher median alkalinity in this study compared to the earlier study could be attributed to the Village's proximity to salty surface water (Great South Bay). Sulfate and potassium concentrations in Patchogue in the 2009 study were between the medians for medium- and high-density residential regions of Nassau and Suffolk Counties in the previous study (table 2). The 2009 median nitrate concentration for Patchogue was less than the median concentrations for residential land use in the Nassau-Suffolk Counties study. Organic-rich soils remove nitrate from groundwater by denitrification. The sandy surficial aquifer of Long Island is typically poor in organic carbon content. However, organic carbon present in this study's samples may

Table 2. Median concentrations of selected constituents in shallow groundwater collected at the Village of Patchogue, N.Y., March 2009, and in Nassau and Suffolk Counties in the late 1980s.

[All values are in milligrams per liter; $CaCO_3$, calcium carbonate]

Constituent	This study in the Village of Patchogue (2009)	Nassau and Suffolk Counties (Eckhardt and others, 1989)	
		Medium-density residential	High-density residential
Nitrate	1.64	2.9	4.6
Chloride	170	16	31
Sulfate	18.6	12	37
Potassium	2.67	1.6	4.3
Calcium	36.9	9.3	16
Alkalinity (mg/L as $CaCO_3$)	55	15	15

explain the lower median concentration of nitrate within the Village of Patchogue in comparison to the median values reported by Eckhardt and others (1989).

Monti and Scorca Study

Monti and Scorca (2003) describe geographic trends in total nitrogen concentrations using 1,155 samples from 167 shallow wells (<125 ft deep) located within 1 mi of the south shore of Long Island. They delineated five geographic zones along the south shore between Nassau (two zones) and Suffolk Counties (three zones). Analyses were conducted on 408 samples from 104 shallow wells (<125 ft deep) in Nassau County and 747 samples from 63 shallow wells in Suffolk County. The median total nitrogen concentration for shallow groundwater in Nassau County was 3.85 mg/L with a range of 0.008 mg/L to 40.1 mg/L, whereas the median for Suffolk County was 1.74 mg/L with a range of less than 0.01 mg/L to 21.6 mg/L. The zone in which the Village of Patchogue lies had a median total nitrogen concentration of 2.36 mg/L with a range of less than 0.01 mg/L to 19.06 mg/L. The Monti and Scorca (2003) median total nitrogen concentration (in filtered shallow groundwater samples) is similar to the median for the Village of Patchogue, 2.87 mg/L (table 1) in this study, but the range in total nitrogen for this study is higher—0.56 mg/L to 61.3 mg/L (appendix 2)—than the range in the Monti and Scorca (2003) study.

Other Studies

Several studies have correlated contributing sources of nitrate with land use (Katz and others, 1980; Porter, 1980) and with nitrogen isotope values (Kreitler and others, 1978; Flipse and others, 1984; and Böhlke and others, 2009). Previously reported nitrogen-isotope signature ranges for Long Island can be used to identify probable sources of nitrate in the shallow groundwater of the Village of Patchogue. The $\delta^{15}N$ signature ranges reported in the studies named above represent water from the surficial aquifer located in Queens, Nassau, and Suffolk Counties; the ranges are summarized in figure 5. Of the eight samples analyzed for nitrogen isotopes in the present (2009) study, seven were within the ranges reported in the

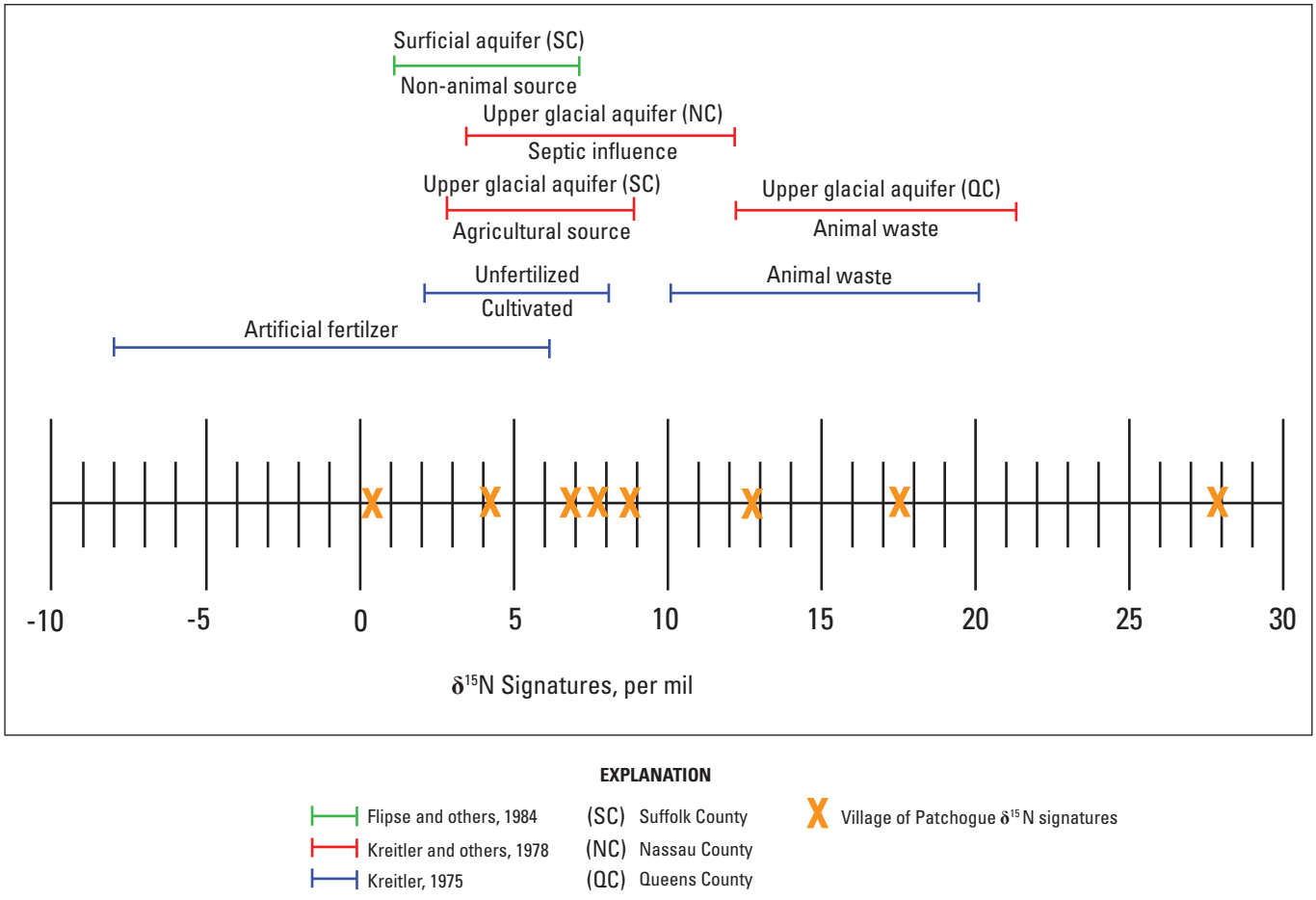


Figure 5. $\delta^{15}N$ signatures for eight samples from wells in the Village of Patchogue, Suffolk County, N.Y., 2009, and ranges reported for Queens, Nassau, and Suffolk Counties in previous studies by Kreitler (1975), Kreitler and others (1978), and Flipse and others (1984).

previous studies (fig. 5). The $\delta^{15}N$ signature in one sample (well S128332) exceeded the previously reported ranges, with an enriched nitrogen isotope value of 27.86 ‰. Comparison of this study's isotope values with the previously reported isotope ranges indicates that the groundwater at the Village of Patchogue contains a mixture of nitrate from fertilizer, septic effluent, and animal waste.

Summary

The Village of Patchogue is a residential community on the south shore of Long Island that is bordered to the south by the Great South Bay; the tidal and non-tidal reaches of the Patchogue River are within the south-central part of the Village. The river, which has important aquatic habitats, receives its water from the surface-water inflow and the direct discharge of shallow groundwater.

Groundwater samples were collected from 10 shallow observation wells in March 2009 to define the water-quality conditions and assess the possible effects of onsite wastewater disposal. One sample was collected from each well and analyzed for physical properties (pH, dissolved oxygen, temperature, specific conductance, and turbidity) as well as for concentrations of nutrients, organic carbon, major ions, and trace elements. At well S128337, the nitrate concentration was 40 mg/L, exceeding the USEPA drinking-water standard of 10 mg/L. Well S128337 also had the highest concentration of ammonia (16.2 mg/L), phosphorus (filtered, 1.91 mg/L), and orthophosphate (1.84 mg/L). Chloride concentrations at wells S128335 and S128392 exceeded the maximum contaminant limit (MCL) of 250 mg/L with concentrations of 504 mg/L and 252 mg/L, respectively. Sodium concentrations exceeded the USEPA Drinking Water Advisory Taste Threshold of 60 mg/L in samples from all wells except well S128334 (11 mg/L). Dissolved iron concentrations exceeded NYSDOH and USEPA drinking-water standards of 300 µg/L at three wells—S128336 (554 µg/L), S128335 (30,600 µg/L), and S128334 (4,140 µg/L).

The concentrations of chloride, calcium, and alkalinity measured for this study exceed the median concentrations present in groundwater samples from medium- to high-density residential areas elsewhere on Long Island; the higher chloride concentrations and higher median alkalinity may be due to the Village's proximity to Great South Bay. The median total nitrogen concentration (in filtered, shallow groundwater samples) for wells within 1 mi of the SSER shoreline of the residential areas in Nassau and Suffolk Counties during 1952–97 was similar to the median for the Village of Patchogue wells, 2.87 mg/L, but the range for the 2009 study was higher, 0.56 mg/L to 61.3 mg/L.

Wells at which a measurable amount of nitrate was detected also were sampled for nitrogen isotope analysis. $\delta^{15}N$ signatures can give an indication of the potential nitrate sources within the Village. Comparison of the Village of Patchogue isotope values with previously reported isotope ranges for Long Island indicates that the groundwater in this study contains a mixture of nitrate from fertilizer, septic effluent, and animal waste.

Acknowledgments

Thanks are extended to Joseph Dean and Marian Russo of the Village of Patchogue, N.Y., for their assistance in obtaining sewer district maps for the Village of Patchogue and organization of meetings between all pertinent parties during this study. Thanks also are extended to Suffolk County Department of Health Services for assistance with well drilling. This project was made possible by funding from the New York Department of State, New York State Comptroller's Contract number C006563. Assistance with water-quality sampling was provided by Tristen Tagliaferri and William Capurso of the USGS, and assistance with well-head surveying was provided by Michael Noll and Simonette Rivera of the USGS.

References Cited

Böhlke, J.K., Hatzinger, P.B., Sturchio, N.C., Gu, B, Abbene, I., and Mroczkowski, S.J., 2009, Atacama perchlorate as an agricultural contaminant in groundwater—Isotopic and chronologic evidence from Long Island, New York: Environmental Science and Technology, v. 43, p. 5619–5625.

Childress, C.J.O., Foreman, W.T., Connor, B.F., and Maloney, T.J., 1999, New reporting procedures based on long-term method detection levels and some considerations for interpretations of water-quality data provided by the U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 99–193, 19 p.

Eckhardt, D.V., Flipse, W.J., and Oaksford, E.T., 1989, Relation between land use and ground-water quality in the Upper Glacial Aquifer in Nassau and Suffolk Counties, Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 86–4142, 35 p.

Flipse, W.J., Katz, B.G., Lindner, J.B., and Markel, R., 1984, Sources of nitrate in ground water in a sewered housing development, central Long Island, New York: Ground Water, v. 22, p. 418–426.

Heisig, P.M., 1999, Effects of residential and agricultural land uses on the chemical quality of base flow of small streams in the Croton watershed, southeastern New York: U.S. Geological Survey Water-Resources Investigations Report 99–4173, 16 p.

Helsel, D.R., and Hirsh, R.M., 2002, Statistical Methods in Water Resources: U.S. Geological Survey Techniques of Water-Resources Investigations 04–A3, 523 p.

Hinkle, S.R., Böhlke, J.K., Duff, J.H., Morgan, D.S., Weick, R.J., 2007, Aquifer-scale controls on the distribution of nitrate and ammonium in ground water near La Pine, Oregon, USA: Journal of Hydrology, v. 333, p. 486–503.

Howarth, R.W., and Marino, R., 2006, Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems—Evolving views over three decades: Limnology and Oceanography, v. 51, p. 364–376.

Katz, B.G., Lindner, J.B., and Ragone, S.E., 1980, A comparison of nitrogen in shallow ground water from sewered and unsewered areas, Nassau County, New York, from 1952 through 1976: Ground Water, v. 18, p. 607–616.

Kreitler, C.W., 1975, Determining the source of nitrate in ground water by nitrogen isotope studies: Austin, Texas, University of Texas, Austin, Bureau of Economic Geology Report Investigation 83, 57 p.

Kreitler, C.W., Ragone, S.E., and Katz, B.G., 1978, N^{15}/N^{14} ratios of ground-water nitrate, Long Island, New York: Ground Water, v. 16, p. 404–409.

LeBlanc, D.R., 1984, Sewage plume in a sand and gravel aquifer, Cape Cod, Massachusetts: U.S. Geological Survey Water-Supply Paper 2218, 28 p.

Long Island Power Authority, 2008, Population survey 2008, Current population estimates for Nassau and Suffolk Counties and the Rockaway Peninsula: Uniondale, N.Y., Long Island Power Authority, 64 p.

Massachusetts Dept. of Environmental Protection and University of Massachusetts, 2010, The estuaries project: Southeastern Massachusetts embayments restoration, accessed January 19, 2010, at http://www.oceanscience.net/estuaries/about.htm.

Modica, E., Buxton, H.T., and Plummer, L.N., 1998, Evaluating the source and residence times of groundwater seepage to streams, New Jersey Coastal Plain: Water Resources Research, v. 34, p. 2797–2810.

Monti, J., Jr., and Scorca, M.P., 2003, Trends in nitrogen concentration and nitrogen loads entering the South Shore Estuary Reserve from streams and ground-water discharge in Nassau and Suffolk Counties, Long Island, New York, 1952–97: U.S. Geological Survey Water-Resources Investigations Report 02–4255, 36 p.

Patchogue Village, 2008, Local waterfront revitalization plan: Patchogue, N.Y., AKRF, Inc., and Arch Spire Architecture, PC, 165 p., accessed January 19, 2010, at http://www.patchoguevillage.org/local_waterfront_revitalization.htm.

Porter, K.S., 1980, An evaluation of sources of nitrogen as causes of ground-water contamination in Nassau County, Long Island: Ground Water, v. 18, p. 617–625.

Ragone, S.E., Katz, B.G., Kimmel, G.E., and Lindner, J.B., 1981, Nitrogen in ground water and surface water from sewered and unsewered areas, Nassau County, Long Island, New York: U.S. Geological Survey Water-Resources Investigations 80–21, 72 p.

Robertson, W.D., Cherry, J.A., and Sudicky, E.A., 1991, Ground-water contamination from two small septic systems on sand aquifers: Ground Water, v. 29, p. 82–92.

Robertson, W.D., Cherry, J.A., and Zanini, L., 1996, Impacts on a sand aquifer from an old septic system—nitrate and phosphate: Ground Water, v. 34, p. 1105–1114.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A1–A9, variously paged (available at http://pubs.water.usgs.gov/twri9A).

This page has been left blank intentionally.

Appendixes 1–2

1. Observation well data from, and water levels measured in, 15 shallow wells in the Village of Patchogue, Suffolk County, N.Y., March 2009.

2. Concentrations of detected constituents in water samples collected from 10 shallow wells in the Village of Patchogue, Suffolk County, N.Y., March 2009.

Appendix 1. Observation well data from, and water levels measured in, 15 shallow wells in the Village of Patchogue, Suffolk County, N.Y., March 2009.

[Measuring point is top of 2-inch polyvinyl chloride well casing. USGS, U.S. Geological Survey; NAVD88, North American Vertical Datum of 1988; NA, not analyzed]

Well number	USGS site identification number	Sampling date	Elevation of measuring point, in feet (NAVD 88)	Screened zone (feet below measuring point surface)	Depth to water table (feet below measuring point)	Water level, in feet (NAVD 88)
S128330	404532073010101	3/18/09	5.84	4.20	4.00	1.84
S128331	404525073005801	3/18/09	5.58	4.25	4.05	1.53
S128332	404519073005301	3/18/09	6.10	4.20	4.62	1.48
S128333	404513073005401	3/18/09	4.12	2.70	2.83	1.29
S128334	405000073005201	3/19/09	2.78	0.83	0.41	2.37
S128335	404507073005201	3/19/09	1.98	1.50	0.87	1.11
S128336	404458073003801	3/25/09	2.36	2.00	1.48	0.88
S128337	404530073004401	3/25/09	11.42	8.25	8.26	3.16
S128338	404544073003201	NA	13.60	10.00	NA	NA
S128339	404602073003301	NA	18.98	10.00	NA	NA
S128340	404515073002001	NA	4.48	2.50	NA	NA
S128341	404537073001901	NA	8.14	4.20	NA	NA
S128392	404509073003701	3/25/09	4.71	3.00	3.27	1.44
S128393	404519073003901	3/25/09	8.12	5.50	5.90	2.22
S128394	404459073001801	NA	2.46	2.40	NA	NA

Appendix 2. Concentrations of detected constituents in water samples collected from 10 shallow wells in the Village of Patchogue, Suffolk County, N.Y., March 2009.

[Number in parentheses is U.S. Geological Survey National Water Information System (NWIS) parameter code. mg/L, milligrams per liter; µS/cm at 25°C, microsiemens per centimenter at 25 degrees Celsius; NTU, nephelometric turbidity units; E, estimated; NA, not available; <, less than; $CaCO_3$, calcium carbonate; SiO_2, silicon dioxide; µg/L, micrograms per liter; N, nitrogen; P, phosphorus; per mil, or in parts per thousand. Well locations are shown in figures 1 and 3]

Well number	Sampling date	Dissolved oxygen (mg/L)	pH water unfiltered field (standard units)	Specific conductance water unfiltered (µS/cm at 25°C)	Temperature water (°C)	Turbidity (NTU)	Residue on evaporation (mg/L)	Calcium water filtered (mg/L)	Magnesium water filtered (mg/L)	Potassium water filtered (mg/L)	Sodium water filtered (mg/L)
		(00300)	(00400)	(00095)	(00010)	(63675)	(70300)	(00915)	(00925)	(00935)	(00930)
S128330	3/18/09	5.0	5.9	697	8.2	25.0	359	22.8	4.39	3.49	84.2
S128331	3/18/09	6.0	4.9	637	8.0	6.0	357	14.9	4.56	2.37	87.3
S128332	3/18/09	1.9	6.3	588	7.9	10.0	335	32.0	4.25	1.97	69.6
S128333	3/18/09	7.5	6.2	817	9.5	4.0	443	40.1	9.32	2.96	77.8
S128334	3/19/09	NA	6.3	165	6.8	6.5	107	12.6	2.48	1.70	11.0
S128335	3/19/09	<1.0	6.2	1,930	7.2	5.4	1,060	39.3	15.8	7.19	270
S128336	3/25/09	1.7	6.5	952	8.3	180.0	495	34.5	14.7	4.44	128
S128337	3/25/09	2.6	4.3	938	10.2	2.0	510	41.2	7.82	15.7	80.5
S128392	3/25/09	2.1	6.1	1,060	7.1	19.0	593	47.9	4.86	2.10	160
S128393	3/25/09	6.3	6.2	657	8.4	3.0	370	39.2	3.22	1.83	80.7

Appendix 2. Concentrations of detected constituents in water samples collected from 10 shallow wells in the Village of Patchogue, Suffolk County, N.Y., March 2009.—Continued

[Number in parentheses is U.S. Geological Survey National Water Information System (NWIS) parameter code. mg/L, milligrams per liter; µS/cm at 25°C, microsiemens per centimenter at 25 degrees Celsius; NTU, nephelometric turbidity units; E, estimated; NA, not available; <, less than; CaCO3, calcium carbonate; SiO_2, silicon dioxide; µg/L, micrograms per liter; N, nitrogen; P, phosphorus; per mil, or in parts per thousand. Well locations are shown in figures 1 and 3]

Well number	Sampling date	Acid neutralizing capacity water unfiltered, fixed end point laboratory (mg/L as $CaCO_3$)	Alkalinity water filtered, inflection point titration field (mg/L as $CaCO_3$)	Bicarbonate water filtered, inflection point titration field (mg/L)	Carbonate water filtered, inflection point titration field (mg/L)	Chloride water filtered (mg/L)	Fluoride water filtered (mg/L)	Silica water filtered (mg/L as SiO_2)	Sulfate water filtered (mg/L)	Ammonia water filtered (mg/L as N)	Nitrate + Nitrite water filtered (mg/L as N)
		(90410)	(39086)	(00453)	(00452)	(00940)	(00950)	(00955)	(00945)	(00608)	(00631)
S128330	3/18/09	32	36	44	0.0	163	<0.08	6.50	12.6	E 0.019	3.64
S128331	3/18/09	<8	28	7	0.0	176	<0.08	7.00	22.4	<0.020	0.98
S128332	3/18/09	59	58	71	0.0	128	<0.08	5.20	26.0	<0.020	1.31
S128333	3/18/09	31	28	34	0.0	193	<0.08	3.90	16.9	<0.020	3.97
S128334	3/19/09	43	51	62	0.0	12.4	0.20	15.7	5.43	0.325	<0.04
S128335	3/19/09	97	143	174	0.0	504	E0.07	5.40	6.50	2.87	<0.04
S128336	3/25/09	112	114	140	0.0	192	E0.09	6.70	32.8	0.101	0.48
S128337	3/25/09	NA	3	6	0.0	143	<0.08	16.1	25.1	16.2	40.0
S128392	3/25/09	104	104	126	0.0	252	E0.06	7.60	20.3	0.032	1.96
S128393	3/25/09	68	67	82	0.0	132	<0.08	4.80	13.5	0.031	5.16

Appendix 2. Concentrations of detected constituents in water samples collected from 10 shallow wells in the Village of Patchogue, Suffolk County, N.Y., March 2009.—Continued

[Number in parentheses is U.S. Geological Survey National Water Information System (NWIS) parameter code. mg/L, milligrams per liter; µS/cm at 25°C, microsiemens per centimenter at 25 degrees Celsius; NTU, nephelometric turbidity units; E, estimated; NA, not available; <, less than; $CaCO_3$, calcium carbonate; SiO_2, silicon dioxide; µg/L, micrograms per liter; N, nitrogen; P, phosphorus; per mil, or in parts per thousand. Well locations are shown in figures 1 and 3]

Well number	Sampling date	Nitrite water filtered (mg/L as N)	Ortho-phosphate water filtered (mg/L as P)	Phosphorus water filtered (mg/L as P)	Phosphorus water unfiltered (mg/L as P)	Total nitrogen water filtered by analysis (mg/L)	Total nitrogen water unfiltered by analysis (mg/L)	Iron water (µg/L)	Boron water (µg/L)	Organic carbon water filtered (mg/L)	N^{15}/N^{14} in nitrate water filtered (per mil)
		(00613)	(00671)	(00666)	(00665)	(62854)	(62855)	(01046)	(01020)	(00681)	(82690)
S128330	3/18/09	E0.002	E0.005	E0.005	0.046	4.16	3.75	5	26	4.0	6.82
S128331	3/18/09	<0.002	<0.008	<0.006	E0.006	1.15	1.05	6	24	2.3	12.71
S128332	3/18/09	0.014	<0.008	<0.006	0.028	1.56	1.44	8	36	5.1	27.86
S128333	3/18/09	E0.002	<0.008	<0.006	0.015	4.61	4.17	15	25	5.5	7.75
S128334	3/19/09	E0.001	0.390	0.367	0.393	0.56	0.60	4,140	25	4.4	NA
S128335	3/19/09	0.005	<0.008	0.025	0.045	3.52	3.52	30,600	34	18.2	NA
S128336	3/25/09	E0.002	E0.007	0.007	0.221	0.98	1.07	554	59	6.2	8.70
S128337	3/25/09	0.055	1.84	1.91	2.55	61.3	61.2	14	20	3.7	0.37
S128392	3/25/09	0.010	E0.006	E0.003	0.044	2.22	2.13	19	68	2.8	17.53
S128393	3/25/09	<0.002	0.036	0.033	0.041	5.24	5.06	E3	24	2.2	4.27

This page has been left blank intentionally.

Prepared by the Pembroke Publishing Service Center.

For more information concerning this report, contact:

Director
U.S. Geological Survey
New York Water Science Center
425 Jordan Road
Troy, NY 12180-8349
dc_ny@usgs.gov

or visit our Web site at:
http://ny.water.usgs.gov

ISBN 978-1-4113-2970-6