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# A Vulnerability Assessment of Public-Supply Wells in Rhode Island

Water-Resources Investigations Report 99-4160

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

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By LESLIE A. DESIMONE and LANCE J. OSTIGUY

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Northborough, Massachusetts
1999

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director



For additional information write to:

Chief, Massachusetts-Rhode Island District
U.S. Geological Survey
Water Resources Division
10 Bearfoot Road
Northborough, MA 01532

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Denver, CO 80225-0286

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## CONVERSION FACTORS, VERTICAL DATUM, AND WATER-QUALITY INFORMATION

### CONVERSION FACTORS

| Multiply | By | To obtain |
|---|---|---|
| foot (ft) | 0.3048 | meter |
| foot per day (ft/d) | 0.3048 | meter per day |
| gallon per minute (gal/min) | 0.06308 | liter per second |
| inches (in.) | 25.4 | millimeter |
| mile (mi) | 1.609 | kilometer |
| square mile ($mi^2$) | 12.590 | square kilometer |

Temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:

°C = (°F-32)/1.8

### VERTICAL DATUM

**Sea level:** In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

### WATER-QUALITY INFORMATION

Concentrations of chemical constituents are given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter and micrograms per liter are units expressing the concentration of a chemical constituent in solution as weight (milligrams or micrograms) of solute per unit volume (liter) of water. For concentrations less than 7,000 mg/L, milligrams per liter is equivalent to "parts per million" and micrograms per liter is equivalent to "parts per billion."

# A Vulnerability Assessment of Public-Supply Wells in Rhode Island

*By* Leslie A. DeSimone *and* Lance J. Ostiguy

## Abstract

Water-quality data from 256 public-supply wells, and available land use, hydrogeologic, and other spatial data were used to identify factors that contribute to the relative vulnerability to contamination of public-supply wells in Rhode Island. The assessment included community and non-community, non-transient supply wells in stratified-drift and bedrock aquifers. Water-quality data consisted of monitoring results for compliance with Safe Drinking-Water Act regulations for the period 1988 to 1996, obtained from the Rhode Island Department of Health. Spatial data included digital data layers of well locations, wellhead-protection areas (WHPAs), land use, surficial and bedrock geology, soil type, roads, surface-water hydrography, and known waste sites, obtained from the Geographic Information System of the Rhode Island Board of Governors for Higher Education (RIGIS). Relative vulnerability to contamination was investigated for 10 classes of monitored drinking-water contaminants, which were based on potential sources of contaminants. For each contaminant class, a threshold criterion was determined by which to categorize well water as "affected" or "unaffected" based on the historical water-quality data. Contingency tables and nonparametric statistical tests were used to compare well characteristics, hydrogeologic factors, and spatial data in WHPAs between affected and unaffected wells. Factors with statistically significant differences between affected and unaffected wells were identified as indicators of a well's likelihood of being contaminated and, therefore, as potential contributors to a well's vulnerability. This method was used to identify significant vulnerability factors for six classes of contaminants: nutrients, pesticides, solvents and other industrial organic chemicals, road-deicing chemicals, fluoride, and radionuclides. Vulnerability factors could not be identified for four contaminant classes: fuel hydrocarbons, iron and manganese, trace inorganic chemicals, and microbial contaminants.

Land use, aquifer type, and soil characteristics were significant vulnerability factors for several contaminant classes. Residential land use and an urban land-use type that includes parks and golf courses in the WHPA were significant factors for nutrients. For pesticides, the most significant land uses were the urban land use that includes parks and golf courses and institutional land use; median nitrate concentrations at the well also were higher in wells affected by pesticides. Industrial land use in the WHPA was a significant vulnerability factor for solvents and other industrial organic chemicals. Wells affected by road-deicing chemicals were associated with a high density of paved roads, with urban land use, and with more permeable soils in the WHPA. Aquifer type was significant in that wells screened in stratified-drift aquifers were more likely to be affected by nutrients, pesticides, solvents, and road-deicing chemicals than bedrock wells. In contrast, fluoride concentrations and radionuclide activities were more likely to be elevated in bedrock wells. Lithologic rock type also was a significant vulnerability factor for fluoride. Data on land use, aquifer type, and other vulnerability factors, along with information from literature sources, were used to

designate wells as more or less vulnerable to contamination by each of these six contaminant classes; data are presented such that alternative ranking schemes may be implemented. These results may be used to help identify supply wells that may be at greatest risk, to identify the most significant among multiple potential contamination sources, and to direct data collection and analysis towards developing additional, more quantitative and predictive models for vulnerability assessment.

## INTRODUCTION

The protection of public-water supplies and source waters is a high priority for water-resource managers at local, State, and National levels. Knowledge of the degree to which public-water supplies are vulnerable to contamination and the factors that influence their vulnerability has become an important tool for the attainment of these goals. Management practices for water-supply protection can be most effectively designed and implemented when information is available about how hydrogeology, land use, and other factors contribute to vulnerability. The identification of water supplies that are highly vulnerable and of contamination sources that pose the greatest risks to those supplies enables water-resource managers to prioritize areas for protection, monitoring, and remediation. In this way, limited resources may be more efficiently allocated.

Recent changes in Federal drinking-water regulations reflect, enhance, and reinforce the importance of considering vulnerability in the management of public-water supplies. The 1996 Amendments to the Safe Drinking Water Act require that States develop Source-Water Assessment Plans (SWAPs) that include a determination of the susceptibility of all public-water supplies to contamination. These susceptibility determinations, which may include absolute or relative measures of vulnerability, are considered by the U.S. Environmental Protection Agency (USEPA) to be integral components of the States' long-term plans for source-water protection (U.S. Environmental Protection Agency, 1997a). In addition, proposed changes by USEPA to chemical monitoring regulations for public-water systems would allow monitoring strategies that are based on relative risk for many contaminants, including nitrate, inorganic chemicals such as arsenic, metals, and fluoride, and many synthetic organic contaminants (U.S. Environmental Protection Agency, 1997b). These changes in monitoring requirements potentially could result in substantial reductions in monitoring costs while continuing to protect public health (U.S. Environmental Protection Agency, 1997c).

Determining the vulnerability of a surface- or ground-water supply to contamination is problematic because vulnerability, the likelihood or ease with which the supply can be contaminated, cannot be measured; it must be inferred from the multiple, disparate factors that influence contaminant transport and occurrence (National Research Council, 1993). For a ground-water source, these factors include hydrogeologic and well characteristics, such as aquifer permeability and well depth, and characteristics of contaminant use, occurrence, and transport near the well (U.S. Environmental Protection Agency, 1993a). Many methods have been developed in which the relevant factors are identified, evaluated, and combined to map or otherwise predict vulnerability. Available methods include: index-and-overlay methods, in which hydrogeologic and other variables are ranked, weighted, and overlain to delineate high- and low-risk areas; water-quality-based or statistical methods, in which relations between the measured distribution of contaminants in an area and explanatory variables are determined using statistical tests and used to predict vulnerability; or process-based methods, in which the transport of specific contaminants is modeled, commonly to predict concentrations at specific locations in the subsurface (National Research Council, 1993; U.S. Environmental Protection Agency, 1993a). Selection of the most appropriate method depends on the purpose and spatial scale of the assessment and the data and resources available.

The State of Rhode Island needs information about the vulnerability of its ground-water resources to contamination. Ground water, an important source of drinking water in Rhode Island, is used wholly or in part by two-thirds of the communities in the State (Rhode Island Department of Environmental Management, 1995). Hydrogeologic conditions, such as shallow and unconfined aquifers, make these ground-water resources relatively susceptible to contamination from surface activities, and ground-water quality has been degraded at many locations (Johnston and Barlow, 1988; Randall and others, 1988; Rhode Island Department of Environmental Management, 1995). Information about the vulnerability of ground-water supply systems in Rhode Island is needed to comply with Safe Drinking Water Act regulations, to take advantage of revisions in USEPA regulations for chemical monitoring, and, more generally, to facilitate the management and protection of ground-water resources at all levels of government. To provide information for these purposes, the U.S. Geological Survey, in cooperation with the Rhode Island Department of Health (RIDOH), used existing data to investigate the vulnerability of two classes of public-supply wells to contamination. A method was developed by which existing data on well characteristics; statewide spatial data on hydrogeology, land use, and other features; and available water-quality data for the wells could be used to identify indicators of contamination by 10 classes of contaminants. These indicators were evaluated for all the public-supply wells and provide a basis for determining the relative vulnerability of the wells to contamination.

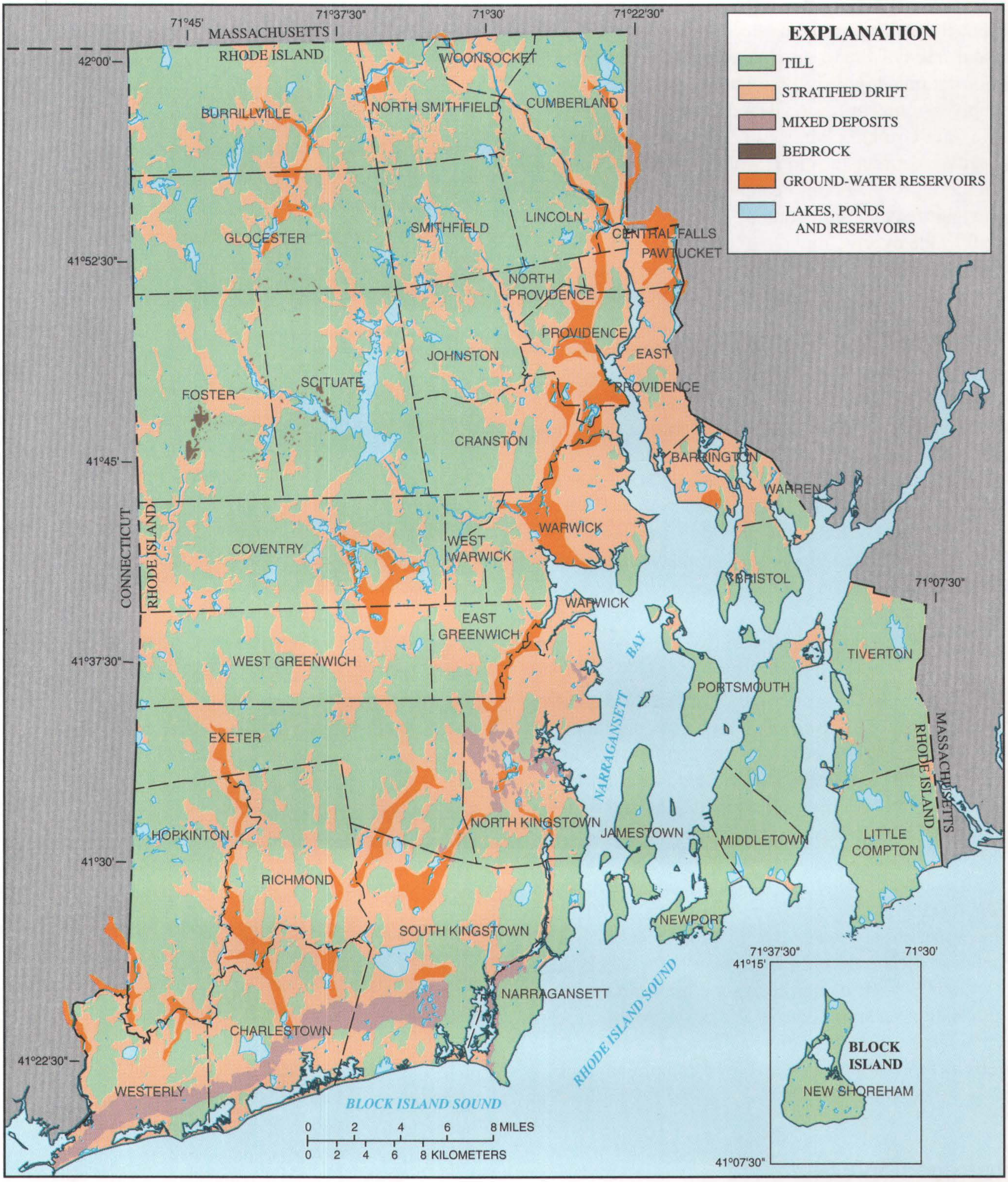
## Purpose and Scope

This report describes the results of an assessment of the vulnerability to contamination of community and non-community, non-transient supply wells in Rhode Island. The assessment is based on available data that include (1) aquifer and well characteristics, (2) statewide spatial data on hydrogeology, land use, and other features, and (3) water-quality data collected for compliance with drinking-water standards from 1988 to 1996 at 256 wells throughout Rhode Island. The analytical approach used to identify indicators of contamination is described and results for 10 classes of drinking-water contaminants are presented. Information on significant indicators of contamination is tabulated for all the wells and is used to designate wells as more or less vulnerable to contamination by 6 of the 10 contaminant classes.

## Hydrogeologic Setting

Rhode Island encompasses an area of 1,045 mi$^2$ in southern New England (fig. 1). The climate is humid and temperate, with annual precipitation ranging from 40 to 50 in. and an average annual temperature of about 50°F (National Oceanic and Atmospheric Administration, 1997). About half of the annual precipitation is returned to the atmosphere through evaporation or plant transpiration, with the remainder becoming ground-water recharge or stream runoff. Mean elevation and topographic relief generally increases from less than 500 ft in flat or gently rolling areas in the southern and eastern parts of the State to hilly uplands in the northwest, where the maximum elevation is about 800 ft above sea level (Lang, 1961).

Ground water in Rhode Island occurs in unconsolidated glacial till and stratified drift and in the underlying fractured bedrock and is typically unconfined. Stratified drift consists of coarse sand and gravel, sometimes containing layers of fine sand and clay, that was deposited and sorted by meltwater from retreating glaciers of the late Pleistocene Epoch. Stratified-drift deposits occur in stream valleys and in low-lying areas, and range in thickness from a few feet to more than 100 ft (fig. 1; Trench, 1995). These deposits form the most productive aquifers in the State, typically yielding from 100 to 700 gal/min to public-supply wells (Trench, 1991). Till, unsorted material that was deposited directly by glacial ice, is a mixture of sediments ranging in particle size from clay to boulders. Till, which averages about 20 ft in thickness, covers much of the State and generally underlies stratified-drift deposits (fig. 1; Trench, 1995). Mixed deposits of till and stratified drift also occur in glacial end moraines, which were formed at the ice margins. Because of its low permeability and low saturated thickness, till is not a major source of drinking water in Rhode Island; the few large-diameter dug wells in till generally yield less than 2 gal/min (Johnston and Dickerman, 1974a; Trench, 1991). Bedrock consists primarily of igneous and metamorphosed igneous rocks in the western and central parts of the State and sedimentary and metasedimentary rocks of Pennsylvanian Age in areas adjacent to Narragansett Bay in the east (Hermes and others, 1994). Ground water stored and transmitted through fractures in bedrock supplies low-yield public and private supplies throughout the State; wells drilled in bedrock generally yield from 1 to 20 gal/min (Trench, 1991).




Base from the Rhode Island Geographic Information System (RIGIS) of the Rhode Island Board of Governors for Higher Education, State base map, 1:24,000, 1989, Based on Rhode Island coordinate system

**Figure 1.** Surficial geology and ground-water reservoirs in Rhode Island.

Ground water flows in discrete basins from highland recharge areas toward discharge areas in stream valleys or at the coast. Water-table contours tend to mimic topography in till and bedrock in upland areas and slope toward discharge areas in valleys and low-lying areas in stratified drift (Randall and others, 1988; Dickerman and Barlow, 1997). Bedrock aquifers are recharged primarily in the upland areas by downward movement of infiltrated precipitation through the overlying till (Johnston and Dickerman, 1974a). Stratified-drift aquifers are recharged directly from precipitation and from inflow from adjacent till and bedrock uplands; the proportions of recharge from inflow may be as much as 20 to 50 percent of the total recharge for these aquifers (Johnston and Dickerman, 1974a, 1974b; Dickerman and others, 1990; Dickerman and Bell, 1993; Dickerman and others, 1997). Stratified-drift aquifers generally are in close hydraulic connection with surface-water systems (Rosenshein, 1988; Trench, 1991), and streams generally are areas of ground-water discharge. However, recharge to stratified-drift aquifers from streams and ponds may be induced by pumping wells located near the stream- or lake-aquifer boundary. Streams also may recharge aquifers naturally in some cases, particularly where streams draining till-covered uplands reach more permeable stratified-drift deposits (Johnston and Dickerman, 1985).

Ambient ground-water quality reflects the relatively unreactive character of the crystalline bedrock and unconsolidated materials that compose the aquifers (Randall and others, 1988). Concentrations of dissolved solids generally are low (less than 200 mg/L), and the water typically is soft (hardness less than 60 mg/L as calcium carbonate), slightly acidic (pH 5.5 to 7.0), and poorly buffered (Johnston and Barlow, 1988). Sodium, calcium, bicarbonate, chloride, and sulfate are the predominant ions, and concentrations of nitrate are typically considerably below 1 mg/L as N in ground water unaffected by human activities (Johnston and Barlow, 1988; Dickerman and others, 1990; Dickerman and Bell, 1993).

## Acknowledgments

The authors thank Brian Barrette, Deborah Lafleur, Donna Pytel, and others at RIDOH, for their assistance in providing and interpreting water-quality and ancillary well data; Eugene Pepper, Rhode Island Department of Environmental Management (RIDEM), for providing information about the RIDEM soil-leachability classification system of risk for pesticide contamination; and Ernie Pancierra, RIDEM, for assistance with determining the locations of wells and wellhead-protection areas.

# METHODS OF VULNERABILITY ASSESSMENT

The approach and methods used in this study were developed from a literature review and a review of the data available for Rhode Island public-supply wells. Previous studies of ground-water vulnerability and of the patterns of contaminant occurrence in ground water were reviewed to identify methods that would be appropriate for the scale and purposes of the present study. Data for the present study were obtained from the RIDOH and RIDEM, the Rhode Island Geographic Information System of the Rhode Island Board of Governors for Higher Education (RIGIS), and other sources. Finally, analytical methods were developed for using the available data in a statewide assessment of the relative vulnerability of public-supply wells in Rhode Island.

## Previous Studies

Studies of ground-water vulnerability have been conducted in many parts of the United States. The studies vary according to the purpose, spatial scale, and available data and with the physical setting of the assessment area (National Research Council, 1993). Hydrogeologic classification or index-and-overlay methods of varying complexity often have been used in regional or statewide assessments. DRASTIC is a commonly used index-and-overlay method (Aller and others, 1985). In this method, vulnerability indices are calculated as weighted sums of seven hydrologic variables—depth to water, recharge, aquifer media, soil media, unsaturated-zone media, land-surface slope, and hydraulic conductivity—that are determined for areas of 100 acres or greater. Modified DRASTIC methods have been used to map ground-water vulnerability in a 24,000-square-mile area surrounding Denver, Colo., and in the 34,000-square-mile Snake River Plain in Idaho (U.S. Environmental Protection Agency, 1993a;

Hearne and others, 1995; Rupert, 1997). Categories of low, moderate, high, or very high vulnerability were based on the calculated indices in these approaches. A statewide assessment of ground-water vulnerability in Iowa distinguished areas of low, moderate, and high vulnerability within several aquifer types using factors related to time of travel, such as thickness and type of overlying material (National Research Council, 1993). Factors describing contaminant sources (for example, land use and hazardous-waste sites) and historical water-quality (exceedences of USEPA drinking-water standards) were incorporated into a complex assessment of drainage basins within a five-state area in the south-central United States by USEPA (Bechdol and others, 1998).

The Colorado, Idaho, Iowa, and five-state assessments were conducted to provide planning tools for land-use management, to help prioritize management, monitoring, and remedial actions for ground-water protection, and to increase public awareness. Index-and-overlay methods such as those used in these studies may be less useful than other methods in predicting the likelihood of contamination, especially if they do not incorporate information about contaminant sources. Moreover, these indices may not adequately characterize some hydrogeologic settings. For example, DRASTIC indices were positively correlated with detections of volatile organic compounds (VOCs) in Nebraska, but were poorly correlated with ground-water contamination in Maine (Garrett and others, 1989; Kalinski and others, 1994). The methods also are limited by the difficulties of selecting relevant variables and in combining them so as to reflect their actual importance in controlling vulnerability (U.S. Environmental Protection Agency, 1993a; Tesoriero and Voss, 1997). For example, reevaluation of the vulnerability maps produced for the Snake River Plain in Idaho with ground-water-quality data found that the most highly weighted variable, based on the soil medium, was not correlated with nitrate concentrations; consequently nitrate concentrations were not significantly different among several of the vulnerability categories (Rupert, 1997). Similarly, a nationwide assessment of risk for nitrate contamination of ground water, based on soil drainage and nitrogen loading from agricultural sources, did not predict accurately the contamination risk in the southeastern United States or on Long Island, New York, because it did not include variables representing nitrate-attenuation processes or urban nitrogen sources (Nolan and others, 1997).

Water-quality-based, statistical methods use the measured distribution of contaminants in an area to determine aquifer and well vulnerability. In these methods, statistical tests are used to identify relevant hydrogeologic, contaminant-use, and other variables and to quantify their relative contribution to the likelihood that contamination will occur. This approach was used to develop a numerical model of vulnerability to pesticide contamination for public-supply wells in New Jersey (Vowinkel and others, 1994, 1996; Clawges and Vowinkel, 1996; Vowinkel, 1996). The model was based on data from 1,700 wells and was tailored to the hydrogeology and contaminant sources in New Jersey. Six variables were significantly related to nitrate contamination (used as a surrogate for pesticide contamination), using Kruskal-Wallis tests and discriminant analysis. Three variables, distance of the well to the aquifer outcrop area, percent soil-organic matter, and depth to the open interval of the well, were related to the intrinsic sensitivity of the aquifer to contamination; and three variables, dominant land use within 2,600 ft of the well, distance to the nearest agricultural parcel, and distance to the nearest golf course, were related to the intensity of contaminant use near the well. In Washington, pesticide contamination was related to well depth, agricultural or urban land use, and high nitrate concentrations based on data from about 1,300 wells (Ryker and Williamson, 1996a, 1996b); high nitrate concentrations were related to well depth, surficial geology, and agricultural, urban, and forest land uses within 10,500 ft of the well based on data from about 2,000 wells and logistic-regression analysis (Erwin and Tesoriero, 1997; Tesoriero and Voss, 1997). Logistic regression also was used to identify population density, residential, commercial, and agricultural land uses within 2,640 ft of a well, and unsaturated-zone thickness as predictors of high nitrate concentrations and VOCs in 90 monitoring wells on Long Island, New York (Eckhardt and Stackelberg, 1995). Finally, linear and multiple regression analyses have been used to predict nitrate and pesticide contamination in midwestern States (Steichen and others, 1988; Druliner, 1989).

Water-quality-based assessments such as the New Jersey, Washington, and Long Island studies can provide a firm scientific basis for management decisions involving aquifer or well vulnerability. The predictive indicators of vulnerability were developed in these studies for pesticide-control and monitoring-waiver programs and for land-use-planning purposes

(Eckhardt and Stackelberg, 1995; Ryker and Williamson, 1996a, 1996b; Vowinkel and others, 1996). The rigorous analysis techniques used in these studies were supported by large sample sizes and by stratified-random sampling designs, targeted data collection, or both (Barringer and others, 1990). The large data sets also allowed for the vulnerability ranking schemes to be tested with independent data. Thus, substantial resources may be required for these approaches to vulnerability assessment.

Numerous studies of the distribution of contaminants in relation to land use and hydrogeologic conditions also provide information that is useful for vulnerability assessments. Recent studies in southern New England include those by Mullaney and others (1991), Trombley (1992), Grady (1994), Stone and Webster Engineering Corporation (1988), Grady and Mullaney (1998), and Veeger and Ruderman (1998). Results of these studies indicate that agricultural and urban land uses, well depth, aquifer type (stratified drift or bedrock), and population density can be related to the distribution of nitrate, chloride, pesticides, and VOCs.

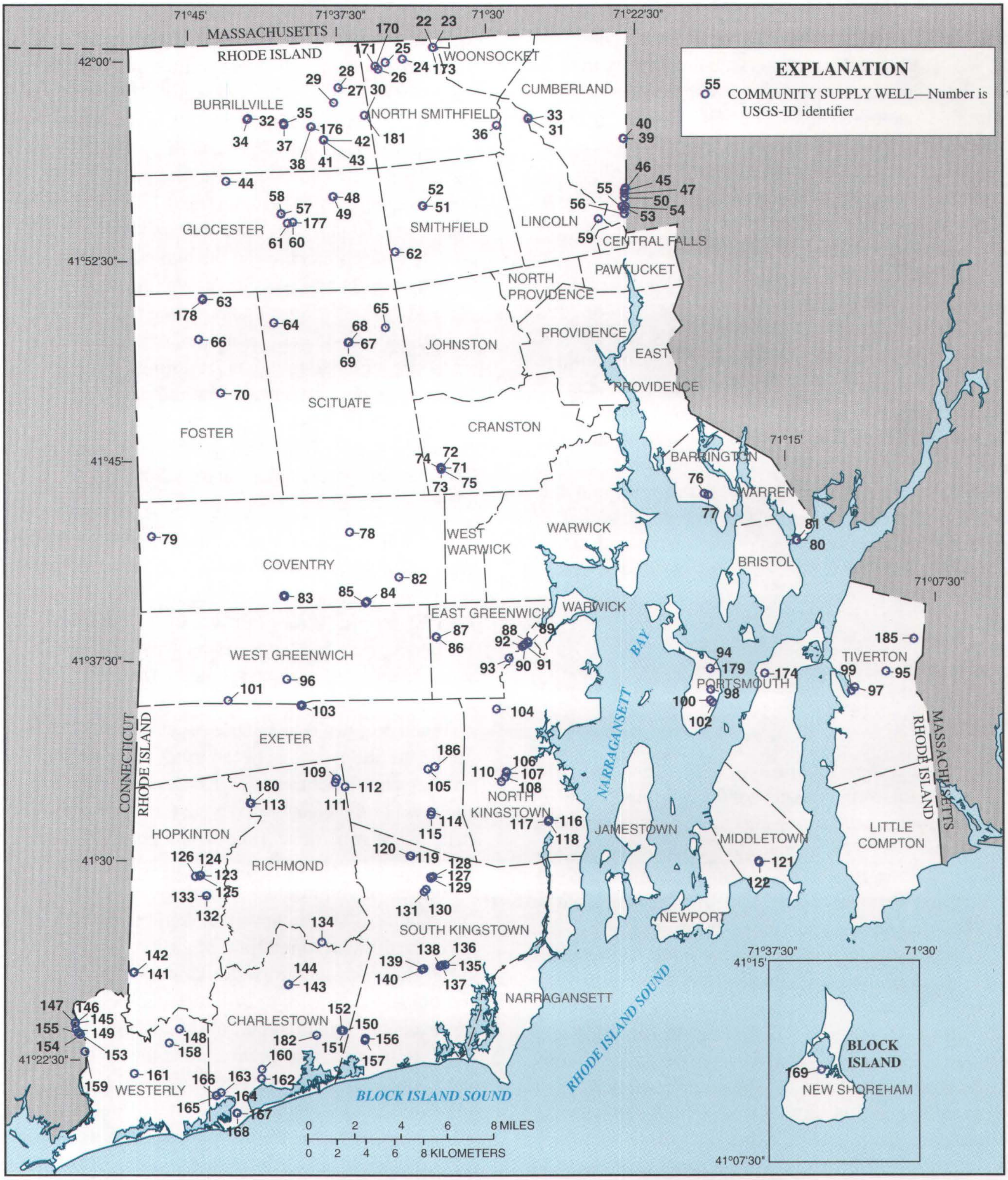
## Available Data

### Well Data

Public-supply wells used in this study consist of 256 wells that supply water for 73 community and 74 non-community, non-transient supply systems that were active as of December 1996 (table 12, at back of report; B. Barrette, RIDOH, written commun., 1996). Community systems serve year-round residents (at least 25 people or 15 service connections); non-community, non-transient systems serve non-residents (at least 25 of the same people at least 6 months per year) in places such as schools and workplaces [Code of Federal Regulations (CFR), title 40, part 141, section 2,1996]. Wells are in nearly every community in the State (figs. 2 and 3). The largest systems, in terms of population served by ground-water sources, are those in Cumberland, North Kingstown, South Kingstown, and Westerly. Locations were obtained for most wells as digital data sets from RIGIS or were obtained directly from the RIDEM.

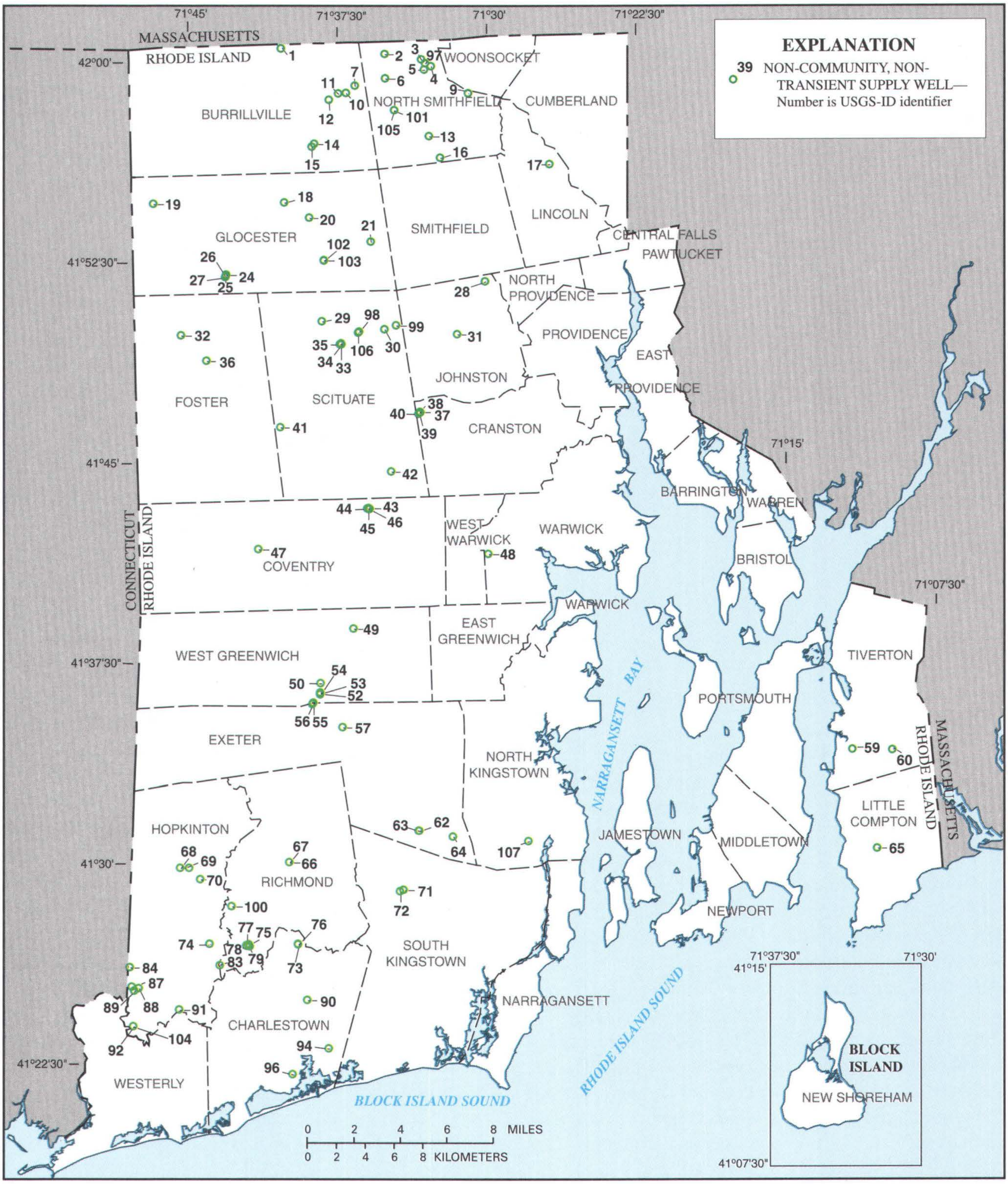
Ancillary data on aquifer type, well depth, depth to water, depth to bedrock, and pumping rate were compiled from sanitary-survey and monitoring-waiver files maintained by the RIDOH and from the RIGIS well-location coverages (table 12; pumping rate is not shown because the data were limited and did not always agree among sources). Aquifer type was defined as stratified drift (sand and gravel), bedrock, or undetermined. About 37 percent of the public-supply wells tapped stratified-drift aquifers; these mostly supplied community systems (fig. 4). Bedrock wells were about 60 percent of the total and were almost equally distributed between the two classes of systems (fig. 4). Aquifer type was unknown (undetermined) for eight wells. Three large-diameter dug wells, which may be in till, stratified drift, alluvium, or other aquifer types, are included in the undetermined category. Because of their shallow depths and other unique characteristics, the dug wells may be considered a separate category for vulnerability assessment, and information is provided separately for these wells where available.

Well depths were available for most wells and averaged 69 ($\pm$26 ft at 1SD; $n$ equal to 84) for sand-and-gravel wells and 332 ($\pm$208 ft at 1SD; $n$ equal to 124) for bedrock wells. Because of this large difference, well depth was tested separately for bedrock and sand-and-gravel wells. Depth to water, for which data were available only for about half the wells, averaged 18 ($\pm$24 ft at 1SD; $n$ equal to 114), with no significant difference between sand-and-gravel and bedrock wells. Depth to water may approximate the thickness of the unsaturated zone (and thus the unsaturated-zone travel time) when ground water is under unconfined conditions; under confined conditions or conditions where the well is open throughout its length, however, depth-to-water values are more difficult to interpret in terms of their implications for ground-water vulnerability. Depth to bedrock, averaging 25 ($\pm$27 ft at 1SD; $n$ equal to 67), was available for about half of the bedrock wells. Depth to bedrock may approximate the depth to the open interval of the well for some bedrock wells, because well casing sometimes extends only from the surface to just below the overburden/bedrock interface for bedrock wells. Depth to the top of the open interval of the well for bedrock and sand-and-gravel wells would have been useful in assessing the vulnerability of the wells, based on previous studies (for example, Vowinkel and others, 1994, 1996), but these data were not available for the Rhode Island supply wells.




Base from the Rhode Island Geographic Information System (RIGIS)
of the Rhode Island Board of Governors for Higher Education,
State base map, 1:24,000, 1989,
Based on Rhode Island coordinate system

**Figure 2.** Community supply wells in Rhode Island.




Base from the Rhode Island Geographic Information System (RIGIS) of the Rhode Island Board of Governors for Higher Education, State base map, 1:24,000, 1989, Based on Rhode Island coordinate system

**Figure 3.** Non-community, non-transient supply wells in Rhode Island.

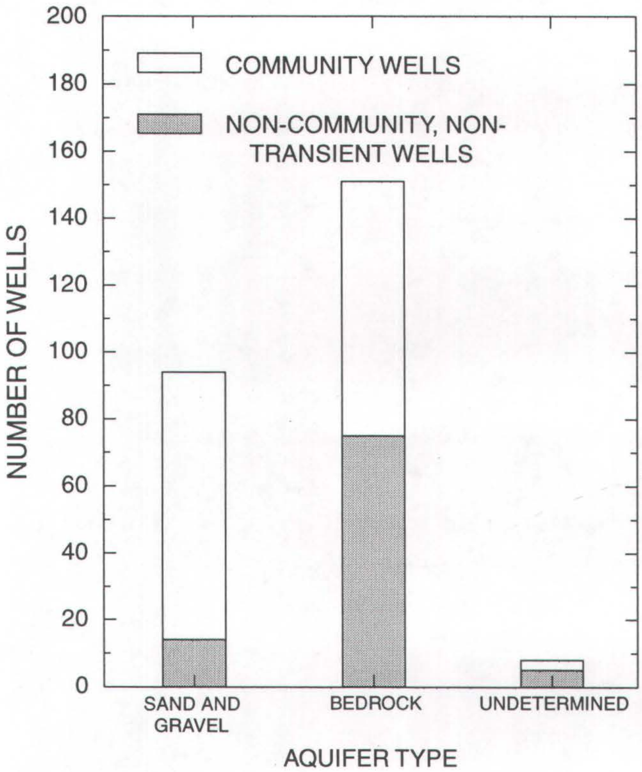



**Figure 4.** Aquifer type for community and non-community, non-transient supply wells in Rhode Island.

### Water-Quality Data

Available water-quality data consisted of monitoring results for compliance with drinking-water standards from 1988 to 1996. These data were obtained from RIDOH digital files and totalled about 180,000 analyses for the 256 active wells. All analyses were of raw, or untreated and unfiltered, water obtained from individual, identified sources or supply wells (D. Pytel, RIDOH, personal commun., 1998). Sample collection and analysis methods are described in "Rules and Regulations Pertaining to Public Drinking Water" (State of Rhode Island and Providence Plantations, 1996); samples were collected by RIDOH personnel (E. Girard, RIDOH, personal commun., 1998). The number of analyses varied by contaminant and by well, depending on the size of the water-supply system, its length of service, and any previous contamination, as required by RIDOH and USEPA regulations (table 13, at back of report).

### Spatial Data

Spatial data included well locations, wellhead-protection areas, and data on hydrogeology, land use, and other features. Primary criteria for spatial data sets included in the data analysis was that they be available for the entire State and at an appropriate scale. Most spatial data used in the study were digital data layers at 1:24,000 scale that were obtained from RIGIS (table 1). Data also were obtained for small, adjacent areas of Massachusetts and Connecticut from various sources (table 1).

Well-location coverages were updated on the basis of information obtained from the RIDOH files. Thirty-one wells were identified as no longer active, and twenty-four new wells were added. Locations of most new wells were determined relative to existing wells in the same system from narrative descriptions in the sanitary-survey and monitoring-waiver files. Seven wells were newly located by the RIDEM, and were added to the coverage using latitude-longitude locations (E. Pepper, RIDEM, written commun., 1997).

Wellhead-protection areas (WHPAs) were used to represent the land area contributing water to the wells (figs. 5 and 6). The WHPAs were delineated by the RIDEM using several methods as described by Bradley and Kaczor-Babiak (1993). For large wells (pumping rate greater than 10 gal/min) in stratified drift, the WHPA was delineated using available hydrogeologic data and the uniform-flow equation (Todd, 1980; Blandford and Huyakorn, 1991) to define the downgradient boundary of the contributing area of the well; the WHPA boundary was extended upgradient to the till/stratified-drift boundary, a 10-year time-of-travel boundary, a ground-water divide, or 1 mi. For large wells in bedrock, the Theis equation (Fetter, 1988) and uniform hydrogeologic values (transmissivity equal to 50 ft/d; storativity equal to 0.1) were used to define a circular area based on maximum drawdown criteria and the assumption of an initially flat water table. Hydrogeologic mapping was used to include additional surface-drainage and stratified-drift areas contributing water to the WHPAs for large wells. WHPAs also may have been refined by the RIDEM based on numerical modeling.

**Table 1.** Spatial data used to assess the vulnerability to contamination of community and non-community, non-transient supply wells in Rhode Island

[Spatial data obtained from the Geographic Information System of the Rhode Island Board of Governors for Higher Education (RIGIS) unless otherwise indicated. Date refers to date of compilation or revision for digital data and date of publication for non-digital data. USDA, U.S. Department of Agriculture]

| Type of data | Description | Spatial data-layer source | |
|---|---|---|---|
| | | Date | Scale |
| Well locations | Community supply wells | 1994 | 1:24,000 |
| | Non-community supply wells | 1994 | 1:24,000 |
| Wellhead-protection areas | Wellhead-protection areas for community supply wells | 1996 | 1:24,000 |
| | Wellhead-protection areas for non-community supply wells | 1996 | 1:24,000 |
| Surficial geology | Glacial deposits in Rhode Island | 1989 | 1:24,000 |
| | Surficial geology in Massachusetts[1] | 1993 | 1:25,000 |
| | Surficial geology in Connecticut digitized from Schafer (1968) | 1968 | 1:24,000 |
| Bedrock geology | Digital data layer for the bedrock geologic map of Rhode Island by Hermes and others (1994) | 1994 | 1:100,000 |
| | Bedrock geology in Connecticut digitized from Feininger (1965) | 1965 | 1:24,000 |
| Soils | Soil types for Rhode Island from the 1981 USDA Soil Survey, revised in 1989 | 1990 | 1:15,840 |
| | Soil types for Massachusetts from the 1978 USDA Soil Survey of Bristol County, Massachusetts[2] | 1978 | 1:20,000 |
| | Soil types for Connecticut from USDA State Geographic Soil Survey (SSURGO) data[3] | 1996 | 1:5,840 |
| Hydrography | Rivers and stream centerlines (intermittent and perennial), from USGS 7.5-minute quadrangles | 1989 | 1:24,000 |
| | Lakes, ponds, and reservoirs from USGS 7.5-minute quadrangles | 1988 | 1:24,000 |
| Ground-water reservoirs | Ground-water reservoirs defined by RIDEM as significant water resources | 1989 | 1:24,000 |
| Land use | Land use and land cover in Rhode Island from 1988 aerial photography, with modified Anderson[4] Level III coding | 1988 | 1:24,000 |
| | Land use and land cover in Massachusetts from aerial photography from 1971–92, coded with 37 land-use categories[1] | 1995 | 1:25,000 |
| | Land use and land cover in Connecticut, with Anderson[4] Level II coding[5] | 1994 | 1:250,000 |
| Roads | All roads in Rhode Island and parts of adjacent States, coded according to type, use, and function | 1996 | 1:24,000 |
| Sewers | Sewer lines greater than about 10 inches in diameter | 1995 | 1:24,000 |
| Leaking underground storage tanks | Leaking underground storage tanks greater than 1,100 gallons (excluding home heating tanks) | 1993 | 1:24,000 |
| Hazardous-waste sites | Sites in Rhode Island inventoried in the USEPA Comprehensive Environmental Response and Liability Information System (CERCLIS) | 1997 | 1:24,000 |

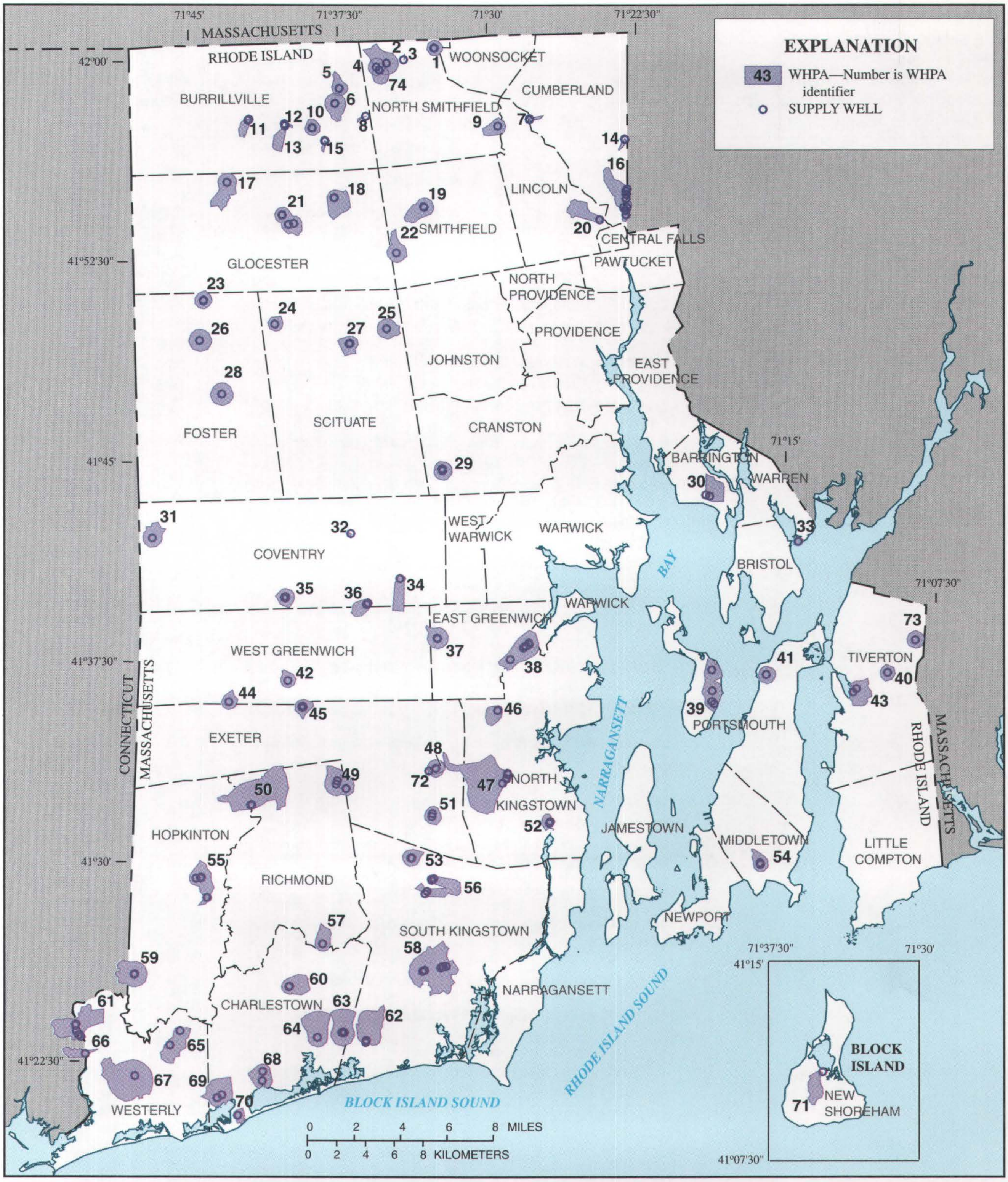
[1] Data from MassGIS

[2] Digitized from sheets 10 and 14, U.S. Department of Agriculture, 1978.

[3] Data from the Map and Geographic Information Center of the University of Connecticut

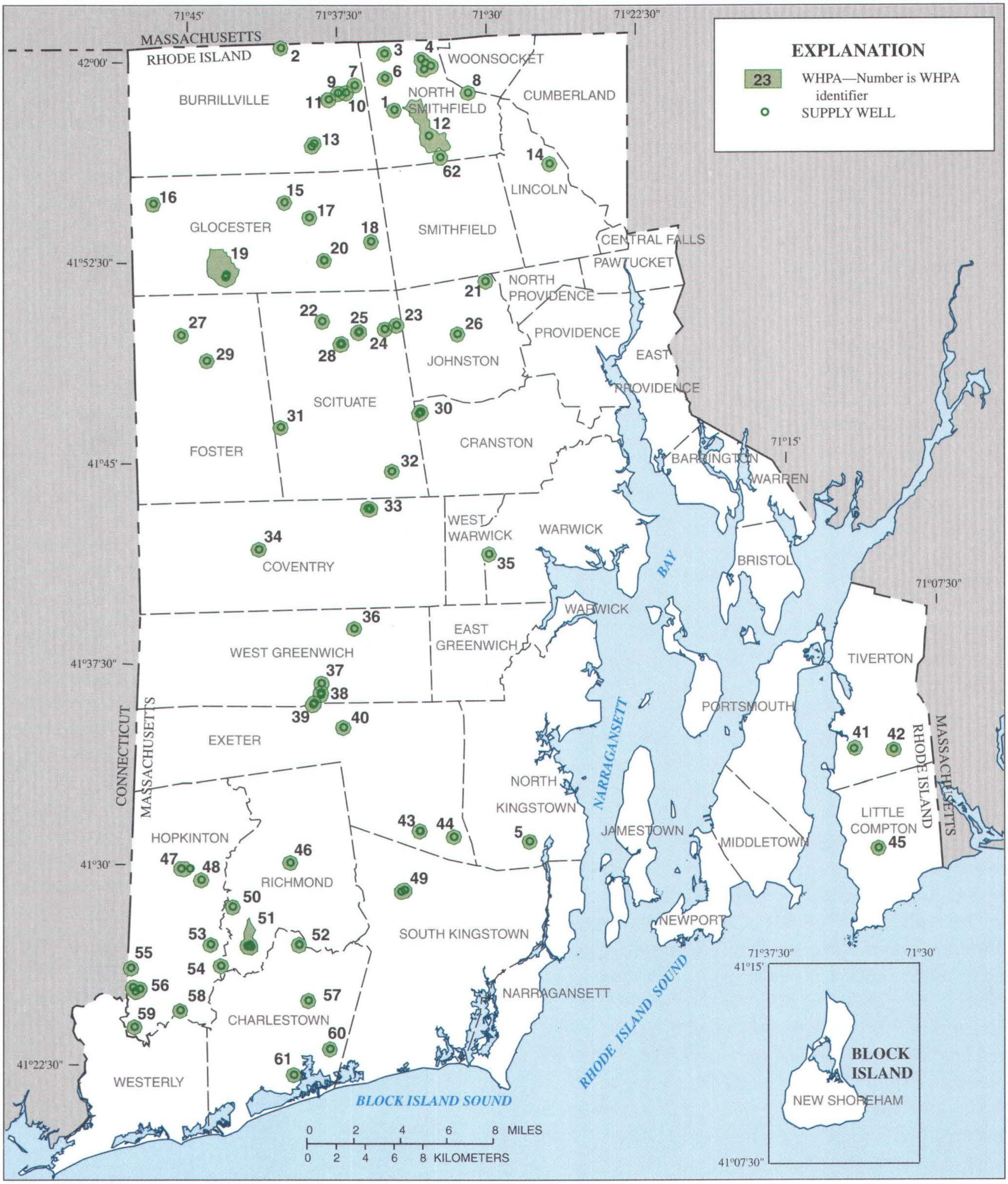
[4] Anderson, J.R., and others, 1976.

[5] Data from the USGS Geographic Information and Retrieval System (GIRAS) system




Base from the Rhode Island Geographic Information System (RIGIS)
of the Rhode Island Board of Governors for Higher Education,
State base map, 1:24,000, 1989,
Based on Rhode Island coordinate system

**Figure 5.** Wellhead-protection areas (WHPAs) for community supply wells in Rhode Island.




Base from the Rhode Island Geographic Information System (RIGIS) of the Rhode Island Board of Governors for Higher Education, State base map, 1:24,000, 1989, Based on Rhode Island coordinate system

**Figure 6.** Wellhead-protection areas (WHPAs) for non-community, non-transient supply wells in Rhode Island.

For small wells in bedrock (pumping rate estimated at less than 10 gal/min), the Theis equation was used with the same hydrogeologic values as for large bedrock wells and with a uniform pumping rate of 10 gal/min; this approach generated a 1,750-foot-radius circle surrounding the well for the WHPA. As the result of the multiple methods used for their delineation, the WHPAs differ considerably in size and shape (figs. 5 and 6).

WHPAs, delineated by the RIDEM for management and regulatory purposes, generally constitute a fraction of the total contributing area that is designated for protection and can be delineated using available resources (U.S. Environmental Protection Agency, 1993b). Thus, WHPAs may not represent the actual contributing areas of wells in many cases. WHPA-delineation methods generally cannot incorporate all of the complex features, such as three-dimensional flow, aquifer heterogeneity, surface-water/ground-water relations, and pumping of nearby wells, that influence the shapes and sizes of contributing areas. These effects are discussed by Handman (1986), Morrissey (1989), Barlow (1993), Reilly and Pollock (1993), Franke and others (1998), and Masterson and others (1998); several authors also compare contributing areas that are delineated with methods of different complexity (Hansen, 1991; Delin and Almendinger, 1993; Forster and others, 1997). WHPAs for the larger systems, which incorporate the most site-specific hydrogeologic information and are based on relatively complex delineation methods, are likely to be more representative of actual contributing areas than WHPAs for smaller wells. Contributing areas to bedrock wells may differ considerably from the circular WHPAs, because flow through bedrock aquifers is controlled primarily by fracture orientation and connectedness (U.S. Environmental Protection Agency, 1991; Shapiro, 1998; Vernon, 1998). Despite these limitations, WHPAs delineated by the RIDEM methods were considered to be the best available representations of the land area contributing water to the supply wells used in this study and were preferable to simple buffer radii for relating spatial data to water quality at the well.

RIGIS coverages of RIDEM-delineated WHPAs also were reviewed and updated based on information obtained from RIDOH files. Narrative descriptions in monitoring-waiver files of WHPA shapes and sizes were compared with the digital data to verify the overlay method used to relate wells and WHPAs. WHPAs associated with inactive wells were identified. New wells located near an existing well(s) in the same system were assigned the same WHPA as the existing well(s). WHPAs for other new wells were created as 2,000- or 1,750-foot-radii circles centered on the wells for community or non-community, non-transient wells, respectively, following RIDEM procedures for interim WHPA delineation (E. Pancierra, RIDEM, personal commun., 1997). Single polygons in the WHPA coverages that clearly represented several independently delineated WHPAs were subdivided based on 1,750-foot-radii circles, where appropriate, or other obvious boundaries. For example, non-community, non-transient (P) WHPAs P7, P9, P10, and P11 were split from a single polygon using circles centered on the wells, and community (C) WHPAs C47 and C48 were separated (figs. 6 and 5, respectively).

Hydrogeologic data included surficial and bedrock geology and locations of ground-water reservoirs (table 1). For surficial geology, a coverage of glacial geology that delineated areas of stratified drift, till, mixed till and stratified drift, and bedrock outcrops was used (fig. 1). Bedrock geology is based on a recent statewide map of Hermes and others (1994). The areal extent of the bedrock geology data extended beyond State borders to include all WHPAs partly in Massachusetts. Bedrock and surficial geology for parts of WHPAs in Connecticut was digitized from Feininger (1965) and Schafer (1968), respectively, at 1:24,000 scale. Surficial geology for Massachusetts, which had the same original source as the Rhode Island data layer, was obtained from MassGIS of the Massachusetts Executive Office of Environmental Affairs (MassGIS, 1997). More detailed hydrogeologic information than these statewide data layers was available for several basins and aquifers, but not on a statewide basis, except for a data layer of ground-water reservoirs (fig. 1). These areas, originally delineated by the USGS and modified by RIDEM, are stratified-drift areas of high thickness and permeability that are considered to be important ground-water resources.

Soils data for Rhode Island were obtained from RIGIS as separate, 1:15,840-scale data layers for the 24 7.5-minute quadrangles in the State. These coverages are based on the 1981 Soil Survey of Rhode Island (U.S. Department of Agriculture, 1981; digital data were revised in 1989). Soil data for areas of Massachusetts were digitized from parts (sheets 10 and 16) of the Soil Survey of Bristol County, Northern Part

(U.S. Department of Agriculture, 1978). Soil data for areas of Connecticut were preliminary data from the State Geographic Soil Survey Database (SSURGO) of the National Resources Conservation Service, which were obtained from the Map and Geographic Information Center of the University of Connecticut.

Land use for Rhode Island is based on 1988 aerial photography and is coded with modified Anderson Level III categories of land use and land cover (Anderson and others, 1976; table 1). Land use for parts of WHPAs in Massachusetts was obtained from MassGIS (MassGIS, 1997); land-use categories in this data layer were interpreted in terms of the coding scheme used in the Rhode Island data layer. Land use for WHPAs extending into Connecticut was obtained from the USGS Geographic Information and Retrieval System (GIRAS), which is coded with Anderson Level II categories.

Data on known hazardous-waste sites included locations of large (greater than 1,100 gallons) leaking underground storage tanks and sites inventoried in the USEPA Comprehensive Environmental Response Compensation and Liability Information System (CERCLIS; table 1). CERCLIS sites are designated as landfills, formerly used defense sites, surface impoundments, superfund sites, salt piles, dumps, and U.S. Department of Defense sites in the data layer.

## Data Analysis

Several considerations influenced the methods used in this study. First, the spatial distribution of supply wells (figs. 2 and 3) meant that the assessment would cover virtually the entire State. Second, an assessment was needed of the relative vulnerability of the wells to many specific contaminants, which originate from various natural and anthropogenic sources. Finally, available resources were limited in that no new data collection was planned for the study.

A water-quality-based approach rather than an index-and-overlay method was used in the present study. Although often used for statewide assessments, index-and-overlay methods were not considered appropriate for several reasons. The distribution of hydrogeologic conditions and potential contamination sources (as reflected by land use) in the study area is patchy, and the study area is relatively small compared to other States and regions where these methods have been applied. Many hydrogeologic characteristics, such as recharge or depth to water, do not differ greatly or vary systematically across the State, or consistent statewide data were not available. These considerations suggested that an index-and-overlay approach might not adequately delineate subareas of relatively high and low risk at the statewide scale. In addition, defining the factors describing sources for the various contaminants at the outset of the assessment would be complex and uncertain. In contrast, a water-quality-based approach would take maximum advantage of the available water-quality data and would minimize the need to pre-determine significant contaminant sources.

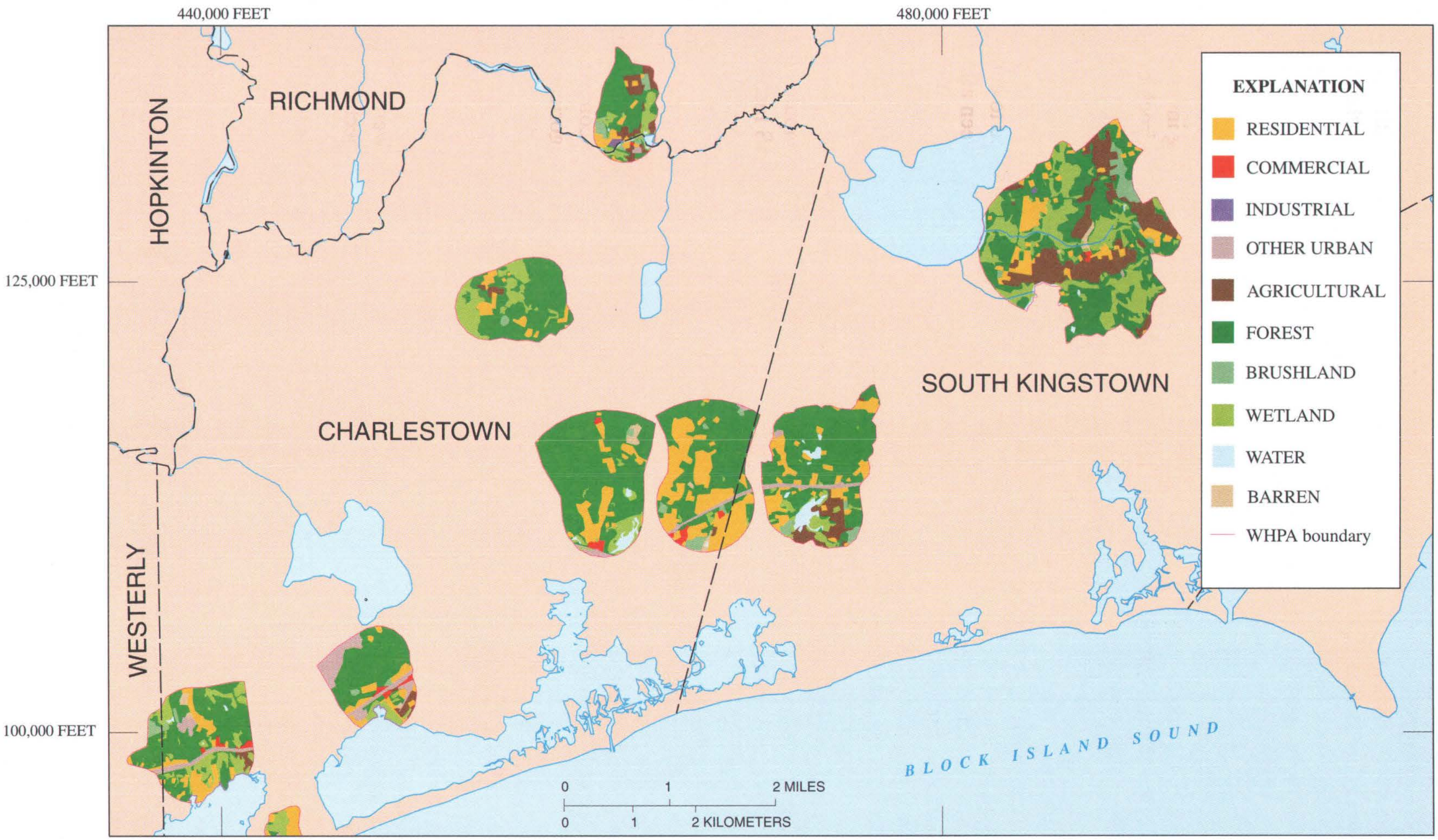
Possible water-quality-based approaches, however, were constrained by the available data and illustrate some of the difficulties that may be encountered when water-quality data are used for purposes beyond those for which the data were collected. For example, the number of sampling locations (wells) was relatively small, and the wells were not randomly located nor were they located so as to represent categories of hydrogeologic conditions or land use. The sampling schedules, representing RIDOH and USEPA drinking-water regulations for systems of different sizes, were designed for the purpose of protecting public health. Thus, wells supplying larger systems or wells where contaminants were historically detected may be sampled more frequently than wells of smaller systems or where contaminants were never detected. Wells supplying smaller systems also may be sampled less frequently for some contaminants, based on site-specific determinations that the contaminants are not used within the WHPA (Rhode Island Department of Environmental Management, 1995). Thus, sampling frequencies may vary considerably among the wells (table 13). In addition, different detection and reporting limits were used for many contaminants during the 10 years of data collection. Finally, well-construction characteristics and sampling procedures also varied, such that the detections of some contaminants present at low concentrations or contaminants that are sensitive to atmospheric oxygen (for examples, some trace metals) may have been affected. These considerations and others limit the capability of statistical methods, such as those used in water-quality-based approaches, to identify relevant factors affecting the distribution of contaminants and to predict quantitatively the probability of contamination. Thus, the approach developed for the present study was relatively simple and was designed to minimize the effects of the available-data limitations on the results.

To address the variety of contaminants to be considered, classes of contaminants were defined for which vulnerability was investigated separately (table 13). The classes were based on potential contaminant sources as described primarily by Hem (1985), Lucius and others (1989), Kroehler (1991), and Fetter (1998). These contaminant classes are: nutrients, pesticides, solvents and other industrial organic chemicals, fuel hydrocarbons, road-deicing chemicals, fluoride, iron and manganese, trace inorganic chemicals (such as metals), radionuclides, and microbial contaminants. Other classes were based on the available water-quality data, but these classes were not assessed, for reasons described below. Classes that were not investigated are constituents related to hardness, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, synthetic organic chemicals related to chlorination (disinfectant by-products), and synthetic organic chemicals related to analytical methods (table 13).

For each contaminant class, a threshold criterion was defined by which to categorize wells as "affected" or "unaffected" by contaminants in that class. For naturally occurring contaminants that also have anthropogenic sources, the threshold criterion was a concentration indicative of human activity or related to a regulatory level. The threshold criterion for synthetic chemicals and some trace elements was any concentration above the reported method detection limit (MDL). All the threshold criteria generally were considerably below drinking-water standards, such that wells categorized as "affected" for the current assessment would not be considered contaminated for health or regulatory purposes. Median or mean concentrations also were calculated for some contaminants, where sufficient and appropriate water-quality data were available—that is, where samples were collected at regular time intervals and a sufficient proportion of analysis results were above MDLs. Median or mean concentrations for wells for which some analytical results were less than the MDL were calculated using the robust probability method for censored data of Helsel and Cohn (1988) and Helsel (1990).

Statistical tests were used to compare well data, hydrogeologic characteristics, land use, and other spatial data between affected and unaffected groups to identify factors that were associated with affected wells for each contaminant class. A statistical software package, Statview (version 5; SAS Institute, 1998), was used for all tests to compute the test statistic from the sample data and the associated probability (*p*-value or attained significance level of the test) of the null hypothesis being true (Helsel and Hirsch, 1992). Contingency tables were used to compare categorical data, such as aquifer type, between affected and unaffected groups. The null hypothesis for the example of aquifer type states that whether a well is affected or unaffected by the contaminant class being investigated is independent of aquifer type (that is, bedrock or stratified drift). Fisher's exact test was used to compute *p*-values for 2-by-2 contingency-table tests and the chi-square large-sample approximation was used for 2-by-3 contingency-table tests (SAS Institute, 1998). The Mann-Whitney *U* (rank-sum) test was used to compare continuous data, such as well depth, between affected and unaffected groups. The null hypothesis tested with the Mann-Whitney test states that observations, for example, values of well depth, in one of the tested groups are likely to be neither higher nor lower than observations of the same factor in the other tested groups (Helsel and Hirsch, 1992); the computed *p*-value for the test is corrected for ties (SAS Institute, 1998). Median or mean concentrations were compared with continuous data using the Kendall's tau rank correlation coefficient; the null hypothesis tested in this case states that the two continuous variables are independent, or not correlated. Finally, the Kruskal-Wallis test was used in a few instances to compare median or mean concentrations with categorical data containing more than two categories. The Mann-Whitney, Kendall's tau, and Kruskal-Wallis methods are nonparametric tests, which do not require that the sample data be normally distributed, and which are relatively unaffected by outliers as compared to parametric statistical tests. Sample sizes were considered too small for testing when expected values for any tested factor were less than five for contingency tests or when the number of values for any group was less than nine for the other tests. Results were considered significant when the *p*-value computed for a statistical test was less than the $\alpha$ level of 0.05.

WHPAs, as the best available representations of the wells' contributing areas, were used to relate the spatial data layers to water quality at the wells for most data layers. The statewide data layer was intersected with the community and non-community, non-transient WHPAs in GIS, as shown in figure 7 for land use.




Base from the Rhode Island Geographic Information System (RIGIS)
of the Rhode Island Board of Governors for Higher Education,
State base map, 1:24,000, 1989,
Based on Rhode Island coordinate system

**Figure 7.** Example of determination of land-use types in wellhead-protection areas (WHPAs) using Geographic Information System analysis.

The area of each land-use type in the WHPA was then calculated. Similar procedures were followed for surficial geology, ground-water reservoirs, soils, and roads. Total length of roads and road density (length per unit area) in the WHPAs were calculated for the roads data layer. WHPA areas and data on land use, surficial geology and ground-water reservoirs, soils, and roads used in the present study are provided in appendixes 1 through 5. The presence or absence of a leaking underground storage tanks or hazardous-waste site within a WHPA was determined, and the distance from each well to the closest site also was measured using GIS.

The proximity of a well to a surface-water feature was determined by measuring the distance from each well to the closest river, stream (perennial or intermittent), lake, pond, or reservoir. The linear features that represent rivers and streams and the shorelines of lakes, ponds, and reservoirs on USGS 7.5-minute quadrangle maps (table 1) were converted to point features using an 80-foot spacing between points, and the distance from each well to the closest such point was measured using GIS. The 80-foot distance was the smallest discretization that could be used within the computation limits of the GIS software. The error associated with this discretization of the stream segments decreases with increasing distance from the stream; for a well at 100 ft from the stream, the maximum error is 7 ft. GIS-measured distances from wells to the closest surface-water body are provided in appendix 6.

Land use, surficial geology, ground-water reservoirs, and soils were analyzed primarily by comparing the areas of land-use types or other spatial-data factors as appropriate within the WHPA by expressing these areas as percentages of the total WHPA. This approach was chosen to account for the wide variation in WHPA size (figs. 5 and 6 and appendix 1). For land use and ground-water reservoirs, the presence or absence and the absolute areas of the tested factor also were compared. These results were similar to the comparisons of areas as percentages of the WHPA (though less statistically significant) and so generally are not reported. Land-use types were compared first in terms of Anderson Level I categories (for example, urban or agricultural). If significant differences were found between affected and unaffected groups for a broader category, or if literature sources indicated a relation between a land-use type and the occurrence of a contaminant, then the Anderson Level II or III categories (for example, residential urban or cropland agricultural) also were compared.

Soils data were further analyzed in two ways. First, soil types were grouped according to hydrologic soil groups, and the area of each group in the WHPA was calculated. Hydrologic groups A, B, C, and D are associated with high, moderate, low, and very low rates, respectively, of water infiltration and movement through the soil (U.S. Department of Agriculture, 1981). Soil types also were grouped according to a leachability classification system developed by the RIDEM to assess the potential risk for ground-water contamination by pesticides that is associated with various soil types (Pepper, 1998). Soils are ranked in six categories of risk for pesticide contamination on the basis of leaching potential from low (1) to high (6). Shallow depth to the water table, low organic-matter content, high permeability, low surface-layer thickness, and low land-surface slope contribute to high risk for pesticide contamination of ground water (soil-leaching potential risk) in this classification system (Pepper, 1998). A rank for soil leaching-potential risk was calculated for each WHPA as the area-weighted average of the risk ranks of all soil types in the WHPA.

In cases where multiple, closely located wells were assigned the same WHPA, the convention was followed that the WHPA was categorized as "affected" if any one of the wells within it was identified as affected. Thus, "double accounting" of the same spatial data was avoided, but the maximum sample size for identifying vulnerability factors with spatial data was reduced from 256 (number of wells) to 136 (number of WHPAs). However, the statistical analyses may still have been affected by autocorrelation in the spatial data, because of the proximity and partial overlay of some WHPAs (figs. 5 and 6; Barringer and others, 1990). Spatial autocorrelation means that some of the dependent variables used in the statistical tests, such as land use in the WHPA, were not completely independent. This phenomenon could have biased the attained significance level of some of the statistical tests (Barringer and others, 1990). Subsampling the data set to such that wells and WHPAs were not as closely spaced as in the complete data set could eliminate some of the spatial autocorrelation in the spatial-data variables, but the sample sizes in the present study were too small to support subsampling.

Bedrock geology was related to water quality at the well by intersecting the data layers of well locations with the bedrock geology data layer in GIS (table 1) and determining the geologic map unit at each well site. In some cases, the rock type at the well site may not best represent the rock type with which ground water from the well is in contact along most of its subsurface flowpath. For several reasons, however, this approach was preferred to using all the bedrock types intersected by the WHPA. For sand-and-gravel wells, the lithologic composition of the glacial aquifer materials from which ground water is withdrawn is likely derived from bedrock sources near (within a few miles) of the well. The source of these materials, however, is likely to be upgradient in the direction of Pleistocene ice flow (that is, generally north), rather than upgradient in the direction of present-day ground-water flow, as defined for the WHPA delineation. Similarly, bedrock material from which water at bedrock wells is withdrawn is likely to be best defined in terms of fracture orientations rather than by the WHPA-delineation methods described previously. Thus, using the WHPAs does not necessarily better define the bedrock type(s) likely to affect water quality at the well than does the more simple approach of determining the rock type at the well location.

Bedrock geologic map units (geologic formations) were grouped for the present data analysis into lithologic categories, which are based on mineralogic and chemical properties relevant to water quality (G.R. Robinson, U.S. Geological Survey, written commun., 1997; Robinson and others, 1999). These categories consist of: (1) felsic igneous and metamorphic rocks (mostly granite and granite gneiss; hereafter "felsic crystalline rocks"); (2) mafic and intermediate igneous rocks, including mixed mafic and felsic lithologies (hereafter "mafic crystalline rocks"); (3) primarily noncalcareous, metamorphosed clastic sedimentary rocks, (mostly quartzite and schist; hereafter "metasedimentary rocks"); (4) primarily noncalcareous, unmetamorphosed or weakly metamorphosed clastic sedimentary rocks (mostly conglomerate, sandstone, and shale; hereafter "sedimentary rocks"); and (5) carbonate-rich rocks. Most wells (178) were located in areas of felsic crystalline rocks, followed by 42 wells in areas of mafic crystalline rocks, and 23 wells in areas of sedimentary rocks. Only 5 wells were located in areas of metasedimentary rocks and only 1 well was located in a rock type classified as carbonate-rich. Information of lithologic rock type and bedrock formation at the well locations is provided in appendix 6.

# IDENTIFICATION OF VULNERABILITY FACTORS FOR PUBLIC-SUPPLY WELLS

## Nutrients

Nitrogen species in ground water originate from septic-tank and sewage effluent, fertilizer application, and animal waste (Fetter, 1998). Nitrate, nitrite, and ammonia are grouped in the "Nutrients" contaminant class (table 13). Nitrate and nitrite are regulated drinking-water contaminants, with USEPA Maximum Contaminant Levels (MCLs) of 10 and 1 mg/L as N, respectively (CFR, title 40, section 141, part 62, 1996). Nitrate concentration was used as the criterion by which to identify wells that are contaminated by nutrients, because nitrate is the most mobile of these constituents. Nitrate generally is transported conservatively in oxygenated ground water, but it may be attenuated by microbial processes under reducing (low dissolved oxygen) conditions (Chapelle, 1993). In contrast, nitrite and ammonia are less stable in oxygenated ground water and may be transformed to nitrate; ammonia (as ammonium ion) also may be sorbed to aquifer sediments.

Nitrate data were available for 96 percent, or 246 of the wells, with yearly samples in most cases (table 13). Concentrations ranged from less than 0.01 to 10.8 mg/L as N. Several threshold criteria, in terms of any measured nitrate concentration at the wells, were chosen by which to categorize the well as "affected" by nutrients for the purposes of this assessment. These threshold criteria were (1) any nitrate concentration greater than 1 mg/L as N, a level indicative of any human activity, (2) any nitrate concentration greater than 2 mg/L as N, the concentration proposed by USEPA as a threshold value for reduced nitrate monitoring (U.S. Environmental Protection Agency, 1997b), and (3) any nitrate concentration greater than 5 mg/L as N, or one-half of the MCL, which is a commonly used threshold for planning purposes. The two more restrictive criteria were used to determine whether factors found to be associated with low levels of nitrate also would be associated with the higher concentrations that could present health concerns.

Comparison of affected and unaffected wells and WHPAs indicated that several factors were significantly associated with elevated nitrate concentrations (table 2). Aquifer type was significant, with affected wells more likely to be in stratified drift (sand-and-gravel wells) than in bedrock for all three threshold criteria (fig. 8). In contrast, well depth, depth to water, or depth to bedrock were similar between affected and unaffected groups (table 2). The lack of correlation between elevated nitrate concentrations and these well characteristics is consistent with findings in some previous studies, especially in regions of shallow water tables (Vowinkel and others, 1994; Eckhardt and Stackelberg, 1995; Hamilton and Helsel, 1995; Clawges and Vowinkel, 1996) like those in Rhode Island; however, the lack of correlation also may be partly due to the limited available data, especially for depth to water and depth to bedrock. Potential vulnerability factors associated with soils and surficial geology were not significantly different between affected and unaffected groups for the three nitrate threshold criteria tested (table 2).

Several land-use types also were related to elevated nitrate concentrations (table 2). WHPAs of affected wells had higher percentages of their total area occupied by residential land use and by an urban land-use type that contains parks and golf courses (RIGIS, 1997), and lower percentages of forest cover, than unaffected WHPAs, where affected WHPAs are defined by nitrate concentrations at the wells that are greater than 1 or 5 mg/L as N (fig. 9*A–C*). The urban land use containing parks and golf courses also was higher in affected WHPAs as defined by nitrate concentrations greater than 2 mg/L as N, and the presence or absence of this land use in the WHPA was significant for all threshold criteria, as determined by contingency-table tests ($p$-values equal to 0.020, 0.029, and 0.067 for 1, 2, and 5 mg/L as N threshold criteria, respectively). The differences in residential land use and forest cover between affected and unaffected groups for the 2 mg/L as N threshold concentration, however, were less distinct than for the other threshold concentrations (table 2), indicating that the relations between the percentages of these land uses in the WHPA and nitrate concentrations are not linear. Thus, although low nitrate concentrations are associated with little residential land use and high amounts of forest cover in the WHPA, and high nitrate concentrations are associated with large areas of residential land use and little forest cover in the WHPA, moderately high nitrate concentrations occur with variable amounts of these land uses.

An association of high concentrations of nitrate with residential or urban land uses, with golf courses, and with the inverse of forest cover has been found in many studies of nitrate contamination of ground water (Hamilton and Helsel, 1995; Nolan and others, 1997; Vowinkel and others, 1996). Agricultural land use also commonly is associated with high nitrate concentrations in ground water in many parts of the United States, but this land use was not significantly higher in WHPAs of affected wells in the present study (table 2 and fig. 9*D*). One explanation for this is that, although agricultural land use may be a source of nitrate contamination where present, areas of agricultural land use (as delineated in the 1988 data on land-use and land-cover) are relatively small compared to residential and other urban land-use areas in Rhode Island. Moreover, public-supply wells may not be located in dense agricultural areas. Thus, most wells with elevated nitrate concentrations are associated with the residential and urban sources, and any effects of agricultural land use are not apparent at the statewide scale (fig. 9*D*).

Residential land use, the urban land use with parks and golf courses, and forest cover also were evaluated separately for bedrock and sand-and-gravel wells to determine whether these potential vulnerability factors were significant for both aquifer types. The threshold concentration of 1 mg/L as N was used for this test to maximize sample sizes. As for all wells, residential land use was higher, and forest cover was lower, in WHPAs of affected bedrock wells ($p$-values equal to 0.042 and 0.080, respectively; $n$ equal to 36 affected and 52 unaffected wells) and sand-and-gravel wells ($p$-values equal to 0.044 and 0.152, respectively; $n$ equal to 11 affected and 27 unaffected wells). The area of the urban land use with parks and golf courses was significantly higher in WHPAs of affected bedrock wells ($p$-value equal to 0.020), but not for WHPAs of sand-and-gravel wells ($p$-value equal to 0.880). These results may have been affected by the small sample size for sand-and-gravel wells.

**Table 2**. Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by nitrate

[*p*-value, the probability that the observed differences in the potential vulnerability factors tested between affected and unaffected groups are due to chance, are for 2-by-2 exact probability contingency-table tests (CT) and for the Mann-Whitney *U* (rank sum) test (MW); *p*-values significant at $\alpha = 0.05$ are shown in **bold**. Wells affected by nitrate are defined as wells at which any measured nitrate concentration at the wells is greater than the threshold concentration. **Direction of association:** +, higher value or presence of tested factor is associated with elevated nitrate concentrations; -, lower value or absence of tested factor is associated with elevated nitrate concentrations; ns, association not statistically significant. WHPA, wellhead-protection area; mg/L as N, milligrams per liter as nitrogen; <, actual value is less than value shown; na, not applicable; --, sample size too small for analysis]

| Potential vulnerability factor | Statistical test | Threshold nitrate concentration: 1 mg/L as N — Attained significance level | 1 mg/L as N — Direction of association | 2 mg/L as N — Attained significance level | 2 mg/L as N — Direction of association | 5 mg/L as N — Attained significance level | 5 mg/L as N — Direction of association |
|---|---|---|---|---|---|---|---|
| Aquifer type[1] | CT | **<0.001** | na | 0.005 | na | **0.015** | na |
| Well characteristics[2] | | | | | | | |
| Well depth, sand-and-gravel wells | MW | .188 | ns | .578 | ns | .575 | ns |
| Well depth, bedrock wells | MW | .059 | ns | .063 | ns | .069 | ns |
| Depth to water, all wells | MW | .480 | ns | .248 | ns | .241 | ns |
| Depth to bedrock, bedrock wells | MW | .129 | ns | .531 | ns | -- | -- |
| Surficial geology, bedrock wells[3] | | | | | | | |
| Till, area in WHPA | MW | .706 | ns | .117 | ns | -- | ns |
| Outwash, area in WHPA | MW | .740 | ns | .067 | ns | -- | ns |
| Soils[4] | | | | | | | |
| Hydrologic group A, area in WHPA | MW | .443 | ns | .600 | ns | .601 | ns |
| Leaching potential risk, area-weighted rank | MW | .435 | ns | .460 | ns | .369 | ns |
| Ground-water reservoirs, sand-and-gravel wells, area in WHPA[5] | MW | .961 | ns | .151 | ns | .193 | ns |
| Land use and land cover, area in WHPA[4] | | | | | | | |
| Urban, all categories | MW | **<.001** | + | .118 | ns | **<.001** | + |
| Residential, all categories | MW | **<.001** | + | .214 | ns | **.016** | + |
| Residential, high density | MW | **<.001** | + | .013 | + | **.001** | + |
| Residential, medium density | MW | **.004** | + | .322 | ns | .068 | ns |
| Commercial | MW | .441 | ns | .608 | ns | .435 | ns |
| Industrial | MW | .632 | ns | .396 | ns | .147 | ns |
| Transportation | MW | .081 | ns | .042 | + | .216 | ns |
| Other urban, all categories | MW | .083 | ns | .113 | ns | **.006** | + |
| Developed recreation (parks, zoos, and golf courses | MW | **.014** | + | **.015** | + | **.013** | + |
| Urban open space and cemeteries | MW | .949 | ns | .951 | ns | .542 | ns |
| Institutional | MW | **.002** | + | .595 | ns | .375 | + |

**Table 2.** Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by nitrate—*Continued*

| Potential vulnerability factor | Statistical test | Threshold nitrate concentration: 1 mg/L as N | | 2 mg/L as N | | 5 mg/L as N | |
|---|---|---|---|---|---|---|---|
| | | Attained significance level | Direction of association | Attained significance level | Direction of association | Attained significance level | Direction of association |
| Land use and land cover, area in WHPA—*Continued* | | | | | | | |
| Agricultural, all categories | MW | 0.809 | ns | 0.127 | ns | 0.787 | ns |
| Pasture and hayfields | MW | .678 | ns | .451 | ns | .859 | ns |
| Cropland | MW | .764 | ns | .094 | ns | .732 | ns |
| Orchards and nurseries | MW | .311 | ns | .726 | ns | .798 | ns |
| Forest, all categories | MW | **<.001** | - | .059 | ns | **<.001** | - |
| Brushland | MW | .393 | ns | .154 | ns | .666 | ns |
| Water | MW | .354 | ns | .192 | ns | .898 | ns |
| Wetland | MW | .893 | ns | .637 | ns | .300 | ns |
| Barren | MW | .108 | ns | .101 | ns | .424 | ns |
| Sewers, presence or absence in WHPA[4] | CT | **.016** | - | .191 | ns | **.004** | - |

[1] Sample sizes for contingency-table tests of aquifer type: for threshold nitrate concentration of 1 mg/L as N, 120 affected and 131 unaffected wells; for threshold nitrate concentration of 2 mg/L as N, 69 affected and 179 unaffected wells; for threshold nitrate concentration of 5 mg/L as N, 20 affected and 228 unaffected wells.

[2] Sample sizes for Mann-Whitney *U* tests of well characteristics vary depending on the available data; see text and table 12 for discussion.

[3] Sample sizes for Mann-Whitney *U* of surficial geology in WHPAs for bedrock wells: for threshold nitrate concentration of 1 mg/L as N, 36 affected and 52 unaffected WHPAs; for threshold nitrate concentration of 2 mg/L as N, 21 affected and 67 unaffected WHPAs.

[4] Sample sizes for Mann-Whitney *U* tests of soils and land use and contingency-table tests of sewers in WHPAs: for threshold nitrate concentration of 1 mg/L as N, 67 affected and 69 unaffected WHPAs; for threshold nitrate concentration of 2 mg/L as N, 39 affected and 97 unaffected WHPAs; for threshold nitrate concentration of 5 mg/L as N, 13 affected and 123 unaffected WHPAs.

[5] Sample sizes for Mann-Whitney *U* tests of ground-water reservoirs in WHPAs for sand-and-gravel wells: for threshold nitrate concentration of 1 mg/L as N, 27 affected and 11 unaffected WHPAs; for threshold nitrate concentration of 2 mg/L as N, 15 affected and 23 unaffected WHPAs; for threshold nitrate concentration of 5 mg/L as N, 9 affected and 29 unaffected WHPAs.

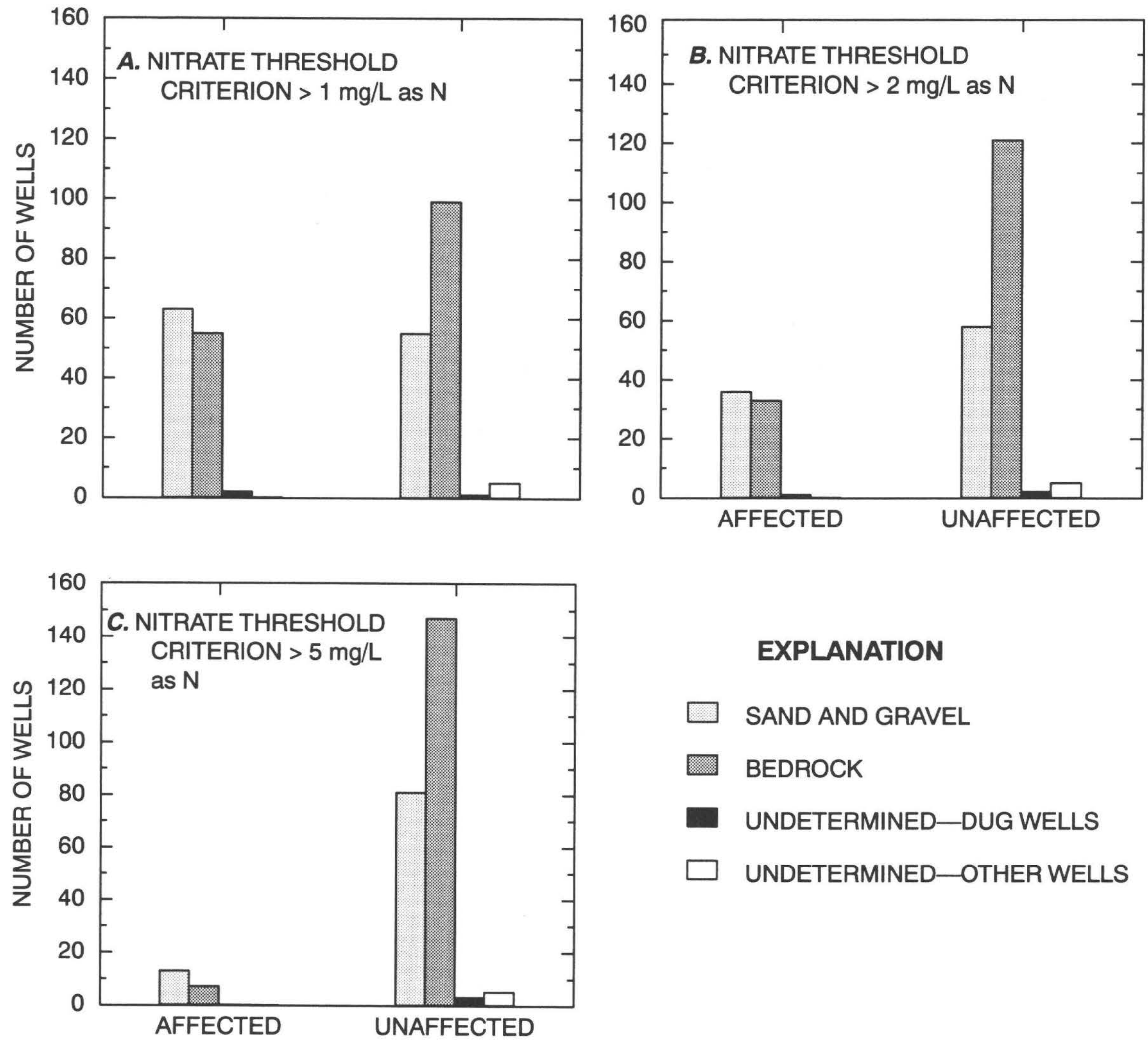



**Figure 8.** Aquifer type for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by nitrate, as defined by three threshold nitrate concentrations. *A.* Nitrate greater than (>) 1 milligram per liter as nitrogen (mg/L as N). *B.* Nitrate greater than 2 mg/L as N. *C.* Nitrate greater than 5 mg/L as N.

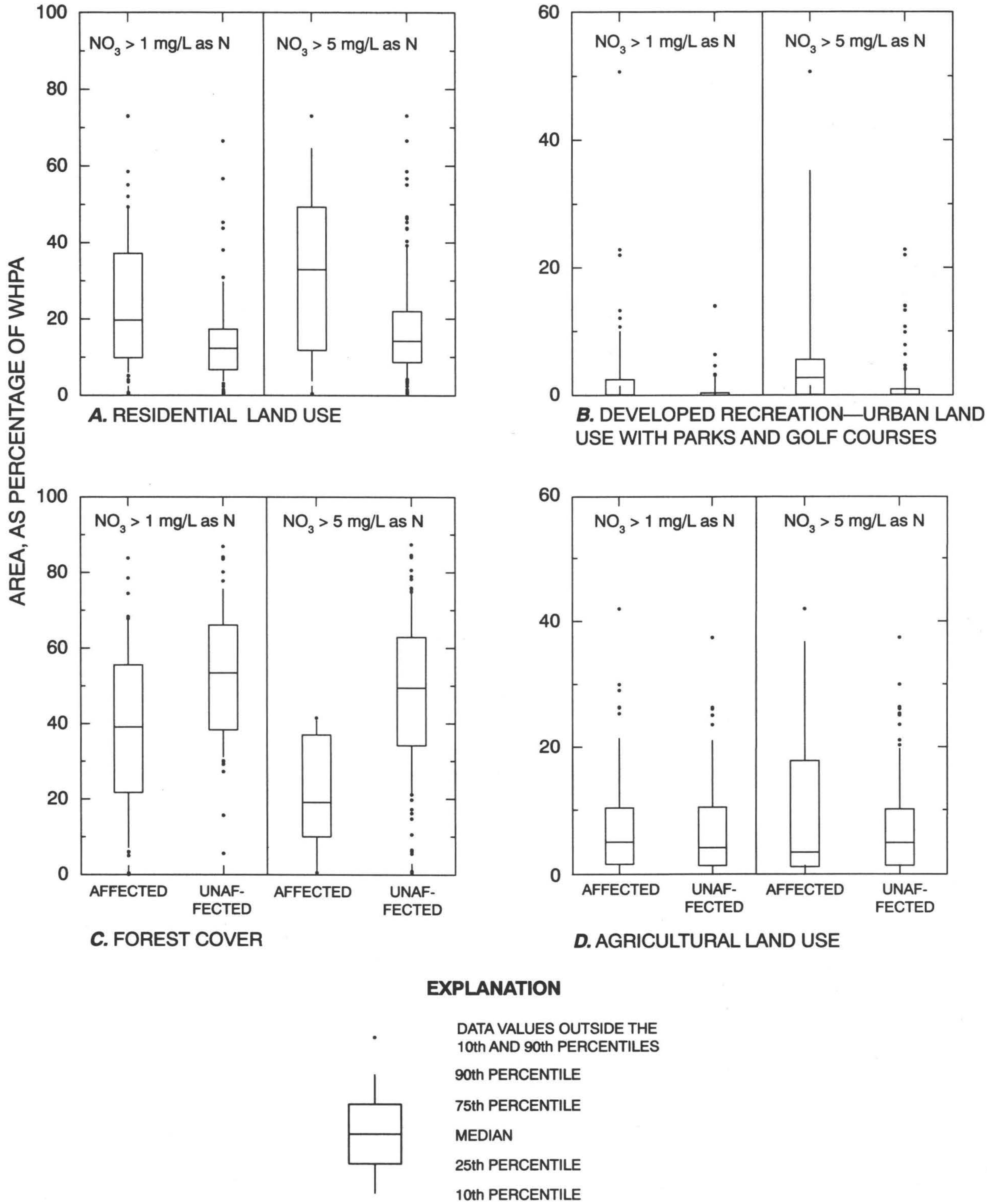



**Figure 9.** Land use and land cover in wellhead-protection areas (WHPAs) for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by nitrate, as defined by nitrate ($NO_3$) concentrations greater than (>) 1 and 5 milligrams per liter as nitrogen (mg/L as N). Numbers of observations are 67 affected and 69 unaffected WHPAs for nitrate > 1 mg/L as N and 13 and 123 WHPAs for 5 mg/L as N. *A.* Residential land use. *B.* Developed recreation—urban land use with parks and golf courses. *C.* Forest cover. *D.* Agricultural land use.

Finally, the presence or absence of sanitary sewers also was a significant vulnerability factor. Wells and WHPAs were more likely to be affected by nutrients in areas where sanitary sewers were present (table 2). This apparently counter-intuitive result is likely due to the association of sewers with urban and more densely developed residential areas and the additional sources of nitrate contamination (fertilizer application, stormwater runoff) in these areas. Leaks from sanitary sewers also could be a source of nitrate contamination.

## Pesticides

Pesticides generally include a wide range of chemicals that are used to control weeds, insects, fungi, mites, nematodes, bacteria, and other unwanted organisms (Fetter, 1998). Data were available for as many as 60 different pesticides; however, the number of analyses and number of wells for which data were available for each contaminant were variable (table 13). Data were available for 34 pesticides for about 85 percent of the wells; these contaminants are primarily pesticides for which MCLs, at concentrations of less than 0.001 mg/L to 0.1 mg/L, have been established (CFR, title 40, part 141, section 61, 1996). Ground-water contamination may result from pesticide applications to agricultural land, orchards and silvicultural land, transportation rights-of-way, golf courses, lawns, and other areas. Interactions with soils and aquifer sediments and microbial transformations may be important processes affecting pesticide mobility. Although pesticides may be classified according to these various potential sources, they were grouped into a single contaminant class in the present study because of the small sample size of pesticide-affected wells (see below). Because they do not occur naturally, any detection of a pesticide at a well was used to categorize the well as "affected." Frequency of detections or other refinements were not used in order to avoid incorporating effects of the irregular sampling frequency and schedules into the data analysis; several wells with analyses for only three of the compounds in the group were omitted from the data analysis.

Pesticides were detected at 13 of the 245 wells for which substantial data were available. Metalochlor, the most frequently detected compound, was found at four wells (three supply systems), followed by aldicarb and its degradation products, found at three wells (two systems). Metalachlor is an herbicide used in agricultural and urban areas and is one of the more frequently used pesticides in Rhode Island (Pepper, 1998). Aldicarb is an insecticide and nematicide also used in agriculture, formerly on potato fields in Rhode Island; its agricultural use in the State has been discontinued (Pepper, 1998). Other detected compounds (table 13) were found at only one well (or system) each and consist of pesticides used primarily in agriculture, lawn and turf care, and structural insect control (Ware, 1978). Wells with detections of pesticides were more likely to be sand-and-gravel than bedrock wells (fig. 10), as were wells affected by nitrate. Sample sizes were too small to compare well characteristics for bedrock wells, but well depth was associated positively with pesticide detections for sand-and-gravel wells.

Hydrogeologic characteristics in WHPAs of affected and unaffected wells for pesticides generally were similar on the basis of the available data (table 3). However, *p*-values for the comparisons of soil characteristics were relatively low—0.056 for the percent of the WHPA occupied by very well drained soils (hydrologic group A) and 0.196 for the area-weighted rank of leaching potential risk (table 3). This suggests that the permeability of surficial materials is probably an important factor for contamination by pesticides. In addition, WHPAs of sand-and-gravel wells with pesticide detections were more likely to include high-yield ground-water reservoirs.

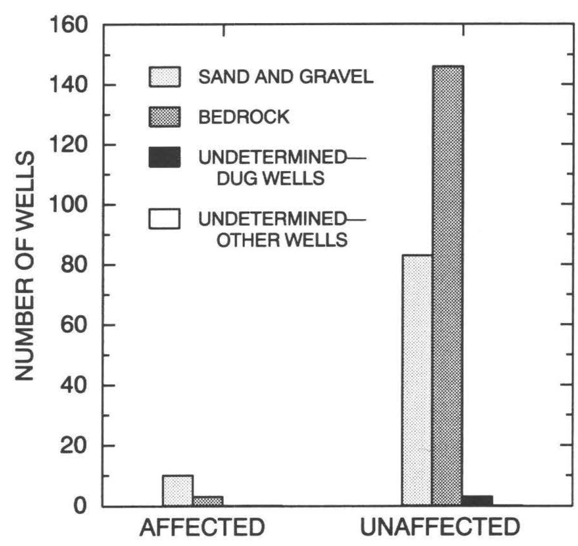



**Figure 10.** Aquifer type for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by pesticides.

**Table 3.** Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by pesticides

[*p*-value, the probability that the observed differences in the potential vulnerability factors tested between affected and unaffected groups are due to chance, are for 2-by-2 exact probability contingency-table tests (CT) and for the Mann-Whitney *U* (rank sum) test (MW); *p*-values significant at $\alpha$ = **0.05** are shown in **bold. Direction of association:** +, higher value or presence of tested factor is associated with detections of pesticides; -, lower value or absence of tested factor is associated with detections of pesticides; ns, association not statistically significant. WHPA, wellhead-protection area; >, actual value is greater than value shown; na, not applicable; --, sample size too small for analysis; mg/L as N, milligrams per liter as nitrogen]

| Potential vulnerability factor | Statistical test | Attained significance level | Direction of association |
|---|---|---|---|
| Aquifer type[1] | CT | **0.006** | na |
| Well characteristics[2] | | | |
| Well depth, sand-and-gravel wells | MW | **.011** | + |
| Well depth, bedrock wells | MW | -- | -- |
| Depth to water, all wells | MW | .742 | ns |
| Depth to bedrock, bedrock wells | MW | -- | -- |
| Surficial geology, bedrock wells | | | |
| Till, area in WHPA | MW | -- | -- |
| Outwash, area in WHPA | MW | -- | -- |
| Soils[3] | | | |
| Hydrologic group A, area in WHPA | MW | .057 | ns |
| Leaching potential risk, area-weighted rank | MW | .196 | ns |
| Ground-water reservoirs, sand-and-gravel wells, area in WHPA[4] | MW | **.022** | + |
| Land use and land cover, area in WHPA[3] | | | |
| Urban, all categories | MW | .432 | ns |
| Residential, all categories | MW | .725 | ns |
| Residential, medium density | MW | .411 | ns |
| Commercial | MW | .958 | ns |
| Industrial | MW | .314 | ns |
| Transportation | MW | .984 | ns |
| Other urban, all categories | MW | **.028** | + |
| Land use and land cover, area in WHPA—*Continued* | | | |
| Developed recreation (parks, zoos, and golf courses | MW | **0.007** | + |
| Urban open space and cemeteries | MW | .494 | ns |
| Institutional | MW | **.012** | + |
| Agricultural, all categories | MW | .291 | ns |
| Pasture and hayfields | MW | .229 | ns |
| Cropland | MW | .261 | ns |
| Orchards and nurseries | MW | .812 | ns |
| Forest, all categories | MW | .084 | ns |
| Brushland | MW | .970 | ns |
| Water | MW | .257 | ns |
| Wetland | MW | .100 | ns |
| Barren | MW | .223 | ns |
| Nitrate concentration[5] | | | |
| Median concentration at well | MW | **.020** | + |
| Nitrate concentration threshold criterion | | | |
| Any concentration > 1 mg/L as N | CT | **.044** | + |
| Any concentration > 2 mg/L as N | CT | .051 | + |
| Any concentration > 5 mg/L as N | CT | -- | -- |

[1] Sample sizes for contingency-table test of aquifer type: 13 affected and 229 unaffected wells.
[2] Sample sizes for Mann-Whitney *U* tests of well characteristics vary depending on the available data; see text and table 12 for discussion.
[3] Sample sizes for Mann-Whitney *U* tests of ground-water reservoirs in WHPAs for sand-and-gravel wells: 7 affected and 37 unaffected WHPAs.
[4] Sample sizes for Mann-Whitney *U* and contingency-table tests of soils and land use in WHPAs: 9 affected and 120 unaffected WHPAs.
[5] Sample sizes for Mann-Whitney *U* and contingency-table tests of nitrate concentrations: 13 affected and 232 or 233 unaffected wells.

Comparisons of land use in WHPAs of affected and unaffected wells for pesticides indicated that areas of the urban land use with parks and golf courses and institutional land use (educational, health, correctional, and religious facilities) were significantly higher in WHPAs of affected wells (table 3 and fig. 11); the urban land use with parks and golf courses was previously found associated with elevated nitrate concentrations also. Areas of these two land uses, which may involve lawn or turf care, occupy about 1 to 5 percent of affected WHPAs, but generally do not occur in or occupy less than 1 percent of unaffected WHPAs (fig. 11). Unfortunately, the sample sizes were too small to test whether these land uses were significant for sand-and-gravel and bedrock wells separately. Other land uses that were expected to be associated with detections of pesticides, medium-density residential land use and agricultural land uses, tended to be higher in WHPAs of affected wells than in WHPAs of unaffected wells, but the difference was not statistically significant (table 3). Forest cover was lower in affected WHPAs, but not significantly so (table 3 and fig. 11).

Finally, detections of pesticides were related to the occurrence of elevated nitrate concentrations, based on two methods of comparison. Median nitrate concentrations were higher in wells that were affected by pesticides than in unaffected wells (fig. 12), and pesticide-affected wells were more likely also to be affected by nitrate (1 and 2 mg/L as N threshold criteria; table 3). An assoication of elevated nitrate concentrations and pesticide detections also was found in public-water supplies in New Jersey (Vowinkel, 1994; Vowinkel and others, 1994, 1996).

The significant land uses and other results obtained for pesticides in the present study are consistent with results of many other studies. High nitrate concentrations or the proximity of a golf course were found to be indicators of ground-water vulnerability to pesticide contamination in several studies; pesticides were more frequently detected in ground water in agricultural and urban areas than in undeveloped areas in the northeast (Koplin and others, 1994; Eckhardt and Stackelberg, 1995; Ryker and Williamson, 1996a, 1996b; Vowinkel and others, 1996; Grady and Mullaney, 1998). The lack of significant association between agricultural and residential land uses and pesticide detections in the present study is likely due at least partly to the small sample size of affected wells and WHPAs, and to the different sources for different pesticides that are not accounted for by the data-analysis approach. The relatively limited extent of agricultural land-use areas in Rhode Island compared to areas of other activities in which pesticides are used also may contribute to the lack of statistically significant association of pesticide detections with agricultural land use, as suggested for nitrate. These results illustrate a limitation of using historical water-quality data for determining the vulnerability to contamination by infrequently detected contaminants; they also illustrate the need to consider all available knowledge about the sources, occurrence, and transport of contaminants when assessing the vulnerability of specific supply wells.

## Solvents and Other Industrial Organic Chemicals

Synthetic organic chemicals used as solvents and for other purposes in industry and manufacturing include 38 volatile and semi-volatile compounds; many of these are chlorinated hydrocarbons (table 13). The many potential sources of these chemicals include waste dumps and landfills, discharges from metal degreasing, dry cleaning, and chemical manufacturing activities, and septic tanks (Zoeteman, 1985).

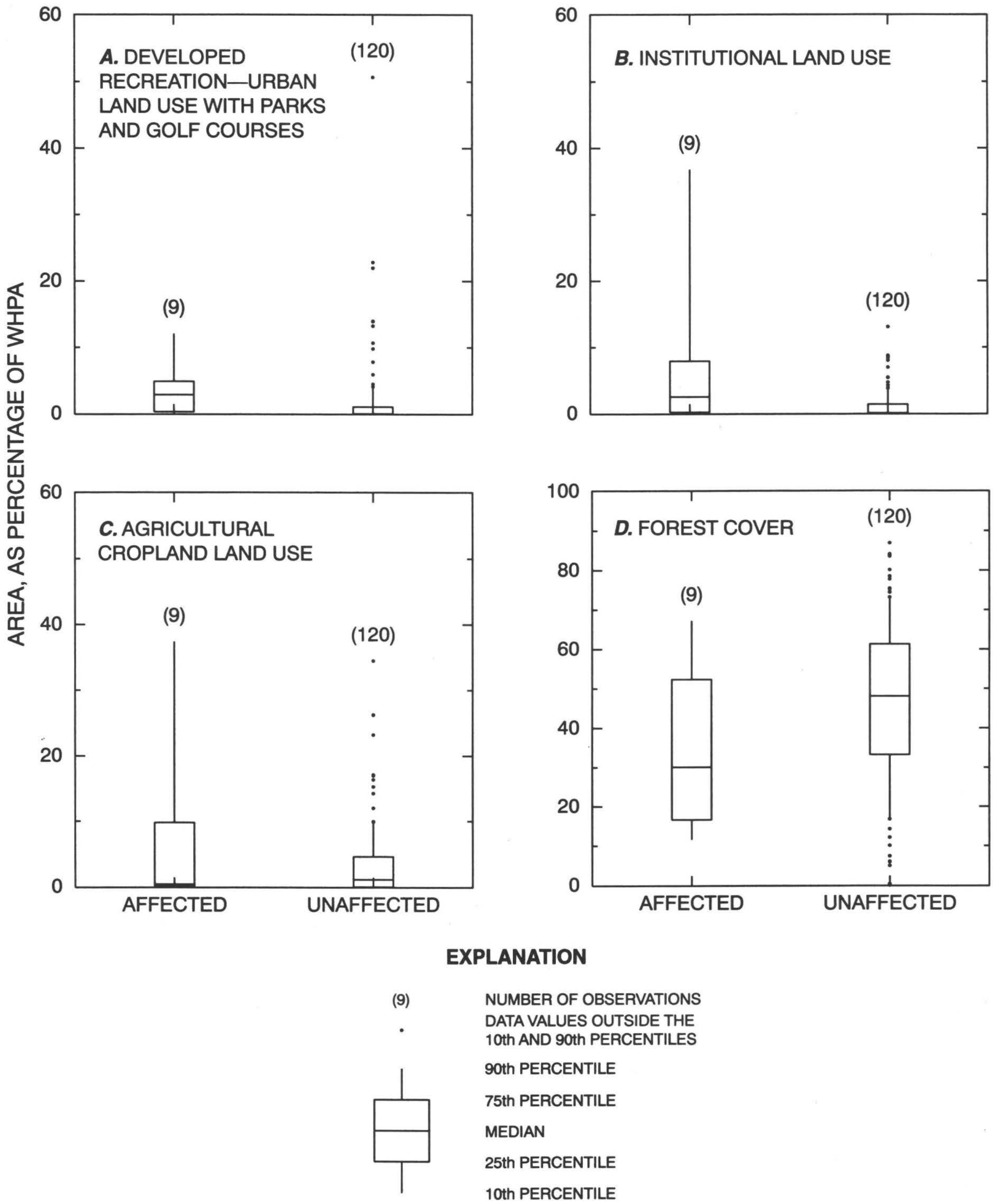



**Figure 11.** Land use and land cover in wellhead-protection areas (WHPAs) for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by pesticides. *A.* Developed recreation—urban land use with parks and golf courses. *B.* Institutional land use. *C.* Agricultural cropland land use. *D.* Forest cover.

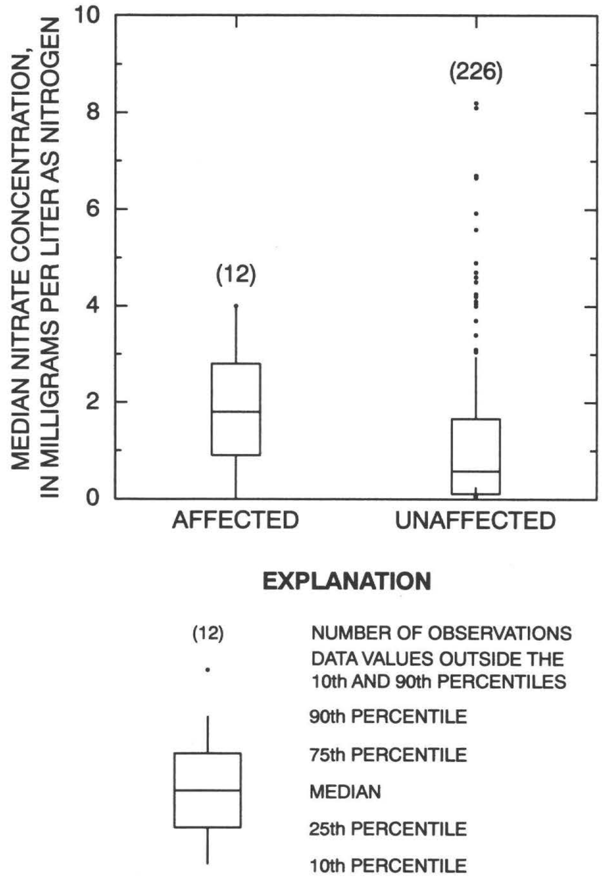



**Figure 12.** Median concentrations of nitrate in community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by pesticides.

The mobility of these chemicals in soils and ground water varies, and may be affected by multiphase flow, interaction with sediments, and microbial transformations. MCLs, generally considerably below 1 mg/L, have been established for about half of the chemicals in this group, and most are listed by USEPA as priority pollutant organic compounds (CFR, title 40, section 141, part 61, 1996). Data were available for about 95 percent of the wells for most chemicals, in sets of 1 to 3 samples (generally including 30 to 37 compounds) collected at 1- to 5-year intervals; samples were taken more frequently for some large community systems and for wells where these chemicals have been detected in the past. Any detection of a solvent or other industrial organic chemical (hereafter referred to as "solvents") at a well was used to categorize the well as "affected," and, as with the pesticides, several wells with data for only three of the compounds in the group were omitted from the data analysis.

Solvents were detected at 46 wells, or about one-fifth of the wells for which data were available. Detected compounds were primarily 1,1,1-trichloroethane, tetrachloroethene, 1,1-dichloroethane, and 1,1-dichloroethene, at concentrations ranging from less than 0.0001 to 0.032 mg/L; these compounds are commonly used solvents and their degradation products. The affected wells were more likely to be sand-and-gravel wells than bedrock wells (fig. 13), as were wells affected by nitrate and pesticides. Well characteristics generally were similar between affected and affected groups, except for well depth for sand-and-gravel wells (deeper wells were more likely to be affected; table 4). Potential vulnerability factors associated with soil type and surficial geology were not significantly associated with detections of solvents, although the area of ground-water reservoirs was significantly higher in WHPAs of affected sand-and-gravel wells than in WHPAs of unaffected wells (table 4).

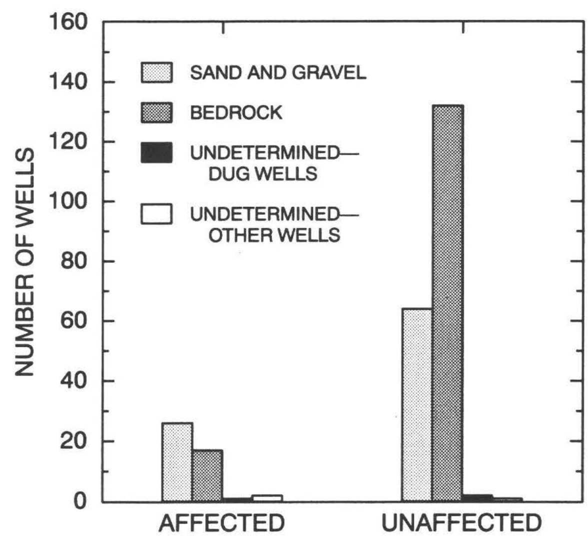



**Figure 13.** Aquifer type for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by solvents and other industrial organic chemicals.

**Table 4.** Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by solvents and other industrial organic chemicals

[*p*-value, the probability that the observed differences in the potential vulnerability factors tested between affected and unaffected groups are due to chance, are for 2-by-2 exact probability contingency-table tests (CT) and for the Mann-Whitney *U* (rank sum) test (MW); *p*-values significant at α = **0.05** are shown in **bold. Direction of association:** +, higher value or presence of tested factor is associated with detections of solvents; -, lower value or absence of tested factor is associated with detections of solvents; ns, association not statistically significant. WHPA, wellhead-protection area; na, not applicable; --, sample size too small for analysis]

| Potential vulnerability factor | Statistical test | Attained significance level | Direction of association |
|---|---|---|---|
| Aquifer type[1] | CT | **<0.001** | na |
| Well characteristics[2] | | | |
| Well depth, sand-and-gravel wells | MW | **.001** | + |
| Well depth, bedrock wells | MW | .679 | ns |
| Depth to water, all wells | MW | .346 | ns |
| Depth to bedrock, bedrock wells | MW | .533 | ns |
| Surficial geology, bedrock wells[3] | | | |
| Till, area in WHPA | MW | .943 | ns |
| Outwash, area in WHPA | MW | .828 | ns |
| Soils[4] | | | |
| Hydrologic group A, area in WHPA | MW | .200 | ns |
| Leaching potential risk, area-weighted rank | MW | .374 | ns |
| Ground-water reservoirs, sand-and-gravel wells, area in WHPA[5] | MW | **.018** | + |
| Land use and land cover, area in WHPA[4] | | | |
| Urban, all categories | MW | .119 | ns |
| Residential, all categories | MW | .120 | ns |
| Residential, medium density | MW | .063 | ns |
| Commercial | MW | .346 | ns |
| Industrial | MW | **.013** | + |
| Land use and land cover, area in WHPA—*Continued* | | | |
| Transportation | MW | 0.197 | ns |
| Other urban, all categories | MW | .719 | ns |
| Developed recreation (parks, zoos, and golf courses | MW | .850 | ns |
| Urban open space and cemeteries | MW | .707 | ns |
| Institutional | MW | .195 | ns |
| Agricultural, all categories | MW | .935 | ns |
| Pasture and hayfields | MW | .648 | ns |
| Cropland | MW | .434 | ns |
| Orchards and nurseries | MW | **.041** | - |
| Forest, all categories | MW | .054 | - |
| Brushland | MW | .018 | + |
| Water | MW | .646 | ns |
| Wetland | MW | .667 | ns |
| Barren | MW | .207 | ns |
| Hazardous-waste sites | | | |
| Site in the WHPA[6] | CT | .240 | ns |
| Distance to closest site[7] | MW | .963 | ns |

[1] Sample sizes for contingency-table test of aquifer type: 17 affected and 132 unaffected wells.
[2] Sample sizes for Mann-Whitney *U* tests of well characteristics vary depending on the available data; see text and table 12 for discussion.
[3] Sample sizes for Mann-Whitney *U* of surficial geology in WHPAs for bedrock wells: 14 affected and 70 unaffected WHPAs.
[4] Sample sizes for Mann-Whitney *U* tests of soils and land use in WHPAs: 32 affected and 97 unaffected WHPAs.
[5] Sample sizes for Mann-Whitney *U* tests of ground-water reservoirs in WHPAs for sand-and-gravel wells: 15 affected and 21 unaffected WHPAs.
[6] Sample sizes for contingency-table tests of hazardous-waste sites in WHPAs: 32 affected and 96 unaffected WHPAs.
[7] Sample sizes for Mann-Whitney *U* tests of distance to hazardous-waste sites: 46 affected and 198 unaffected wells.

Detections of solvents were associated with industrial land use. WHPAs of affected wells had higher areas of industrial land use than unaffected WHPAs (fig. 14), and the presence or absence of industrial land use in the WHPA also was significant (*p*-value equal to 0.010, contingency-table test). As with pesticides, sample sizes were too small to test whether industrial land use was significant for sand-and-gravel and bedrock wells separately. Areas of several urban land-use categories were somewhat higher in affected WHPAs than in unaffected WHPAs, but the differences were not statistically significant (table 4). Forest cover also was somewhat lower in affected WHPAs (fig. 14). Another land use type, brushland (shrub and brush areas being reforested), was significantly higher in affected WHPAs; this association was unexpected, and suggests that some of these disturbed but undeveloped areas may have been formerly used for waste disposal. Finally, the presence of a known hazardous-waste site in the WHPA, or the distance to the closest hazardous-waste site, were not significantly associated with detections of solvents, based on the available statewide data for these sites.

## Fuel Hydrocarbons

Synthetic organic chemicals that were identified primarily as components of gasoline, diesel, and other fuels are included in this contaminant class. The fuel hydrocarbons class consists of 24 mostly volatile organic compounds (table 13); MCLs have been established for four (CFR, title 40, section 141, part 61, 1996). Potential sources of fuel hydrocarbons in ground water include spills and leaking storage tanks at gas stations and other transportation and storage facilities (Fetter, 1998). Multiphase flow, interaction with sediments, and microbial transformations may affect their mobility. The available data for these contaminants were similar to the available data for solvents, in terms of number of samples, number of wells with data, and sample frequency. As for pesticides and solvents, any detection of a fuel hydrocarbon at a well was used to categorize the well as "affected."

Fuel hydrocarbons were detected at 42 wells. Toluene (34 wells, 30 systems) and methyl *tert*-butyl ether (MTBE, 31 wells, 23 systems) were the most frequently detected compounds, followed by xylene (9 wells, 8 systems), benzene (6 wells, 6 systems), and ethylbenzene (5 wells, 4 systems). MTBE, a gasoline additive, is very soluble and relatively non-biodegradable as compared with other fuel hydrocarbons; it recently has been found to be widespread in ground water in urban areas (Squillace and others, 1995). Benzene, toluene, ethylbenzene, and xylene (BTEX compounds) also are relatively soluble components of gasoline commonly found in ground water (Chapelle, 1993). About one-third of the wells with detections of fuel hydrocarbons also had detections of solvents, and this association was significant (*p*-value equal to 0.001, contingency-table test).

Detections of fuel hydrocarbons were significantly associated with few of the potential vulnerability factors tested (table 5). Affected wells were as likely to be sand-and-gravel as bedrock wells (fig. 15), and well characteristics were similar between affected and unaffected groups, except for well depth for bedrock wells (deeper wells were more likely to be affected). Surficial geology for bedrock wells or soil characteristics were similar between affected and unaffected WHPAs; affected sand-and-gravel wells, however, were more likely to include ground-water reservoirs in their WHPAs. No statistically significant differences in areas of various land-use types were found between affected and unaffected WHPAs, although areas of residential and non-residential urban land uses tended to be higher (*p*-values equal to 0.334 and 0.205, respectively), and areas of forest cover tended to be lower (*p*-value equal to 0.156) in affected WHPAs (table 5 and fig. 16).

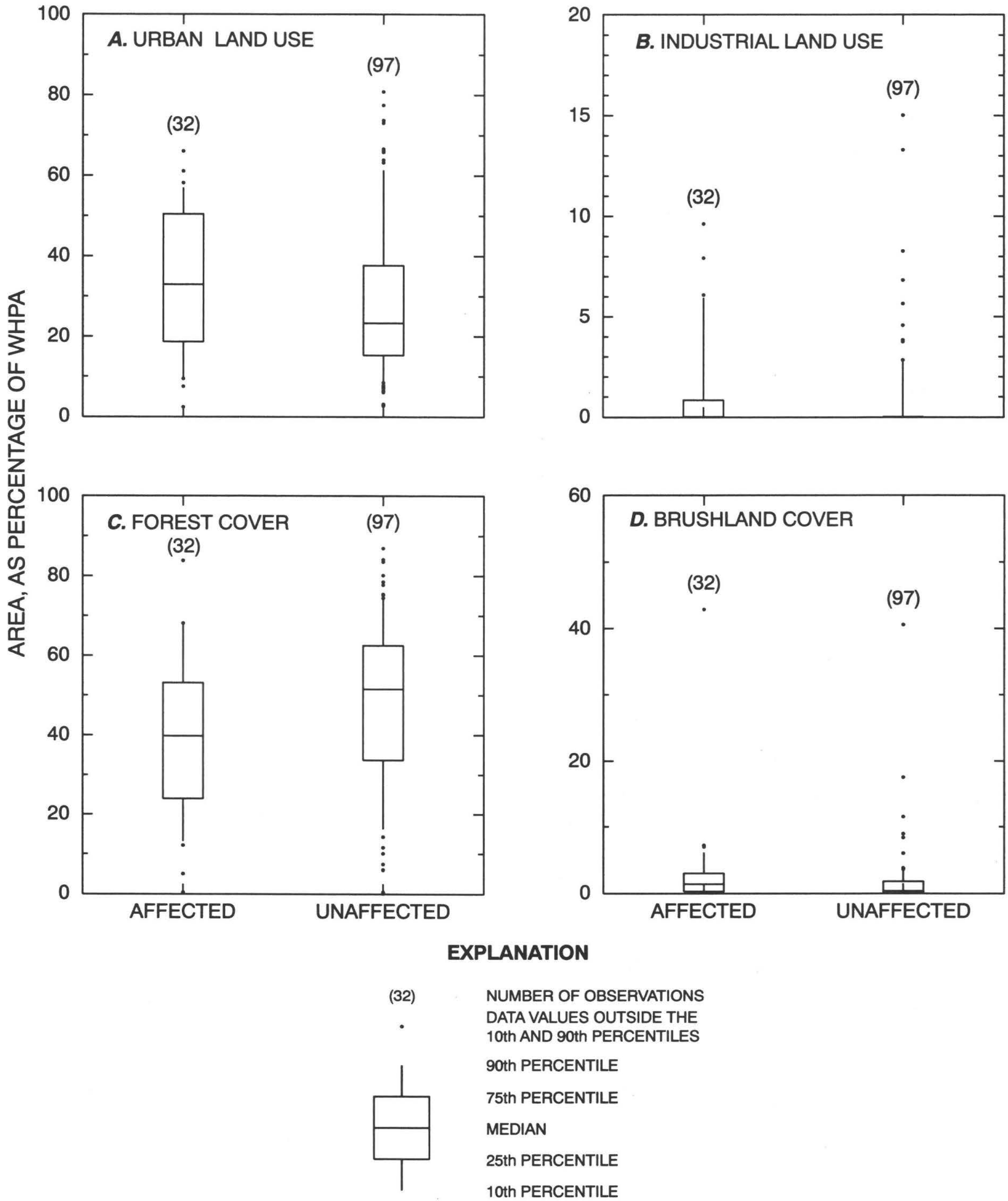



**Figure 14.** Land use and land cover in wellhead-protection areas (WHPAs) for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by solvents and other industrial organic chemicals. *A*. Urban land use. *B*. Industrial land use. *C*. Forest cover. *D*. Brushland cover.

**Table 5.** Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by fuel hydrocarbons

[*p*-value, the probability that the observed differences in the potential vulnerability factors tested between affected and unaffected groups are due to chance, are for 2-by-2 exact probability contingency-table tests (CT) and for the Mann-Whitney *U* (rank sum) test (MW); *p*-values significant at $\alpha = 0.05$ are shown in **bold**. **Direction of association:** +, higher value or presence of tested factor is associated with detections of fuel hydrocarbons; -, lower value or absence of tested factor is associated with detections of fuel hydrocarbons; ns, association not statistically significant. WHPA, wellhead-protection area; >, actual value is greater than value shown; na, not applicable; --, sample size too small for analysis]

| Potential vulnerability factor | Statistical test | Attained significance level | Direction of association |
|---|---|---|---|
| Aquifer type[1] | CT | 0.218 | na |
| Well characteristics[2] | | | |
| Well depth, sand-and-gravel wells | MW | .840 | ns |
| Well depth, bedrock wells | MW | **.017** | + |
| Depth to water, all wells | MW | .170 | ns |
| Depth to bedrock, bedrock wells | MW | .379 | ns |
| Surficial geology, bedrock wells[3] | | | |
| Till, area in WHPA | MW | .371 | ns |
| Outwash, area in WHPA | MW | .463 | ns |
| Soils[4] | | | |
| Hydrologic group A, area in WHPA | MW | .791 | ns |
| Leaching potential risk, area-weighted rank | MW | .601 | ns |
| Ground-water reservoirs, sand-and-gravel wells, area in WHPA[5] | MW | **.027** | + |
| Land use and land cover, area in WHPA[4] | | | |
| Urban, all categories | MW | .979 | ns |
| All urban categories except residential | MW | .205 | ns |
| Residential, all categories | MW | .334 | ns |
| Residential, medium density | MW | .846 | ns |
| Residential, high density | MW | .458 | ns |
| Commercial | MW | .657 | ns |
| Land use and land cover, area in WHPA—*Continued* | | | |
| Industrial | MW | 0.229 | ns |
| Transportation | MW | .871 | ns |
| Other urban, all categories | MW | .246 | ns |
| Developed recreation (parks, zoos, and golf courses) | MW | .610 | ns |
| Urban open space and cemeteries | MW | .553 | ns |
| Institutional | MW | .386 | ns |
| Agricultural, all categories | MW | .717 | ns |
| Pasture and hayfields | MW | .380 | ns |
| Cropland | MW | .933 | ns |
| Orchards and nurseries | MW | .244 | ns |
| Forest, all categories | MW | .156 | ns |
| Brushland | MW | .349 | ns |
| Water | MW | .338 | ns |
| Wetland | MW | .874 | ns |
| Barren | MW | .565 | ns |
| Leaking underground storage tanks (LUST) | | | |
| LUST in the WHPA[4] | CT | -- | -- |
| Distance to closest LUST[6] | MW | .195 | ns |
| Hazardous-waste site | | | |
| Site in the WHPA[4] | CT | .778 | ns |
| Distance to closest site[6] | MW | .963 | ns |
| Service station in WHPA[7] | CT | >.999 | ns |

[1] Sample sizes for contingency-table test of aquifer type: 41 affected and 196 unaffected wells.

[2] Sample sizes for Mann-Whitney *U* tests of well characteristics vary depending on the available data; see text and table 12 for discussion.

[3] Sample sizes for Mann-Whitney *U* of surficial geology in WHPAs for bedrock wells: 16 affected and 88 unaffected WHPAs.

[4] Sample sizes for Mann-Whitney *U* and contingency-table tests of soils, land use, leaking underground storage tanks, and hazardous-waste sites in WHPAs: 33 affected and 96 unaffected WHPAs.

[5] Sample sizes for Mann-Whitney *U* tests of ground-water reservoirs in WHPAs for sand-and-gravel wells: 14 affected and 22 unaffected WHPAs.

[6] Sample sizes for Mann-Whitney *U* tests of distance to the closest leaking underground storage tanks or hazardous-waste sites: 41 affected and 201 unaffected wells.

[7] Sample sizes for contingency-table test of service stations in WHPAs: 17 affected and 85 unaffected WHPAs.

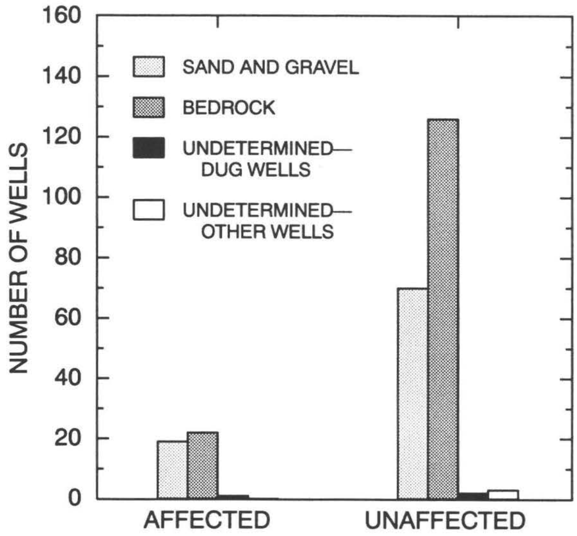



**Figure 15.** Aquifer type for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by fuel hydrocarbons.

The presence of a known leaking underground storage tank or a hazardous-waste site in the WHPA, or the distance from the well to the closest tank or site (where locations of these sites are defined by the available statewide data, table 1), were similar for affected and unaffected WHPAs and wells. Finally, the presence of a service station in the WHPA, as determined from narrative descriptions in monitoring-waiver files obtained from the RIDOH for 102 of the wells, was not associated significantly with detections of fuel hydrocarbons.

In contrast to results for the entire class of fuel hydrocarbons, detections of MTBE only were significantly associated with several land uses. Areas of commercial (*p*-value equal to 0.049), industrial (*p*-value equal to 0.009), transportation (*p*-value equal to 0.041) and brushland (*p*-value equal to 0.041) land uses all were higher in WHPAs of wells with MTBE detections than in WHPAs of wells where MTBE had not been detected. In addition, the area-weighted soil-leaching potential rank was higher in affected WHPAs than in unaffected WHPAs, although the difference was not statistically significant (*p*-value equal to 0.066). Other factors, aquifer type, well characteristics, and distances to the closest leaking underground storage tank or hazardous-waste site, were not significant or were not tested because sample sizes were too small. The association of MTBE detections with the land uses listed above, which is similar to results found for the solvents contaminant class, is consistent with recent studies suggesting that the occurrence of and vulnerability of ground-water supplies to MTBE differs from that of the other fuel hydrocarbons. Because of its solubility and resistance to degradation, MTBE is likely to be more readily transported from distant point sources and through urban air than other fuel hydrocarbons, such as benzene or toluene (Pankow and others, 1997; Zogorski and others, 1997; Landmeyer and others, 1998); MTBE also may originate from spills of heating oil in addition to gasoline spills (Robbins and others, 1999).

The general lack of association between detections of the larger group of fuel hydrocarbons and potential vulnerability factors may result partly from the varying transport characteristics and sources for the different chemicals, as indicated by results of the separate tests of MTBE detections. In addition, there are many potential sources for fuel hydrocarbons, which include service stations and storage tanks. These sources represent small point sources within larger land-use areas of various types. Thus, the areas of these land-use types, as defined by the statewide land-use data layer, may not be statistically significant indicators of the occurrence of fuel hydrocarbons in supply-well water. Alternatively, the proximity of specific land uses in the WHPA to the wells, which was not considered in the present study, may have been more important for fuel hydrocarbons than land-use characteristics of the entire WHPA, because of the tendency for many fuel hydrocarbons to be biodegraded and otherwise attenuated during transport. The inability of existing data to locate small accidental fuel releases and as yet unknown waste-disposal sites, which may occur in many land uses, also may have contributed to the lack of association of fuel hydrocarbons with land-use characteristics.

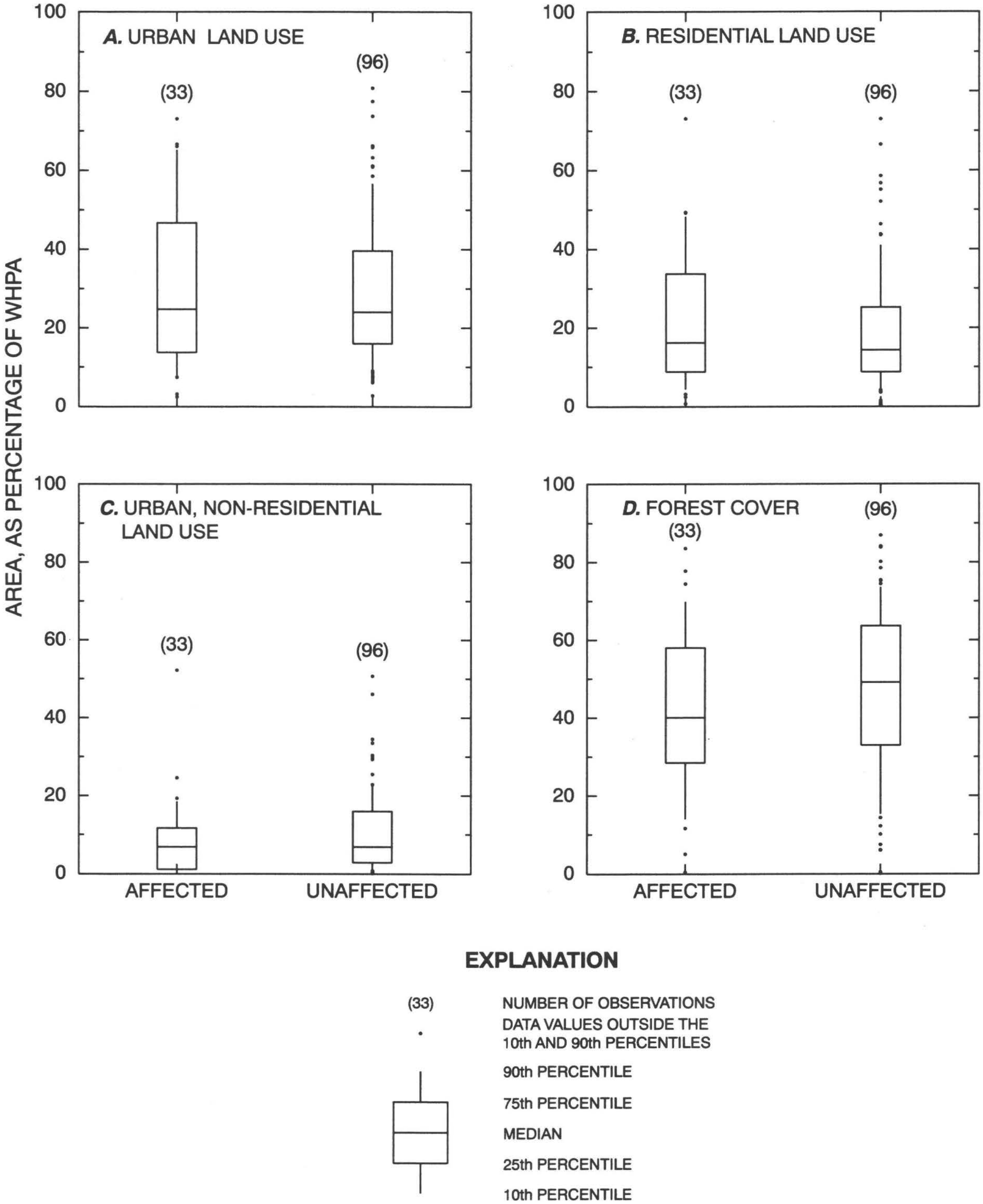



**Figure 16.** Land use and land cover in wellhead-protection areas (WHPAs) for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by fuel hydrocarbons. *A.* Urban land use. *B.* Residential land use. *C.* Urban, non-residential land use. *D.* Forest cover.

## Road-Deicing Chemicals

Sodium chloride (rock salt) and, to a lesser extent, calcium chloride, commonly are used to melt snow and ice on roadways. Infiltration of highway and street runoff and leaching from salt-storage sites can deliver these chemicals to ground water (Mattson and Godfrey, 1994). Other, trace constituents of road-deicing chemicals, such as sulfate, potassium, and bromide, or additives such as ferric ferrocyanide and sodium ferrocyanide, may potentially reach ground water in very small quantities (Granato, 1996; Fetter, 1998). Sodium, potassium, chloride, and specific conductance, which is directly related to dissolved ionic concentrations, are grouped in the contaminant class for road-deicing chemicals (calcium is grouped separately with constituents related to hardness). Sodium is the constituent of primary concern for contamination of drinking water, although the concentration levels that result in adverse health effects are not well defined. Currently, guidance levels of 20 mg/L are established by USEPA and the RIDOH (U.S. Environmental Protection Agency, 1998); the RIDOH requires that the public be notified when sodium concentrations greater than or equal to 100 mg/L are measured in a water from a public-supply source. Sodium also is a constituent of septic-tank effluent and, along with chloride, calcium, and other ions, may enter ground water from this source, from sea-spray precipitation or salt-water intrusion, from fertilizer use, and from mineral dissolution.

Data on sodium, chloride, and potassium were available for 75 to 80 percent of the wells, generally as yearly samples (table 13). Because sodium is the contaminant that poses health concerns, the threshold criterion to identify wells affected by road-deicing chemicals was set in terms of sodium concentrations. An average sodium concentration at the well greater than the guidance level of 20 mg/L was used to identify a well as "affected." A higher threshold concentration, 50 mg/L (one-half the RIDOH notification level) also was considered, but resulted in too few affected wells (four) and WHPAs (three) for testing. Average sodium concentrations could be used, because the sampling frequency of the available data was regular and nearly all results were above the reporting limit of 2 mg/L. These characteristics also allowed direct comparison of sodium and chloride concentrations with potential vulnerability factors. Because sodium can be attenuated by sorption or cation exchange with soil and aquifer materials, concentrations of chloride, which generally is not attenuated during transport, also were investigated.

Average sodium concentrations exceeded 20 mg/L at 31 wells, or about 15 percent of the wells for which data were available (fig. 17). Most of these wells were located in inland areas and contained sodium concentrations that, while elevated above ambient concentrations, generally were less than 100 mg/L. Thus, salt-water intrusion, which generally results in higher sodium concentrations (Frimpter and Gay, 1979) or sea spray were not likely to be major contributing factors for the occurrence of sodium in the affected wells. Two wells in the affected group, which were located within 500 ft of the coast and contained sodium concentrations of 100 to 200 mg/L, may have been affected by salt-water intrusion, but this possibility was not separately investigated.

Wells with elevated sodium concentrations were more likely to be sand-and-gravel than bedrock wells (fig. 17); other well characteristics were similar between affected and unaffected groups (table 6). The percentage of very well-drained soils (hydrologic group A) and the area-weighted rank of soil-leaching potential risk in the WHPA were significantly higher in affected WHPAs than in unaffected WHPAs (figs. 18*A* and 18*B*). This result may reflect the greater ease of infiltration of street and highway runoff through the more permeable soils and possibly the lower capacity of these soils to attenuate sodium through sorption and cation exchange. Land-use types significantly higher in WHPAs of affected wells than in unaffected wells were urban (all categories) and residential land use; forest

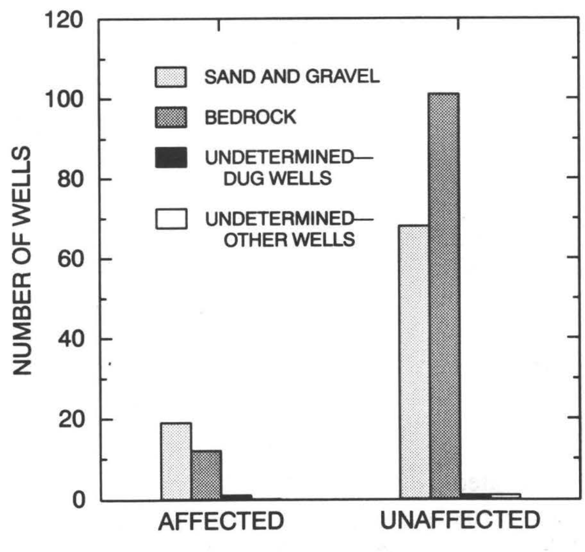



**Figure 17.** Aquifer type for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by sodium.

**Table 6.** Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by sodium

[*p*-value, the probability that the observed differences in the potential vulnerability factors tested between affected and unaffected groups are due to chance, are for 2-by-2 exact probability contingency-table tests (CT) and for the Mann-Whitney *U* (rank sum) test (MW); *p*-values significant at $\alpha = 0.05$ are shown in **bold**. **Direction of association:** +, higher value or presence of tested factor is associated with elevated sodium concentrations; -, lower value or absence of tested factor is associated with elevated sodium concentrations; ns, association not statistically significant. WHPA, wellhead-protection area. <, actual value is less than value shown; na, not applicable; --, sample size too small for analysis]

| Potential vulnerability factor | Statistical test | Attained significance level | Direction of association |
|---|---|---|---|
| Aquifer type[1] | CT | **0.047** | na |
| Well characteristics[2] | | | |
| Well depth, sand-and-gravel wells | MW | .287 | ns |
| Well depth, bedrock wells | MW | .127 | ns |
| Depth to water, all wells | MW | .730 | ns |
| Depth to bedrock, bedrock wells | MW | .474 | ns |
| Surficial geology, bedrock wells[3] | | | |
| Till, area in WHPA | MW | .393 | ns |
| Outwash, area in WHPA | MW | .505 | ns |
| Soils[4] | | | |
| Hydrologic group A, area in WHPA | MW | **.021** | + |
| Leaching potential risk, area-weighted rank | MW | **.006** | + |
| Ground-water reservoirs, sand-and-gravel wells, area in WHPA[5] | MW | .168 | ns |
| Land use and land cover, area in WHPA[4] | | | |
| Urban, all categories | MW | **.009** | + |
| Land use and land cover, area in WHPA—*Continued* | | | |
| All urban categories except residential | MW | 0.063 | ns |
| Residential, all cateogories | MW | **.014** | + |
| Commercial | MW | .168 | ns |
| Industrial | MW | .468 | ns |
| Transportation | MW | .178 | ns |
| Other urban, all categories | MW | .358 | ns |
| Institutional | MW | .069 | nd |
| Agricultural, all categories | MW | .577 | ns |
| Forest, all categories | MW | **<.001** | - |
| Brushland | MW | .354 | ns |
| Water | MW | .176 | ns |
| Wetland | MW | .691 | ns |
| Barren | MW | .098 | ns |
| Road density in WHPA[4] | | | |
| All paved roads | MW | **<.001** | + |
| State roads and interstate highways | MW | **.009** | + |

[1] Sample sizes for contingency-table test of aquifer type: 31 affected and 169 unaffected wells.
[2] Sample sizes for Mann-Whitney *U* tests of well characteristics vary depending on the available data; see text and table 12 for discussion.
[3] Sample sizes for Mann-Whitney *U* of surficial geology in WHPAs for bedrock wells: 6 affected and 48 unaffected WHPAs.
[4] Sample sizes for Mann-Whitney *U* tests of soils, land use, and road density in WHPAs: 16 affected and 79 unaffected WHPAs.
[5] Sample sizes for Mann-Whitney *U* tests of ground-water reservoirs in WHPAs for sand-and-gravel wells: 8 affected and 26 unaffected WHPAs.

cover was significantly lower in affected WHPAs than unaffected WHPAs (fig. 19). Transportation land use was not significant. Areas of urban land use, residential land use, forest cover, and hydrologic group A soils in the WHPA also were directly correlated with average sodium and chloride concentrations for WHPAs, with *p*-values nearly all less than 0.005 (Kendall's Tau correlation).

Elevated sodium concentrations also were associated with road density. Road density (road miles per square mile of WHPA), either of all paved roads or of State roads and interstate highways, was significantly higher in affected than in unaffected WHPAs (figs. 18*C* and 18*D*); average sodium and chloride concentrations also were correlated with the density of paved roads (*p*-values less than 0.001). This result is expected, because both measures of road density are correlated with urban land use (*p*-values less than 0.001, Kendall's Tau correlation); and paved-road density is linearly related to urban land use in the WHPA ($R^2$ equal to 0.51). This correlation and additional sources of sodium associated with urban land use (for example, septic tanks, sewage effluent, or fertilizer) may partly explain why high concentrations of sodium are associated more closely with the density of all paved roads rather than with the density of State roads and interstate highways (table 6), to which more road salt generally is applied (Mattson and Godfrey, 1994).

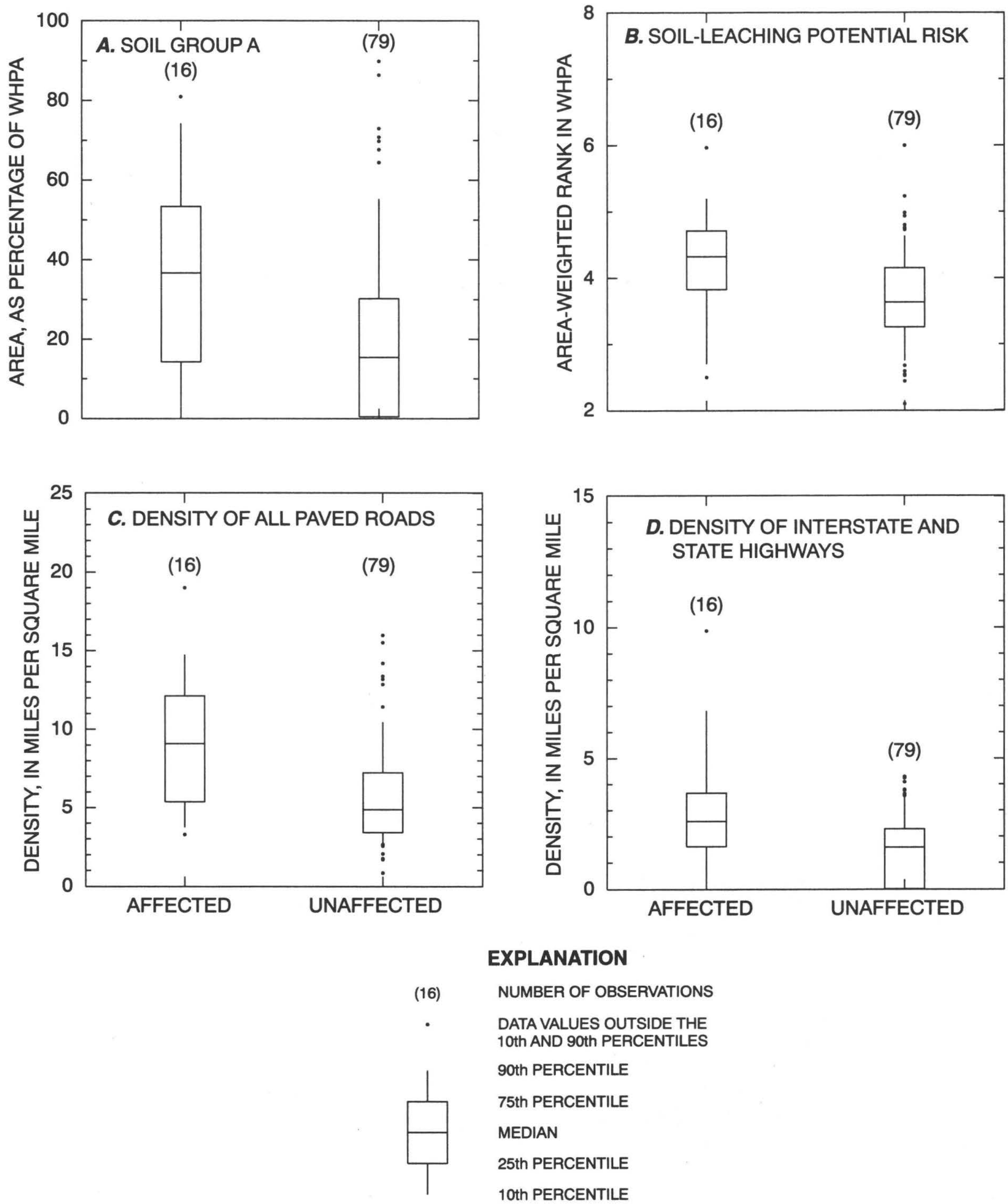



**Figure 18.** Soil characteristics and density of roads in wellhead-protection areas (WHPAs) for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by sodium. *A.* Soil hydrologic group A. *B.* Soil-leaching potential risk. *C.* Density of all paved roads. *D.* Density of interstate and state highways.

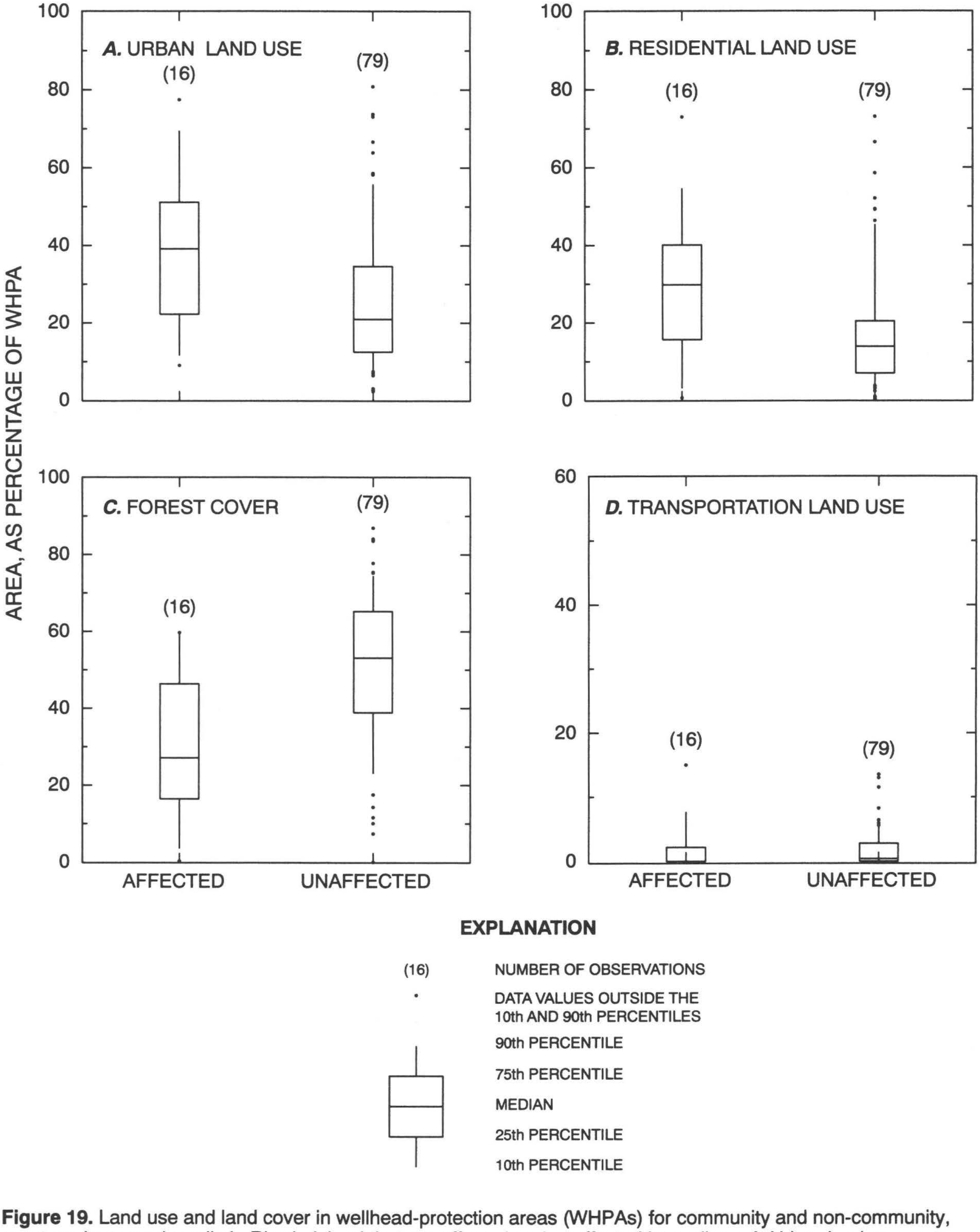



**Figure 19.** Land use and land cover in wellhead-protection areas (WHPAs) for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by sodium. *A.* Urban land use. *B.* Residential land use. *C.* Forest cover. *D.* Transportation land use.

## Fluoride

Fluoride occurs naturally in ground water from mineral dissolution and weathering, generally at low concentrations (Hem, 1985). Fluoride-bearing minerals include fluorite, apatite, amphiboles, and some micas and can be accessory minerals in many rock types. Industrial use of hydrofluoric acid also may be a source of fluoride to ground water (Fetter, 1998). Because of its health benefits in preventing tooth decay, fluoride often is added to drinking-water supplies, generally to a concentration of about 1 mg/L (Manahan, 1984). In high concentrations, fluoride is hazardous to human health, and USEPA has established a MCL for fluoride in drinking water of 4 mg/L (CFR, title 40, section 141, part 62, 1996). Data for fluoride were available for 85 percent (220) of the wells, generally as yearly samples (table 13).

Data analysis of potential vulnerability factors for fluoride used median fluoride concentrations at the wells for several reasons, rather than the threshold-criterion approach used for the previously investigated contaminant classes. Natural sources result in a range of fluoride concentrations that approach the MCL concentration; thus, identification of a threshold concentration that conceptually distinguishes "affected" and "unaffected" wells for fluoride is problematic. A threshold concentration of 2 mg/L, or half the MCL, was investigated, but resulted in few affected wells (six to eight) and WHPAs (four to six, depending on whether the median or any measured concentration was used). However, the regular sampling frequency allowed for the calculation of median or mean concentrations; median values were used because many results were less than the reporting limit. In order to use this approach for analyzing potential vulnerability factors within WHPAs (such as land use), median fluoride concentrations of all wells in a WHPA were averaged.

Median fluoride concentrations at the wells ranged from less than 0.2 mg/L to more than 4 mg/L; median concentrations were above the reported detection limit of 0.2 mg/L at 40 percent (86) of the 218 for which data were available. Concentrations were significantly higher in bedrock wells than in sand-and-gravel wells, and were positively correlated with well depth for both aquifer types (table 7). Higher fluoride concentrations in ground water from bedrock aquifers than from surficial aquifers also were found by Veeger and Ruderman (1998) in southwestern Rhode Island.

Median fluoride concentrations varied by bedrock geologic type, as defined by lithologic groups (fig. 20). Concentrations were significantly higher at wells located in areas of felsic and mafic crystalline rocks than at wells located in areas of sedimentary or metasedimentary rocks, where concentrations generally were less than 1 mg/L (Mann-Whitney tests, $p$-values less than 0.001; fig. 20). These differences were significant for all wells and for bedrock wells only. Median fluoride concentrations also were higher in sand-and-gravel wells located in areas of felsic and mafic crystalline rocks than at wells located in sedimentary or metasedimentary rocks. The differences in lithologic type were not significant for sand-and-gravel wells, however, probably due to the smaller sample sizes and the greater variability of the aquifer materials for these wells. The result that fluoride concentrations in ground water were higher from wells located in areas of felsic and mafic crystalline rocks than from wells in other rock types is consistent with the greater abundance of fluoride-rich minerals, such as apatite and fluorite, in the felsic and mafic crystalline rocks (Hem, 1985). Among the felsic crystalline rocks, which were mostly granites and granite gneisses, the highest fluoride concentrations were measured wells in rocks of the Scituate Igneous Suite, which is consistent with findings of Veeger and Ruderman (1998) for an area in southwestern Rhode Island.

Potential vulnerability factors for soils or for surficial geology were not correlated with median fluoride concentration, except for the areal percentage of ground-water reservoirs in the WHPA for sand-and-gravel wells. Land-use types, as areal percentages of the WHPA, also were not correlated with average median fluoride concentration at wells within the WHPA, except for commercial land use. Although the latter correlation appears strong, it is difficult to interpret in terms of potential fluoride sources.

## Iron and Manganese

Iron and manganese present aesthetic problems in drinking-water supplies, because of their effect on taste and potential for staining of laundry and plumbing fixtures, rather than because of health concerns. Iron is

**Table 7**. Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors with median fluoride concentrations at community and non-community, non-transient supply wells in Rhode Island

[*p*-value, the probability that the observed differences in the potential vulnerability factors tested between affected and unaffected groups are due to chance, are for the Mann-Whitney (MW) *U* (rank sum) test, the Kendall's Tau correlation coefficient (KT), and the Kruskill-Wallis test (KW); *p*-values significant at $\alpha = 0.05$ are shown in **bold. Direction of association:** +, higher value or presence of tested factor is associated with elevated fluoride concentrations; -, lower value or absence of tested factor is associated with elevated fluoride concentrations; ns, association not statistically significant. WHPA, wellhead-protection area. <, actual value is less than value shown; na, not applicable; --, sample size too small for analysis]

| Potential vulnerability factor | Statistical test | Attained significance level | Direction of association |
|---|---|---|---|
| Aquifer type[1] | MW | **<0.001** | na |
| Well characteristics[2] | | | |
| Well depth, sand-and-gravel wells | KT | **<.001** | + |
| Well depth, bedrock wells | KT | **<.001** | + |
| Depth to water, all wells | KT | .439 | ns |
| Depth to bedrock, bedrock wells | KT | .279 | ns |
| Surficial geology, bedrock wells[3] | | | |
| Till, area in WHPA | KT | .499 | ns |
| Outwash, area in WHPA | KT | .365 | ns |
| Bedrock geology[4] | | | |
| Lithologic group at well site, all wells | KW | **<.001** | na |
| Soils[5] | | | |
| Hydrologic group A, area in WHPA | KT | .237 | ns |
| Leaching potential risk, area-weighted rank | KT | .165 | ns |
| Ground-water reservoirs, sand-and-gravel wells, area in WHPA[6] | KT | **0.002** | ns |
| Land use and land cover, area in WHPA[5] | | | |
| Urban, all categories | KT | .841 | ns |
| Residential, all categories | KT | .551 | ns |
| Commercial | KT | **.006** | + |
| Industrial | KT | .597 | ns |
| Transportation | KT | .445 | ns |
| Other urban, all categories | KT | .688 | ns |
| Institutional | KT | .571 | nd |
| Agricultural, all categories | KT | .956 | ns |
| Forest, all categories | KT | .151 | ns |
| Brushland | KT | .482 | ns |
| Water | KT | .180 | ns |
| Wetland | KT | .869 | ns |
| Barren | KT | .414 | ns |

[1] Sample sizes for Mann-Whitney *U* test of aquifer type: 127 bedrock and 88 sand-and-gravel wells.
[2] Sample sizes for Kendall's Tau correlation of well characteristics vary depending on the available data; see text and table 12 for discussion.
[3] Sample size for Kendall's Tau correlation of surficial geology in WHPAs with concentration for bedrock wells: 67 WHPAs
[4] Sample size for Kruskal-Wallis test of bedrock lithologic group: 217 wells.
[5] Sample size for Kendall's Tau correlation of soils and land use with concentration in WHPAs: 110 WHPAs.
[6] Sample size for Kendall's Tau correlation of ground-water reservoirs in WHPAs with concentration for sand-and-gravel wells: 36 WHPAs.

the second most abundant metallic element in the Earth's crust, and occurs in primary and accessory minerals and in weathering products in many rock types and sediments; manganese also is one of the more abundant metallic elements (Hem, 1985). The concentrations of iron and manganese in ground water, however, are controlled primarily by subsurface geochemical conditions rather than abundance. Iron and manganese solubilities are very low in oxygenated waters under neutral or alkaline conditions. Under reducing (low dissolved oxygen) or acid conditions, iron and manganese are soluble. Ground water with low dissolved oxygen may occur naturally from contact with organic material (as in wetlands) or reduced minerals, especially if residence times are long. Anthropogenic sources of large amounts of organic carbon, such as landfill leachate, also result in reducing conditions in ground water, in which iron and manganese may be mobilized. Concentrations of other compounds, such as sulfate, carbonate, and organic compounds, also can affect the solubility and mobility of these elements. For drinking-water supplies, iron and manganese concentrations above 0.3 and 0.05 mg/L, respectively, are considered undesirable, based on secondary maximum contaminant levels (SMCLs) established by USEPA (CFR, title 40, section 143, part 3, 1996).

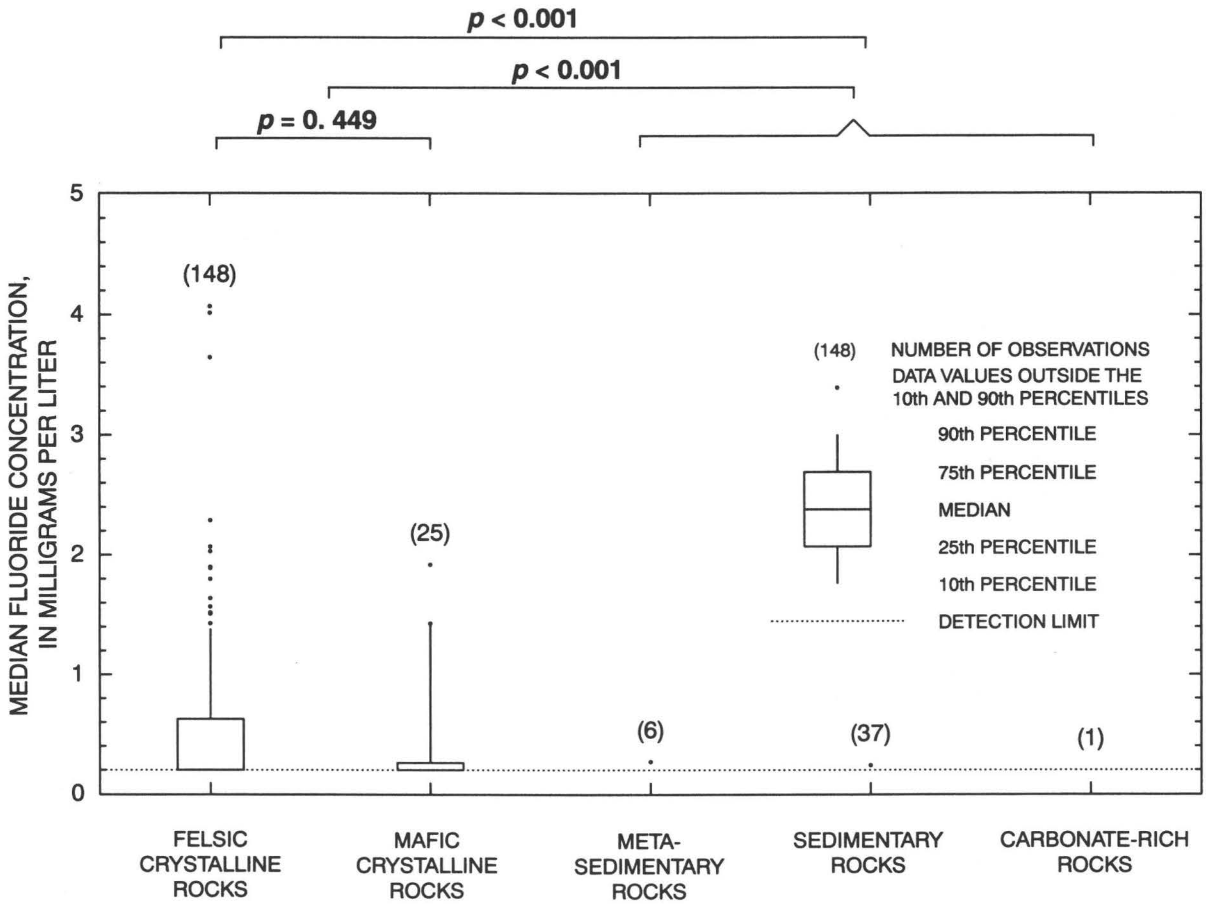



**Figure 20.** Bedrock lithologic type and median fluoride concentrations at community and non-community, non-transient supply wells in Rhode Island. *P*-values shown are for Mann-Whitney *U* (rank-sum) tests of median concentrations between the lithologic groups as indicated; metasedimentary, sedimentary, and carbonate-rich rocks were combined into one category for comparison with felsic and mafic crystalline rocks.

Data on iron and manganese were available for about 75 percent (190) of the wells, generally as yearly samples for several years or as a single sample per well (table 13). The USEPA SMCLs were used as threshold criteria to characterize wells as "affected" and "unaffected" separately for iron and manganese. Median values also were calculated; however, the limited number of samples per well and number of analyses below the method reporting limit made calculating median values problematic in many cases. Fifty-six and sixty-six wells were categorized as affected for iron and manganese, respectively, on the basis of the SMCL threshold criteria, or about one-third of the wells for which data were available (fig. 21). Many of these were the same wells for the two constituents (*p*-value equal to less than 0.001 for contingency test of wells affected by iron and manganese); this result is reasonable because iron and manganese may be mobile under similar geochemical conditions. Based on the threshold-criteria approach, wells affected by iron and manganese were as likely to be in bedrock as in sand and gravel (table 8). Median iron concentrations were higher in bedrock wells, however, than in sand-and-gravel wells (*p*-value less than 0.001 for Mann-Whitney test, *n* equal to 188); median manganese concentrations did not vary by

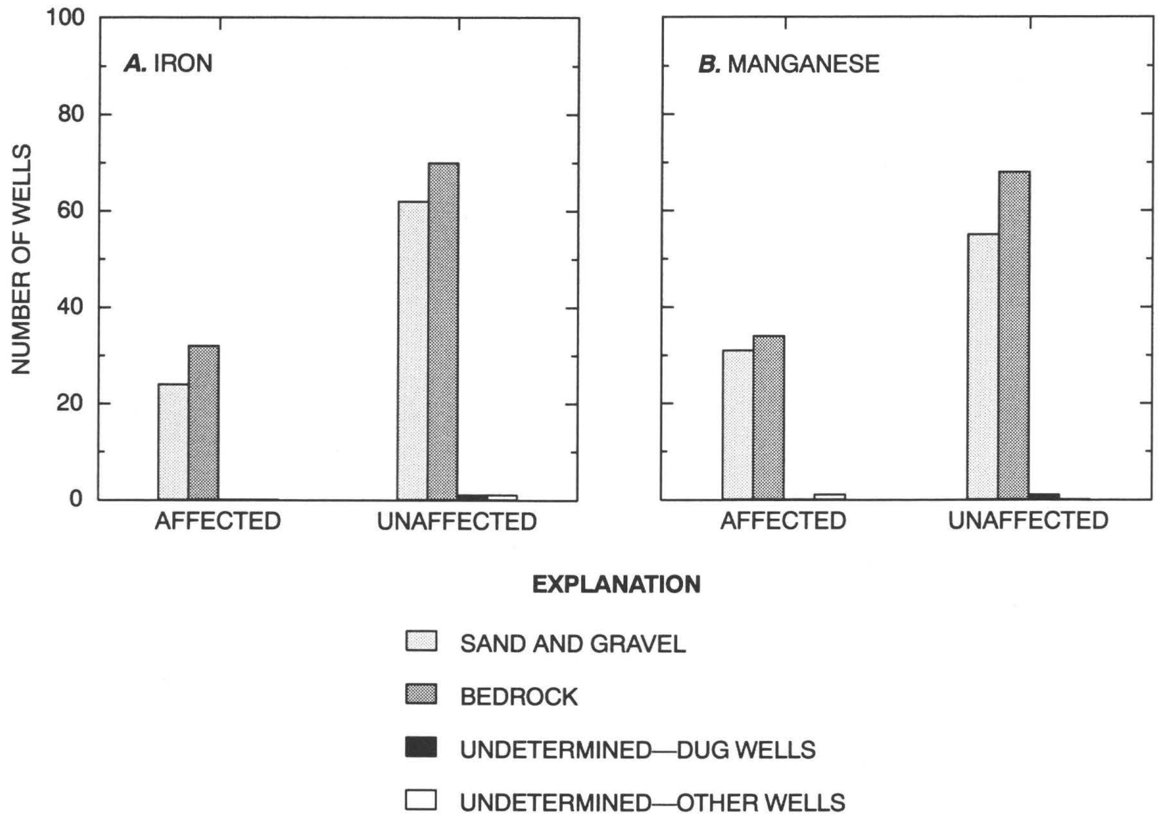



**Figure 21.** Aquifer type for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by iron and manganese. *A.* Iron. *B.* Manganese.

aquifer type (*p*-value equal to 0.703). Well characteristics were similar between affected and unaffected groups.

Few of the potential vulnerability factors based on geology, land use, or other spatial data were significantly different between affected and affected groups for iron or manganese (table 8). For manganese, the distance to the closest stream, the area of water in the WHPA (as mapped in the land-use data), and the soil-leaching potential rank were significantly different [the *p*-value of 0.025 for lithologic group was due to a slight tendency towards higher concentrations in wells of the sedimentary rock type (Narragansett Bay Group), was not considered valid on further investigation]. The proximity and abundance of surface-water bodies (fig. 22) may be important for manganese occurrence, because these measures may reflect the potential for wells to intercept water that has been in contact with organic-rich riparian or wetland sediments (Johnston and Barlow, 1988). Infiltrated water from wetlands or other low-slope water-bodies, either recharged naturally or from the influence of pumping, would be more likely to result in ground water with low concentrations of dissolved oxygen, in which manganese could be mobile. The leaching potential rank may reflect this tendency, because depth-to-water and slope, which are components of this index, are lower in the higher-ranked soils. For iron, the soil leaching potential rank was the only factor tested that was significantly different between affected and unaffected groups, possibly for reasons similar to those for manganese.

**Table 8.** Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by iron and manganese

[*p*-value, the probability that the observed differences in the potential vulnerability factors tested between affected and unaffected groups are due to chance, are for the 2-by-2 (aquifer type) and 2-by-3 (lithologic group) contingency-table tests (CT) and for the Mann-Whitney *U* (rank sum) test (MW); *p*-values significant at $\alpha$ = **0.05** are shown in **bold**. **Direction of association:** +, higher value or presence of tested factor is associated with elevated concentrations of iron or manganese; -, lower value or absence of tested factor is associated with elevated concentrations of iron or manganese; ns, association not statistically significant. WHPA, wellhead-protection area. <, actual value is less than value shown; na, not applicable; --, sample size too small for analysis]

| Potential vulnerability factor | Iron | | | Manganese | | |
|---|---|---|---|---|---|---|
| | Statistical test | Attained significance level | Direction of association | Statistical test | Attained significance level | Direction of association |
| Aquifer type[1] | CT | 0.634 | ns | CT | 0.759 | na |
| Well characteristics[2] | | | | | | |
| Well depth, sand-and-gravel wells | MW | .082 | ns | MW | .609 | ns |
| Well depth, bedrock wells | MW | .522 | ns | MW | .144 | ns |
| Depth to water, all wells | MW | .367 | ns | MW | .508 | ns |
| Depth to bedrock, bedrock wells | MW | .070 | ns | MW | .382 | ns |
| Surficial geology, bedrock wells[3] | | | | | | |
| Till, area in WHPA | MW | .265 | ns | MW | .287 | ns |
| Outwash, area in WHPA | MW | .198 | ns | MW | .256 | ns |
| Bedrock geology[4] | | | | | | |
| Lithologic group at well site, all wells | CT | .425 | na | CT | **.019** | na |
| Surface water, distance to closest stream or pond[5] | MW | .724 | ns | MW | **.024** | - |
| Soils[6] | | | | | | |
| Hydrologic group A, area in WHPA | MW | .098 | ns | MW | .135 | ns |
| Leaching potential risk, area-weighted rank | MW | **.018** | + | MW | **.025** | + |
| Ground-water reservoirs, sand-and-gravel wells, area in WHPA[7] | MW | .770 | ns | MW | .742 | ns |
| Land use and land cover, area in WHPA[6] | | | | | | |
| Urban, all categories | MW | .561 | ns | MW | .122 | ns |
| Urban, all categories except residential | MW | .199 | ns | MW | .291 | ns |
| Residential, all categories | MW | .916 | ns | MW | .772 | ns |
| Agricultural, all categories | MW | .771 | ns | MW | .785 | ns |
| Forest, all categories | MW | .765 | ns | MW | .142 | ns |
| Brushland | MW | .971 | ns | MW | .542 | ns |
| Water | MW | .201 | ns | MW | **.041** | + |

**Table 8.** Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by iron and manganese—*Continued*

| Potential vulnerability factor | Iron | | | Manganese | | |
|---|---|---|---|---|---|---|
| | Statistical test | Attained significance level | Direction of association | Statistical test | Attained significance level | Direction of association |
| Land use and land cover, area in WHPA—*Continued* | | | | | | |
| Wetland | MW | 0.666 | ns | MW | 0.840 | ns |
| Barren | MW | .726 | ns | MW | .730 | ns |
| Geochemical conditions, median pH value measured at the well[8] | MW | .126 | ns | MW | .548 | ns |

[1] Sample sizes for contingency tests of aquifer type: 32 affected and 70 unaffected wells for iron and 34 affected and 68 unaffected wells for manganese.

[2] Sample sizes for Mann-Whitney *U* tests of well characteristics vary depending on the available data; see text and table 12 for discussion.

[3] Sample sizes for Mann-Whitney *U* tests of surficial geology in WHPAs for bedrock wells: 21 affected and 25 unaffected WHPAs for iron and 20 affected and 26 unaffected WHPAs for manganese.

[4] Sample sizes for contingency test of bedrock lithologic group: 56 affected and 130 unaffected wells for iron and 62 affected and 124 unaffected wells for manganese.

[5] Sample sizes for Mann-Whitney *U* tests of distance to the closest stream or pond: 56 affected and 134 unaffected wells for iron and 66 affected and 124 unaffected wells for manganese.

[6] Sample sizes for Mann-Whitney *U* tests of soils and land use in WHPAs: 40 affected and 45 unaffected WHPAs for iron and 42 affected and 43 unaffected WHPAs for manganese.

[7] Sample sizes for Mann-Whitney *U* tests of ground-water reservoirs in WHPAs for sand-and-gravel wells: 15 affected and 18 unaffected WHPAs for iron and 18 affected and 15 unaffected WHPAs for manganese.

[8] Sample sizes for Mann-Whitney *U* test of pH: 54 affected and 113 unaffected wells for iron and 61 affected and 106 unaffected wells for manganese.

Although the correlations between surface-water indicators and manganese and, to a lesser extent, iron are suggestive, they are not adequate to assess the relative vulnerability of supply wells to contamination by these constituents. The general lack of correlation with the potential factors tested is likely due to the variability of geochemical and hydrologic factors that control iron and manganese concentrations in supply-well water and the inadequacy of the available data to characterize these factors. For example, data are not available on concentrations of dissolved oxygen, probably the most important controlling factor. Additionally, the sampling and sample-handling procedures that were used to collect the available water-quality data may alter subsurface pH or redox conditions and allow for the oxidation of dissolved iron and manganese. Sampling effects are unknown sources of variability in the available data that may obscure any relation between iron and manganese concentrations in the source water and the potential explanatory variables tested. Such effects could explain partly the differences in results for iron and manganese. Because dissolved manganese is less rapidly oxidized and precipitated than iron (Hem, 1985), manganese concentrations reported in the available water-quality data may be less likely than iron concentrations to be influenced by variable sampling procedures.

## Trace Inorganic Chemicals

Trace inorganic chemicals include metals and several non-metallic elements that generally occur in low concentrations (less than 1 mg/L) in natural waters (Hem, 1985; table 13). These elements are or have been used in industry and manufacturing and may be present in batteries, electrical equipment, and other common

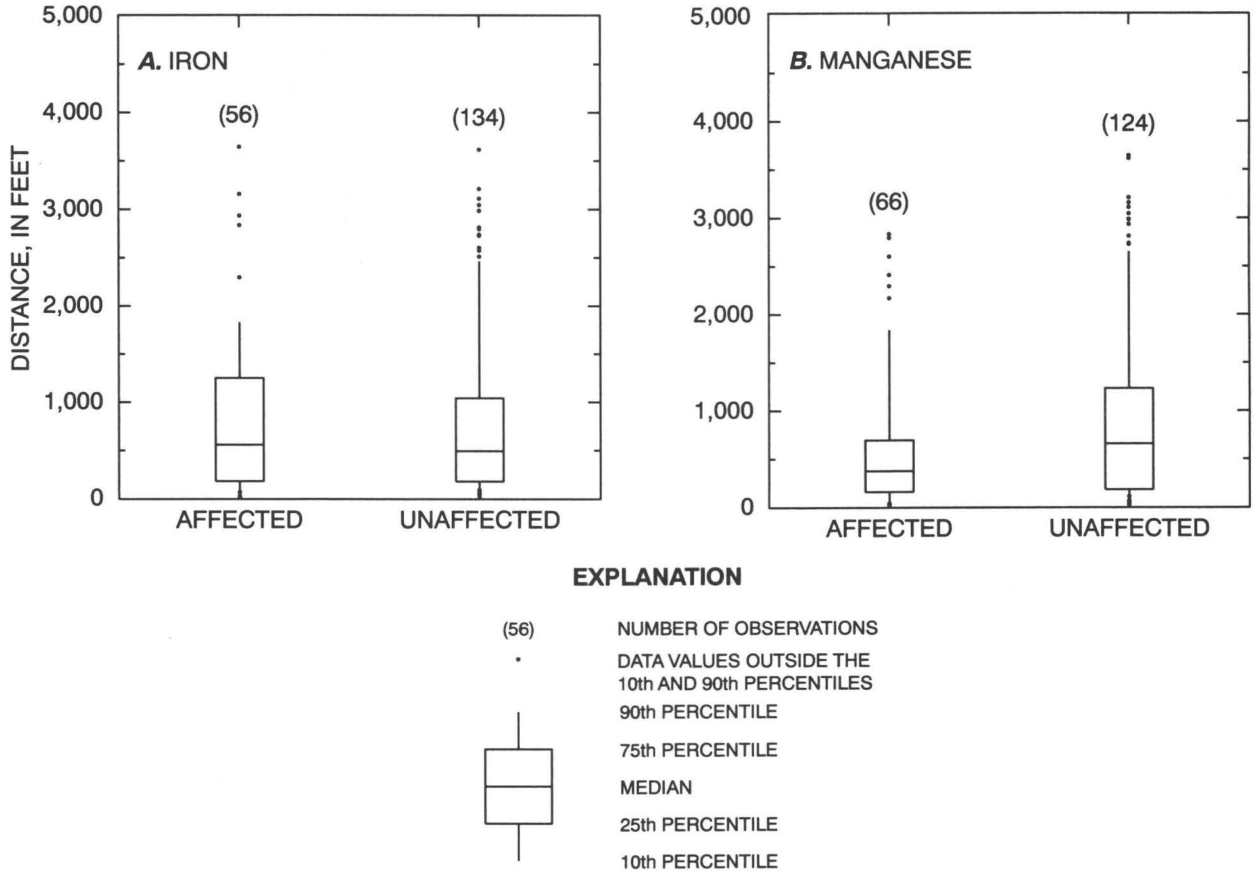



**Figure 22.** Distance to closest surface-water body for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by iron and manganese. *A.* Iron. *B.* Manganese.

products. A few elements, including arsenic, mercury, copper, and zinc, have been used as pesticides (Ware, 1978; Fetter, 1998). Anthropogenic sources of these chemicals to ground water include discharges from industrial activities (especially metal-plating operations), municipal wastewater, landfill leachate, roadway runoff, and fossil fuel combustion. Lead and copper may be leached from water-distribution pipes and solder, especially by low-pH waters; lead also was a gasoline additive and was dispersed through atmospheric transport and deposition. Natural geologic sources, for example, weathering of sulfides or some accessory minerals, may be important sources for some elements. The subsurface mobility of the trace inorganic chemicals and their potential sources vary by constituent. Mobility may be affected by pH and redox conditions, interaction with soil or aquifer materials (especially through sorption), the formation and mobility of colloidal particles, and concentrations of other ions or organic compounds (Hem, 1985; Drever, 1988; Davis and others, 1993; Puls, 1994). Many trace metals and elements are toxic to humans in high concentrations, and the USEPA has established MCLs of 0.002 to 2 mg/L for six of the elements in this contaminant class (CFR, title 40, part 141, section 61, 1996).

Data were available for 75 to 90 percent of the wells for most constituents; data for antimony, beryllium, cyanide, and thallium were available only for about 25 percent of the wells (table 13). For most constituents, data were available generally as yearly samples for several years or as a single sample per well. Many of the constituents were detected in only a small number (less than 10) of samples, however, or in samples collected at a small number of wells, and measured concentrations often were at or near the reported method detection limits. These constituents are arsenic, beryllium, cadmium, chromium, cyanide, mercury, nickel, selenium, silver, and thallium (table 13). The approach used in the present study is not likely to identify potential vulnerability factors for these constituents, and they were not statistically tested.

For barium, copper, lead, and zinc, substantial fractions of the total number of analyses were greater than the reported method detection limits (table 13). Selection of threshold criteria by which to categorize wells as "affected" by these constituents was problematic, however, primarily because of the low concentrations at which they were measured, and also because all have natural and anthropogenic sources. Regulatory levels have been established for all four constituents by USEPA: a MCL and Maximum Contaminant Level Goal (MCLG) of 2 mg/L for barium (CFR, title 40, part 141, section 50, 1996); action levels of 1.3 mg/L for copper and 0.015 mg/L for lead (CFR, title 40, part 141, section 80, 1996); and SMCLs of 1.0 mg/L for copper and 5 mg/L for zinc (CFR, title 40, part 143, section 3, 1996). Except for lead, however, all measured concentrations for the constituents were considerably below the regulatory levels. Consequently, threshold criteria for categorizing wells as "affected" by barium, copper, lead, and zinc were selected as any measured concentrations greater than the method detection limit. For lead, a threshold criterion defined as any concentration greater than the action level of 0.015 mg/L also was investigated, but resulted in no significant differences in the distribution of hydrogeologic or land-use factors between affected and unaffected groups.

Concentrations of barium, copper, lead, and zinc greater than the method detection limits occurred at 30 to 60 percent of the wells for which data were available (fig. 23). For copper and lead, affected wells were more likely to be sand-and-gravel than bedrock wells (figs. 23*B* and *C*), whereas aquifer type was not significant for barium or zinc (figs. 23*A* and 23*D*, table 9). Wells affected by copper and lead also had lower median pH values than unaffected wells (fig. 24); this result is consistent with the tendency for these elements to be more mobile, either from geologic sources or well or distribution-system materials, under low pH conditions (Hem, 1985). The similar results for lead and copper reflect the fact that wells affected by copper also were likely to affected by lead ($p$-value equal to 0.001, contingency-table test). Co-occurrence of any other pair among these four contaminants was not significant.

For barium, urban and residential land uses were higher, and forest cover lower, in WHPAs of affected wells than in WHPAs of unaffected wells; wells with elevated barium concentrations also were less likely to be in areas of felsic crystalline rocks than in mafic crystalline rocks or in sedimentary rocks. However, these results are ambiguous and illustrate a general limitation of the data-analysis approach discussed previously in relation to road density. Land use and bedrock lithologic type for wells for which barium data were available were correlated—that is, urban and residential land uses were higher, and forest cover was lower, in WHPAS of wells in areas of felsic crystalline rocks than in areas of the other two lithologic groups ($p$-values equal to 0.025, equal to 0.010, and less than 0.001 for Kruskal-Wallis test of areal percentage of urban, residential, and forest land use, respectively, in the WHPA and bedrock lithologic type at the well sites; $n$ equal to 104). Thus, it is not possible to determine whether land use or lithologic type is the significant factor for barium occurrence using the methods of the present study. Elevated zinc concentrations were not significantly related to any of the factors tested.

Results of the data analysis for barium, copper, and lead may be suggestive, but are not adequate to permit an assessment of the relative vulnerability of supply wells to contamination by these constituents. As with iron and manganese, important geochemical and hydrologic factors and limitations of the available water-quality data present problems for assessing the contaminants in this class. Sampling procedures that allow for aeration or excessive turbulence of the sample also may have altered source-water pH, redox conditions, or suspended-particle concentrations. Thus, artificial variability may have been introduced into the water-quality data. That this consideration may be important is suggested by the fact that, of the four metals investigated, only barium was significantly (although ambiguously) related to any spatial-data characteristic. Barium, which occurs in only one oxidation state, would be relatively unaffected by changes in redox or pH during sample collection or handling. The sub-milligram-per-liter concentrations at which the trace inorganic chemicals were measured present another limitation to the present study. At these levels, contamination of samples from contact with metallic well-construction or distribution-system materials or from environmental sources could introduce variability into the available water-quality data that may preclude identification of any significant vulnerability factors with the approach used in this study.

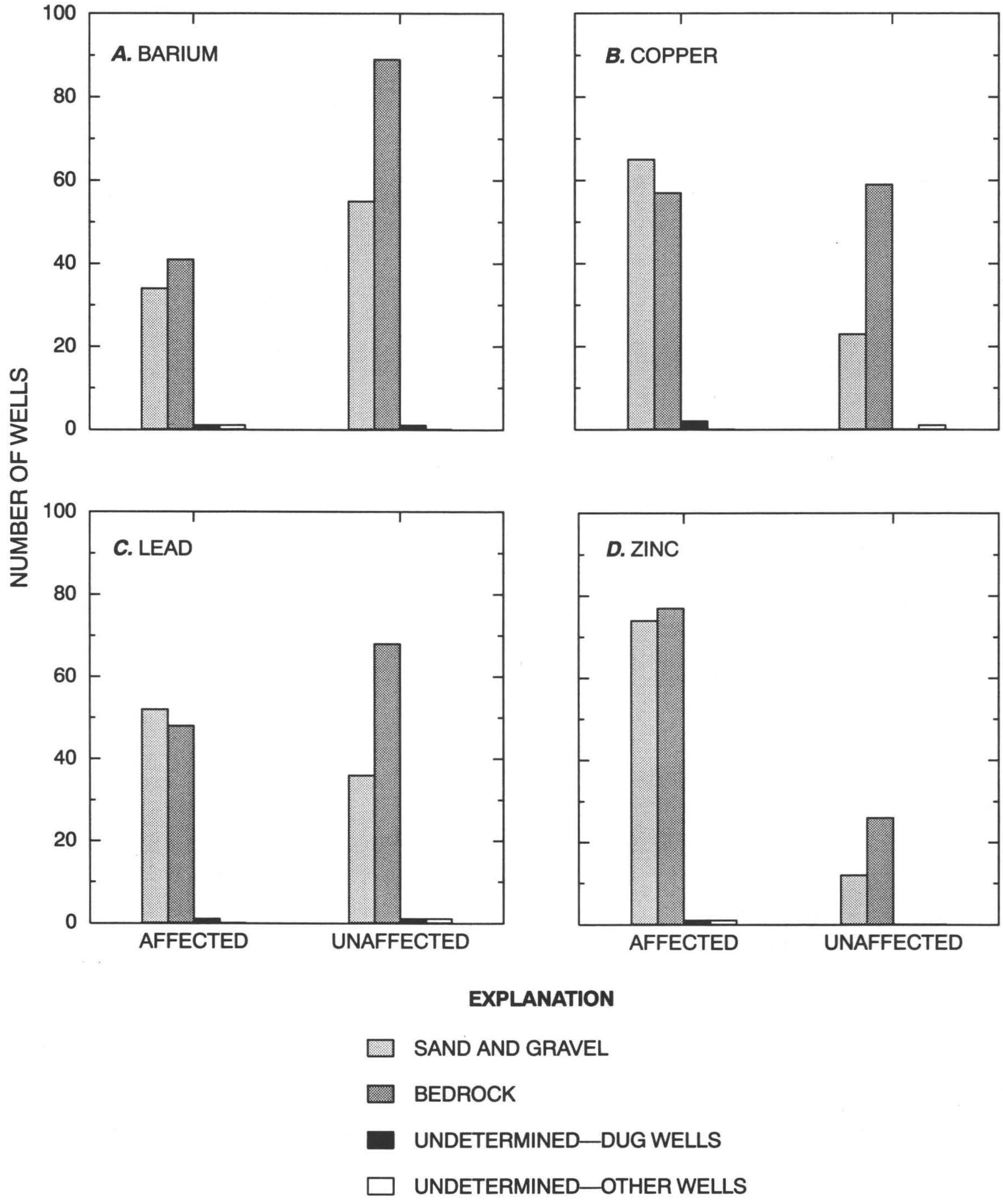



**Figure 23.** Aquifer type for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by trace inorganic chemicals. *A*. Barium. *B*. Copper. *C*. Lead. *D*. Zinc.

**Table 9.** Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by trace inorganic chemicals

[ *p*-value, the probability that the observed differences in the potential vulnerability factors tested between affected and unaffected groups are due to chance, are for the 2-by-2 (aquifer type) and 2-by-3 (lithologic group) contingency-table tests (CT) and for the Mann-Whitney *U* (rank sum) test (MW); *p*-values significant at $\alpha = 0.05$ are shown in **bold. Direction of assciation:** +, higher value or presence of tested factor is associated with elevated concentrations of barium, copper, lead, or zinc; -, lower value or absence of tested factor is associated with elevated concentrations of barium, copper, lead, or zinc; ns, association not statistically significant. WHPA, wellhead-protection area. <, actual value is less than value shown; na, not applicable; --, sample size too small for analysis]

| Potential vulnerability factor | Barium | | | Copper | | | Lead | | | Zinc | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Statistical test | Attained significance level | Direction of association | Statistical test | Attained significance level | Direction of association | Statistical test | Attained significance level | Direction of association | Statistical test | Attained significance level | Direction of association |
| Aquifer type[1] | CT | 0.315 | na | CT | **<0.001** | na | CT | **0.016** | na | CT | 0.068 | na |
| Well characteristics[2] | | | | | | | | | | | | |
| Well depth, sand-and-gravel wells | MW | .198 | ns | MW | .474 | ns | MW | .528 | ns | MW | .850 | ns |
| Well depth, bedrock wells | MW | .512 | ns | MW | .250 | ns | MW | .218 | ns | MW | .299 | ns |
| Depth to water, all wells | MW | .507 | ns | MW | .524 | ns | MW | .994 | ns | MW | .139 | ns |
| Depth to bedrock, bedrock wells | MW | .911 | ns | MW | .185 | ns | MW | .711 | ns | MW | .346 | ns |
| Bedrock geology[3] | | | | | | | | | | | | |
| Lithologic group at well site, all wells | CT | **<.001** | na | CT | .736 | na | CT | .067 | na | CT | -- | na |
| Surface water, distance to closest stream or pond[4] | MW | .1235 | ns | MW | .233 | ns | MW | .098 | ns | MW | .107 | ns |
| Soils[5] | | | | | | | | | | | | |
| Hydrologic group A, area in WHPA | MW | .858 | ns | MW | .824 | ns | MW | **.007** | + | MW | .568 | ns |
| Leaching potential risk, area-weighted rank | MW | .831 | ns | MW | .736 | ns | MW | .194 | ns | MW | .251 | ns |
| Land use and land cover, area in WHPA[5] | | | | | | | | | | | | |
| Urban, all categories | MW | **<.001** | + | MW | .685 | ns | MW | .622 | ns | MW | .419 | ns |
| Residential, all cateogories | MW | **.008** | + | MW | .626 | ns | MW | .612 | ns | MW | .801 | ns |
| Commercial | MW | .061 | ns | MW | .426 | ns | MW | .784 | ns | MW | .830 | ns |
| Industrial | MW | .132 | ns | MW | .513 | ns | MW | .352 | ns | MW | .756 | ns |

**Table 9.** Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by trace inorganic chemicals—*Continued*

| Potential vulnerability factor | Barium | | | Copper | | | Lead | | | Zinc | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Statistical test | Attained significance level | Direction of association | Statistical test | Attained significance level | Direction of association | Statistical test | Attained significance level | Direction of association | Statistical test | Attained significance level | Direction of association |
| Land use and land cover, area in WHPA—*Continued* | | | | | | | | | | | | |
| Forest | MW | **<0.001** | - | MW | 0.462 | ns | MW | 0.846 | ns | MW | 0.570 | ns |
| Water | MW | .456 | ns | MW | .373 | ns | MW | .338 | ns | MW | .581 | ns |
| Geochemical conditions, median pH value measured at the well[6] | MW | .636 | ns | MW | **<.001** | ns | MW | **.012** | - | MW | .073 | ns |

[1] Sample sizes for contingency tests of aquifer type: 130 bedrock and 89 sand-and-gravel wells for barium; 116 bedrock and 88 sand-and-gravel wells for copper and lead; and 103 bedrock and 86 sand-and-gravel wells for zinc.

[2] Sample sizes for Mann-Whitney *U* tests of well characteristics vary depending on the available data; see text and table 12 for discussion.

[3] Sample sizes for contingency test of bedrock lithologic group: 71 affected and 145 unaffected wells for barium; 122 affected and 81 unaffected wells for copper; 101 affected and 102 unaffected wells for lead; and 151 affected and 38 unaffected wells for zinc.

[4] Sample sizes for Mann-Whitney *U* test of distance to the closest stream or pond: 77 affected and 145 unaffected wells for barium; 124 affected and 83 unaffected wells for copper; 101 affected and 106 unaffected wells for lead; and 153 affected and 38 unaffected wells for zinc.

[5] Sample sizes for Mann-Whitney *U* tests of soils and land use in WHPAs: 45 affected and 66 unaffected WHPAs for barium; 72 affected and 29 unaffected WHPAs for copper; 61 affected and 40 unaffected WHPAs for lead; and 73 affected and 12 unaffected WHPAs for zinc.

[6] Sample sizes for Mann-Whitney *U* tests of pH: 67 affected and 111 unaffected wells for barium; 116 affected and 67 unaffected wells for copper; 97 affected and 86 unaffected wells for lead; and 141 affected and 27 unaffected wells for zinc.

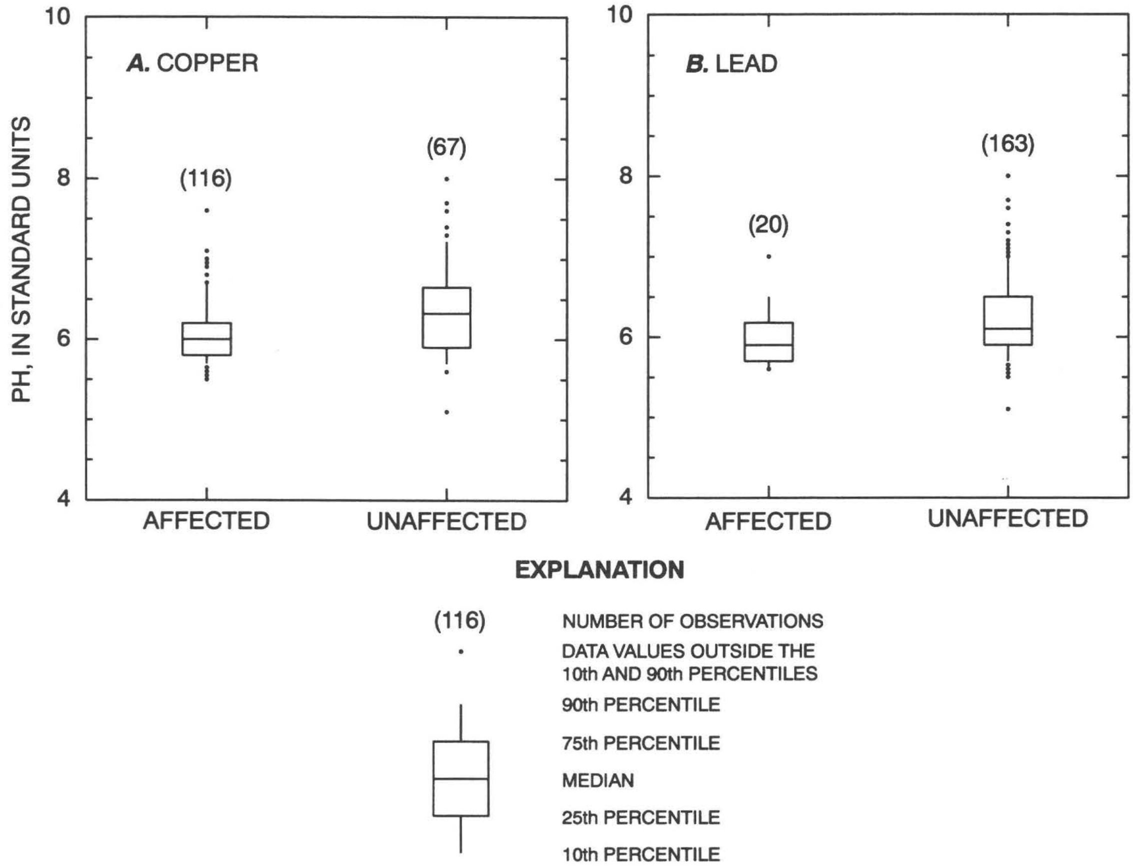



**Figure 24.** Median pH in community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by copper and lead. *A.* Copper. *B.* Lead.

## Radionuclides

Radionuclides in drinking-water supplies are measured in terms of gross alpha and beta radioactivity and concentrations or activity of specific isotopes. Naturally occurring isotopes of radium (radium-226 and radium-224), radon (radon-222), and uranium (uranium-232, uranium-238, and uranium-234) contribute to gross alpha radioactivity (Hem, 1985; Hess and others, 1985). Gross beta activity in natural waters can be due to synthetic radionuclides, such as cesium-134, cobalt-60, strontium-89, and strontium-90, or to a few naturally occurring isotopes, including radium-228 (Hem, 1985). The occurrence of the major naturally occurring radionuclides in ground water is controlled by the distribution of the parent elements, uranium and thorium, in aquifer materials, by geochemical conditions that affect the mobility of the parent elements, and by lithologic characteristics, such as fracture size and secondary mineralization, that affect the extent and duration of the water's contact with the uranium- and thorium-minerals in the aquifer materials (Hess and others, 1985; LeGrand, 1987; Hollocher and Yuskaitis, 1993; Veeger and Ruderman, 1998). Relatively high concentrations of uranium and thorium are found in granites and other felsic igneous rocks, in phosphate deposits, and in sediments derived from these sources as compared with other rock types. Uranium also occurs as a trace element in many rock types (Hess and others, 1985; Fetter, 1998). Uranium mobility may be controlled by redox conditions (uranium is more soluble in oxygenated water), pH, and the concentrations of inorganic and organic chemicals with which it can form complexes; thorium generally is immobile under natural conditions. The mobility of the radium isotopes and many other radionuclides themselves also is strongly affected by cation exchange and sorption. Human activities that may lead to high concentrations of radionuclides derived from uranium and thorium in ground water include uranium mines, phosphate fertilizer manufacturing, and industrial activities associated with radioluminescent paints (Fetter, 1998). These activities generally do not take place in Rhode Island. Synthetic radionuclides may enter ground water from activities associated with nuclear power plants and weapons, research, and medical waste (Fetter, 1998).

Radionuclides in drinking water are potential problems for human health. MCLs have been established by USEPA at 15 pCi/L (picocuries per liter) for gross alpha radioactivity and 5 pCi/L for radium-226 and radium-228 combined; the MCL for gross beta radioactivity depends on the specific radionuclides present (CFR, title 40, part 141, sections 15 and 16, 1996). Testing for specific isotopes is required when measured concentrations of gross alpha or beta radioactivity exceed 5 pCi/L or 15 pCi/L, respectively (CFR, title 40, part 142, section 126, 1996). Water-quality data for gross alpha and beta radioactivity were available for 179 wells each (table 13). Sample frequency was variable. Measurements of gross alpha and beta radioactivity for most wells consisted of one sample per well or samples at several-year intervals; samples were taken more frequently from wells where high activities were measured. Reported method detection limits also varied, as is standard for measurements of radioactivity, but generally were less than 2 pCi/L. Analyses of radium-226 and radium-228 activities were available for only a small number of wells.

The regulatory levels that result in more detailed testing, 5 pCi/L for gross alpha radioactivity and 15 pCi/L for gross beta radioactivity, were investigated for use as threshold criteria by which to categorize wells as "affected" by radionuclides. The 15 pCi/L level for gross beta radioactivity resulted in too few wells (four) for testing; thus, a threshold level of 5 pCi/L was used for both alpha and beta radioactivity. As with other contaminants that originate primarily from natural sources, direct comparison of activity values with potential vulnerability factors (such as was done for fluoride) probably would have been a more effective approach than use of somewhat arbitrary threshold criteria. However, the variable detection limits and precision ranges and generally low activities in the available water-quality data precluded direct statistical testing of activity values.

Wells categorized as affected using the 5 pCi/L threshold value were more likely to be bedrock wells than sand-and-gravel wells for gross alpha and beta radioactivity (fig. 25). In fact, sand-and-gravel wells accounted for only 1 of 28 wells affected by gross alpha radioactivity and for only 4 of 53 wells affected by beta radioactivity. For gross alpha radioactivity, well depth for bedrock wells was significantly greater in affected wells than in unaffected wells. For gross beta radioactivity, depth to water was significantly greater in affected wells than in unaffected wells. Well depth might be associated with longer ground-water residence times and greater weathering of bedrock-aquifer material (see discussion of alkalinity below); the mechanism through which depth to water might affect gross beta radioactivity, however, is unknown.

Bedrock lithologic type at the well was tested by comparing numbers of affected and unaffected wells in felsic crystalline, mafic crystalline, and sedimentary rocks. Most affected and unaffected wells were located in areas of granitic rocks, because of the prevalence of this rock type in Rhode Island. Lithologic rock type was similar between affected and unaffected groups for gross alpha or beta radioactivity (fig. 26 and table 10) This result was unexpected, because granites commonly have higher uranium contents and associated activities of radionuclides than many other rock types, as discussed previously. The average uranium content of the granitic formations in Rhode Island varies among formations, however, and is comparable to the uranium content of some carbonaceous units of the Narragansett Bay Group (Nevins, 1991), which is categorized with the lithologic group containing sedimentary rocks. The prevalence of uranium-containing secondary minerals along fractures, which affects the availability of radioactive decay products in ground water, also is likely to vary spatially and among granite formations (Hollocher and Yuskaitis, 1993). These factors may obscure the influence of lithologic rock type, when defined simply as in the present study, on gross alpha and beta radioactivity in the supply-well water. Several alternative groupings of bedrock formations, based on information about uranium content, radon-contamination potential, and dissolved uranium and radon concentrations in ground water in Rhode Island from Gundersen and Schumann (1993) and Veeger and Ruderman (1998), were tested to address this limitation. The results generally were not significant. The

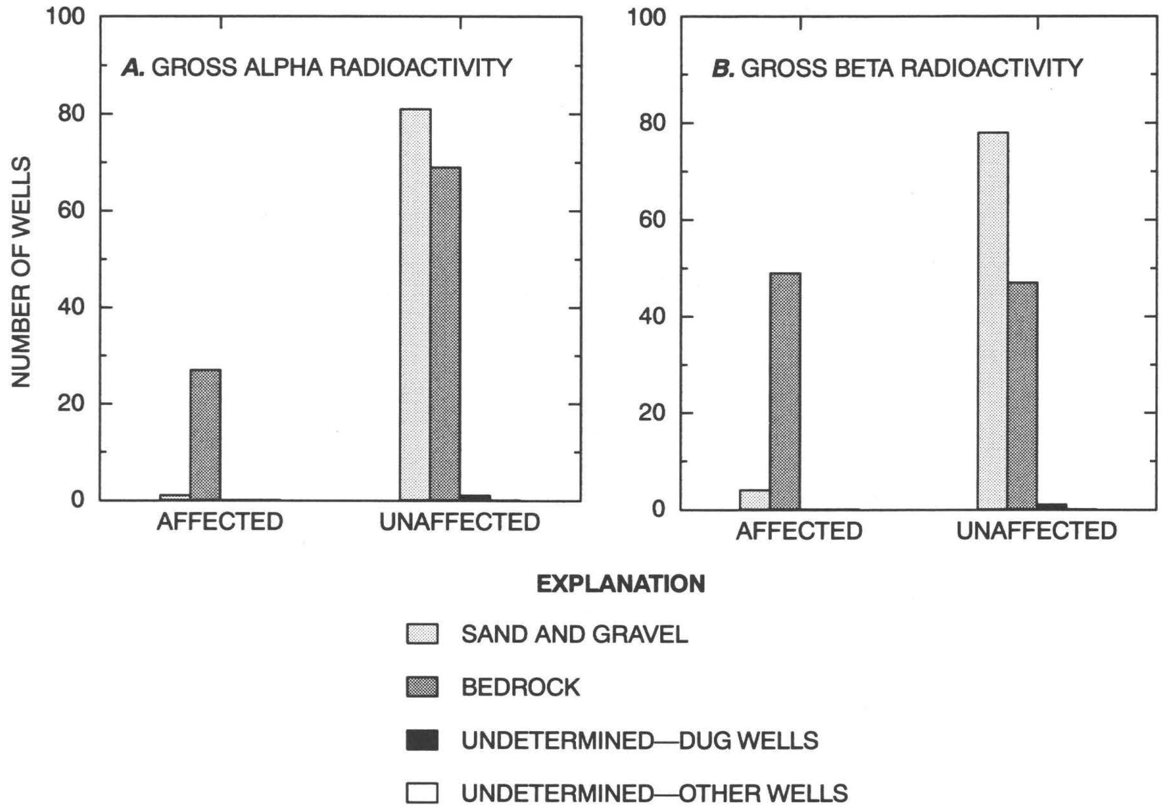



**Figure 25.** Aquifer type for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by radionuclides. *A*. Gross alpha radioactivity. *B*. Gross beta radioactivity.

small sample sizes for some of the lithologic or bedrock categories may have precluded the identification of significant differences in bedrock geology between affected and unaffected groups. The arbitrary nature of the threshold criteria for radionuclides also may have been a factor, similar to the way in which a threshold nitrate concentration of 2 mg/L as N for the nutrients contaminant class was not as effective as other values. Other threshold criteria (2 and 7.5 pCi/L) were tested for radionuclides, but generally did not yield significant results for bedrock characteristics.

Distributions of land-use types in the WHPA were similar between affected and unaffected wells for gross alpha and beta radioactivity. In some cases, the mobility of naturally occurring radionuclides may be enhanced by anthropogenic contaminants (nitrogen species, magnesium), such that elevated activities of radionuclides are associated with specific land uses (Szabo and dePaul, 1998). However, results of the present study did not suggest this relation.

Several geochemical factors were significantly different between wells affected and unaffected by radionuclides. Median fluoride concentrations, pH, and mean alkalinity at the wells all were significantly higher for affected wells than for unaffected wells for gross alpha and beta radioactivity. This result is consistent with positive correlations of alkalinity and fluoride with dissolved radon concentrations found in three granitic formations in southwestern Rhode Island (Veeger and Ruderman, 1998). High alkalinity values may be indicators of weathering that increases contact of water with uranium-bearing minerals; fluoride may be associated with uranium mineralogically and because uranium-fluoride complexes enhance uranium mobility (Veeger and Ruderman, 1998). Fluoride, pH,

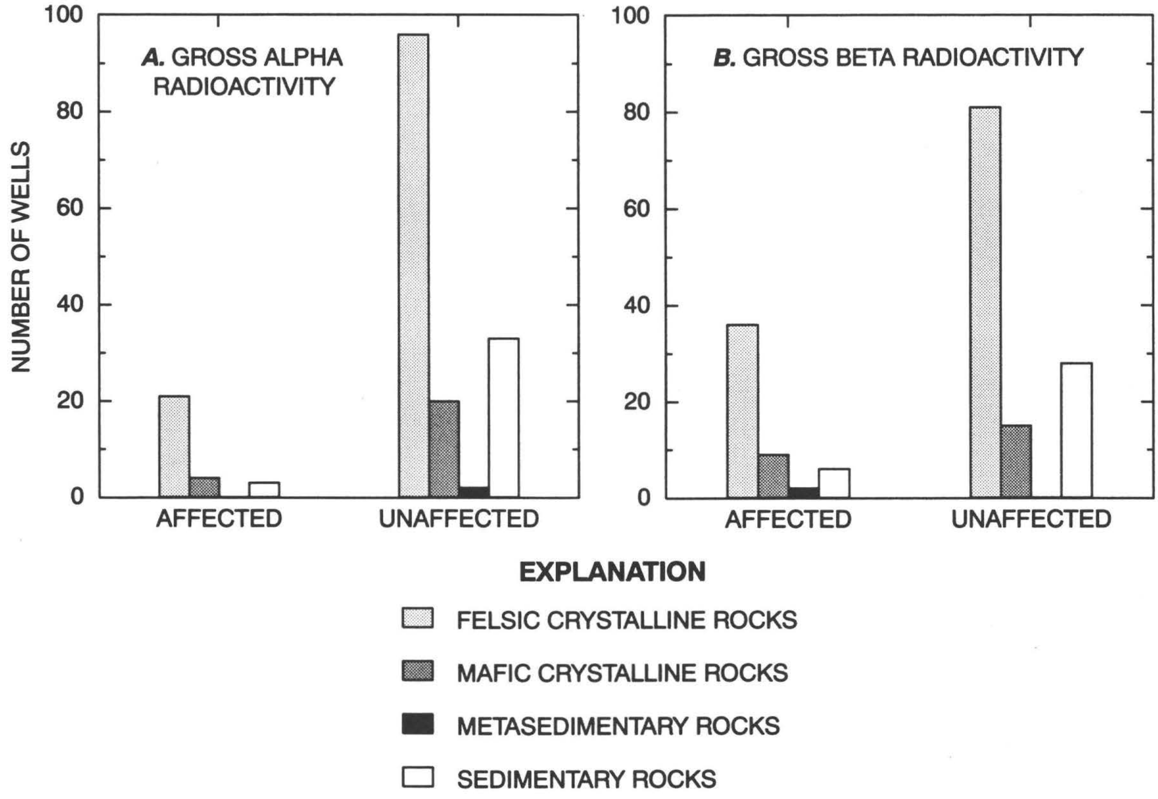



**Figure 26.** Bedrock lithologic type for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by radionuclides. *A.* Gross alpha radioactivity. *B.* Gross beta radioactivity.

and alkalinity also were significantly higher in bedrock wells, however, than in sand-and-gravel wells generally (*p*-values less than 0.001, Mann-Whitney test).

## Microbial Contaminants

Microbial contaminants (bacteria, viruses, and protozoa) that cause gastrointestinal illness or other waterborne diseases may originate in ground water from septic tanks, cesspools, or wastewater effluent or sludge (Craun, 1984; Bitton and Harvey, 1992). Induced infiltration of contaminated surface water also may deliver microbial contaminants to ground-water supply wells (U.S. Environmental Protection Agency, 1989; Gollnitz and others, 1997). The survival of pathogenic microorganisms in the soil and surface is influenced by temperature, moisture content, sunlight, and other variables; their transport through subsurface materials may be attenuated by straining, adsorption, and other filtration mechanisms (Gerba and Bitton, 1984; Bitton and Harvey, 1992; Gollnitz and others, 1997). Thus, characteristics that may influence aquifer vulnerability to microbial contaminants include the presence of saturated conditions near land surface or near potential contaminant sources, aquifer grain size, permeability, and mineralogy, ground-water flow rates, and geochemical conditions.

Total coliform and fecal coliform bacteria are standard indicators of microbial contaminants in drinking-water supplies. Coliform bacteria are generally nonpathogenic bacteria that are present in the intestines of warm-blooded animals and in soils and plants, whereas fecal coliforms originate only from animal intestines (Craun and others, 1997). Thus, detection of coliform bacteria is used to indicate contamination by sewage or other fecal matter and the potential presence of pathogenic microorganisms, which are more difficult to detect and enumerate (Singh and McFeters, 1992). The USEPA has established a MCLG of zero for the number of total coliform bacteria (as colony-forming units) per 100 milliliters of drinking water; the MCL is based on the number of samples required by the system size (CFR, title 40, section 141, parts 52 and 61, 1996).

**Table 10.** Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by radionuclides

[*p*-value, the probability that the observed differences in the potential vulnerability factors tested between affected and unaffected groups are due to chance, are for 2-by-2 exact and probablility and 2-by-3 contingency-table tests (CT) and for the Mann-Whitney *U* (rank-sum) test (MW); *p*-values significant at $\alpha = 0.05$ are shown in **bold**. **Direction of association:** +, higher value or presence of tested factor is associated with elevated radionuclide activities; -, lower value or absence of tested factor is associated with elevated radionuclide activities; ns, association not statistically significant. WHPA, wellhead-protection area. <, actual value is less than value shown; na, not applicable; --, sample size too small for analysis]

| Potential vulnerability factor | Gross alpha radioactivity | | | Gross beta radioactivity | | |
|---|---|---|---|---|---|---|
| | Statistical test | Attained significance level | Direction of association | Statistical test | Attained significance level | Direction of association |
| Aquifer type[1] | CT | **<0.001** | na | CT | **<0.001** | na |
| Well characteristics[2] | | | | | | |
| Well depth, sand-and-gravel wells | MW | -- | -- | MW | -- | -- |
| Well depth, bedrock wells | MW | **.014** | + | MW | .950 | ns |
| Depth to water, all wells | MW | .109 | ns | MW | **<.001** | + |
| Depth to bedrock, bedrock wells | MW | .125 | ns | MW | .481 | ns |
| Bedrock geology[3] | | | | | | |
| Lithologic group at well site, all wells | CT | .382 | ns | CT | .863 | ns |
| Lithologic group at well site, bedrock wells | CT | .835 | ns | CT | .140 | ns |
| Soils[4] | | | | | | |
| Hydrologic group A, area in WHPA | MW | .322 | ns | MW | **.044** | - |
| Leaching potential risk, area-weighted rank | MW | .697 | ns | MW | .051 | ns |
| Land use and land cover, area in WHPA[4] | | | | | | |
| Urban, all categories | MW | .970 | ns | MW | .571 | ns |
| Residential | MW | .841 | ns | MW | .805 | ns |
| Commercial | MW | .893 | ns | MW | .310 | ns |
| Industrial | MW | .270 | ns | MW | .243 | ns |
| Forest | MW | .415 | ns | MW | .829 | ns |
| Water | MW | .369 | ns | MW | .204 | ns |
| Geochemical conditions | | | | | | |
| Median pH at well[5] | MW | **.005** | + | MW | **<.001** | + |
| Mean alkalinity at well[6] | MW | **<.001** | + | MW | **<.001** | + |
| Median fluoride concentration at well[7] | MW | **<.001** | + | MW | **<.001** | + |

[1] Sample sizes for contingency-table tests of aquifer type: 28 affected and 150 unaffected wells for gross alpha radioactivity and 53 affected and 125 unaffected wells for gross beta radioactivity.

[2] Sample sizes for Mann-Whitney *U* tests of well characteristics vary depending on the available data; see text and table 12 for discussion.

[3] Sample sizes for Mann-Whitney *U* of lithologic group at well site: 28 (27 bedrock) affected and 149 (69 bedrock) unaffected wells for gross alpha radioactivity and 51 (49 bedrock) affected and 124 (51 bedrock) unaffected wells for gross beta radioactivity.

[4] Sample sizes for Mann-Whitney *U* tests of soils and land use in WHPAs: 16 affected and 61unaffected WHPAs for gross alpha radioactivity and 33 affected and 44 unaffected WHPAs for gross beta radioactivity.

[5] Sample sizes for Mann-Whitney *U* tests of median pH at wells: 26 affected and 133 unaffected wells for gross alpha radioactivity and 44 affected and 115 unaffected wells for gross beta radioactivity.

[6] Sample sizes for Mann-Whitney *U* tests of mean alkalinity at wells: 26 affected and 146 unaffected wells for gross alpha radioactivity and 50 affected and 122 unaffected wells for gross beta radioactivity.

[7] Sample sizes for Mann-Whitney *U* tests of median pH at wells: 28 affected and 150 unaffected wells for gross alpha radioactivity and 53 affected and 125 unaffected wells for gross beta radioactivity.

Data were available for about 80 percent (209) of the wells for total coliform bacteria (table 13). Samples generally were collected at yearly intervals, or more frequently after the collection of samples in which coliforms were detected. Results for fecal coliform analyses also were available on collection dates when total coliforms were detected. Most analyses were conducted using the membrane-filter method; the available data also included results of multiple-tube fermentation and standard-plate-count methods (American Public Health Association, 1981). A threshold of any detection of total coliform bacteria, reported either as "present" or as a numerical value greater than 1, was used to characterize wells as "affected" for bacteria. For the purposes of this study, detections associated with "unverified" analyses (results that were not confirmed by a second analysis) were not used in identifying affected wells.

Total coliform bacteria were detected at 49 wells, or about one-fourth of wells for which data were available (fig. 27). The affected wells were as likely to be bedrock as sand-and-gravel wells (table 11). Well depth and depth to water were similar between affected and unaffected wells, but depth to bedrock was significantly less in affected bedrock wells. The latter result may reflect a tendency for bedrock wells with thin overburden materials to be more vulnerable to bacterial contamination due to surface flooding.

Detections of coliform bacteria were unrelated to soil type, surficial geology, ground-water reservoirs, or land use in the WHPA or to the distance of the well to the closest surface-water body (table 11). The area of water in the WHPA, as mapped in the land-use data, was higher in WHPAs of affected wells than in WHPAs of unaffected wells, but the difference was marginally insignificant (table 11). Proximity of surface-water bodies and possibly some of the other factors tested may be important in some instances of bacterial contamination of wells. However, results of the data analysis suggest that other factors for which data were not available, such as well-construction or maintenance procedures, are more important for determining wells' vulnerability to bacterial contamination. Moreover, these factors or contamination in the distribution system, which is a common cause of bacterial contamination in ground-water supplies (Craun, 1984), would introduce variability that would obscure any relation with source-water, aquifer, or spatial-data characteristics.

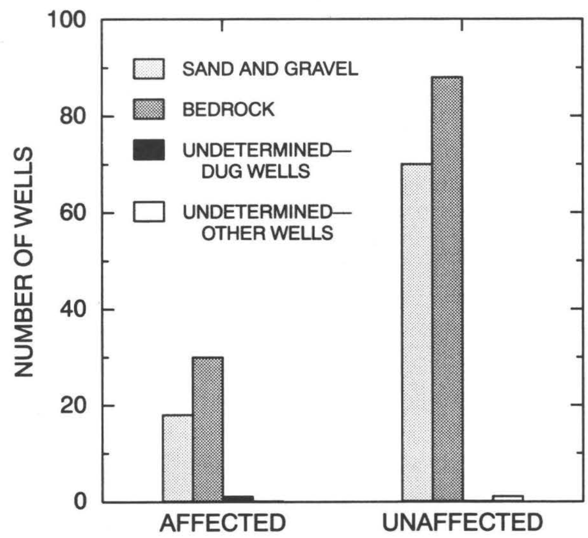



**Figure 27.** Aquifer type for community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by coliform bacteria.

## Other Contaminant Classes

Several other classes of monitored drinking-water contaminants were defined on the basis of available water-quality data, but were not statistically tested. These classes are constituents related to hardness, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, disinfectant by-products, and chemicals related to analytical methods. Hardness is a property of water that describes how the water will react with soap, and whether it will form mineral deposits when heated (Hem, 1985). This effect is mostly due to dissolved calcium and magnesium cations, from which hardness (reported as an equivalent concentration of calcium carbonate) generally is calculated. Water with hardness less than 100 mg/L is considered acceptable for drinking-water purposes (Hem, 1985). Hardness exceeded this value at less than 10 percent of the 190 wells for which data were available (table 13). For this reason, and because hardness, calcium, or magnesium are not health concerns, the available data were not statistically tested to determine vulnerability factors for the hardness class.

Polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) are two classes of synthetic organic compounds that are harmful to human health. MCLs of less than 0.001 mg/L and MCLGs of zero have been established by USEPA for

**Table 11**. Attained significance levels (*p*-values) for statistical tests comparing aquifer type, well characteristics, land use, and other potential vulnerability factors between groups of community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected by coliform bacteria

[*p*-value, the probability that the observed differences in the potential vulnerability factors tested between affected and unaffected groups are due to chance, are for the 2-by-2 contingency-table tests (CT) and for the Mann-Whitney *U* (rank-sum) test (MW); *p*-values significant at $\alpha = 0.05$ are shown in **bold**. **Direction of association:** +, higher value or presence of tested factor is associated with detections of coliform bacteria; -, lower value or absence of tested factor is associated with detections of coliform bacteria; ns, association not statistically significant. WHPA, wellhead-protection area]

| Potential vulnerability factor | Statistical test | Attained significance evel | Direction of association |
|---|---|---|---|
| Aquifer type[1] | CT | 0.404 | ns |
| Well characteristics[2] | | | |
| Well depth, sand-and-gravel wells | MW | .456 | ns |
| Well depth, bedrock wells | MW | .419 | ns |
| Depth to water, all wells | MW | .770 | ns |
| Depth to bedrock, bedrock wells | MW | **.002** | - |
| Surficial geology, bedrock wells[3] | | | |
| Till, area in WHPA | MW | .600 | ns |
| Outwash, area in WHPA | MW | .615 | ns |
| Surface water, distance to closest stream or pond[4] | MW | .478 | ns |
| Soils[5] | | | |
| Hydrologic group A, area in WHPA | MW | .851 | ns |
| Leaching potential risk, area-weighted rank | MW | .137 | ns |
| Ground-water reservoirs, sand-and-gravel wells, area in WHPA[6] | MW | 0.079 | ns |
| Land use and land cover, area in WHPA[5] | | | |
| Urban, all categories | MW | .863 | ns |
| Urban, all categories except residential | MW | .768 | ns |
| Residential, all categories | MW | .513 | ns |
| Agricultural, all categories | MW | .316 | ns |
| Forest, all categories | MW | .540 | ns |
| Brushland | MW | .185 | ns |
| Water | MW | .055 | ns |
| Wetland | MW | .937 | ns |
| Barren | MW | .856 | ns |

[1] Sample sizes for contingency test of aquifer type: 118 bedrock wells and 88 sand-and-gravel wells.
[2] Sample sizes for Mann-Whitney *U* tests of well characteristics vary depending on the available data; see text and table 12 for discussion.
[3] Sample sizes for Mann-Whitney *U* tests of surficial geology in WHPAs for bedrock wells: 18 affected and 42 unaffected WHPAs.
[4] Sample sizes for Mann-Whitney *U* test of distance to the closest stream or pond: 49 affected and 160 unaffected wells.
[5] Sample sizes for Mann-Whitney *U* tests of soils and land use in WHPAs: 32 affected and 70 unaffected WHPAs.
[6] Sample sizes for Mann-Whitney *U* test of ground-water reservoirs in WHPAs for sand-and-gravel wells: 10 affected and 25 unaffected WHPAs.

members of these contaminant classes (CFR, title 40, section 141, part 61, 1996). However, vulnerability to PAHs or PCBs was not investigated, because these contaminants were not detected in the available water-quality analyses. PAHs and PCBs tend to be strongly sorbed by sediment, soil particles, and organic material. Thus, they are not commonly dissolved in ground water (Chapelle, 1993; Fetter, 1998), and ground-water supply wells are not vulnerable to these contaminants.

Synthetic organic chemicals related to chlorination, or disinfectant by-products (DBPs), include trihalomethane organic chemicals that can form as a result of the reaction of chlorinated drinking water with naturally occurring organic compounds (table 13). An MCL of 0.1 mg/L for total trihalomethanes, sampled at points in the distribution system, has been established for drinking water (CFR, title 40, section 141, part 12, 1996). In order to assess vulnerability to these contaminants, information would be needed about chlorination practices, about concentrations of DBPs in water after treatment, and about how the treated water in the distribution system (often a mixture of water from multiple surface- and ground-water sources) relates to specific ground-water sources. This information was not available for the supply wells used in the present study (D. Pytel, RIDOH, personal commun., 1998). Moreover, analyses of trihalomethanes described in table 13 are for untreated samples, and thus are not representative of the DBP-formation potential of the source water. Thus, vulnerability of wells to contamination by DBPs was not assessed. Vulnerability with respect to synthetic organic chemicals that may be by-products of analytical procedures (table 13) also was not assessed in the present study.

## RELATIVE VULNERABILITY OF PUBLIC-SUPPLY WELLS

In this section, the hydrogeologic characteristics, land uses, and other factors that were identified as significant vulnerability factors for each contaminant class are tabulated for the community and non-community, non-transient supply wells. These factors are used to rank the relative vulnerability of the wells to contamination. Contaminant classes that are assessed are nutrients, pesticides, solvents and other industrial organic chemicals, road-deicing chemicals, fluoride, and radionuclides; vulnerability factors were not adequately identified to assess relative vulnerability for the other contaminant classes.

As in most such assessments, uncertainty is inherent in the vulnerability designations presented in this section. Uncertainty in vulnerability assessments generally results from lack of data, measurement errors in the available data, spatial and temporal variability of contaminants and their characteristics, inadequate representations of the relevant environmental processes, and other sources (National Research Council, 1993). In the present study, the lack or incompleteness of the available data is an important source of uncertainty in the designation of wells as more or less vulnerable to contamination. For example, well characteristics such as depth to water or depth to the screened interval may influence vulnerability to some contaminants, but these variables may not have been identified as significant because data were lacking for many or all of the wells. A source of uncertainty that results from the analytical approach of the present study, in which potential vulnerability factors are tested separately, is the lack of knowledge about the relative contribution (or co-dependence in some cases) of multiple vulnerability factors, in cases in which more than one factor was identified. Another limitation of the analytical approach, which results from using the current or historical distribution of contaminants as an indicator of the vulnerability to contamination, is that vulnerability cannot be assessed for contaminant classes by which few, if any, wells have been affected.

Wells are designated as more or less vulnerable to contamination in the present study by combining and categorizing the vulnerability factors identified from the available data. Wells are grouped into two or more categories for each contaminant class based on the presence/absence or intensity of vulnerability factors for that class. Letters in descending order are used to represent vulnerability categories. Wells given an "A" designation have the most significant or the greatest number of vulnerability factors. Wells associated with fewer or none of the vulnerability factors are designated as "B," "C," or "D." In defining well vulnerability categories, factors representing contaminant sources (such as a land-use type) were given greater weight than hydrogeologic factors. Where aquifer type is a factor, dug wells of undetermined aquifer type are treated the same as sand-and-gravel wells, because dug wells are typically shallow. Finally, well characteristics such as well depth were not used, because results of the data analysis for these factors were likely to be less robust than results for other factors, such as land use, for which data sets were more complete.

This approach to vulnerability assessment essentially uses the vulnerability exhibited by wells that have been affected by contaminants to identify currently unaffected wells that are similar to the affected wells in terms of important hydrogeologic, land use, and other spatial-data characteristics. Thus, all affected wells also are considered highly vulnerable, even in cases in which the selected ranking scheme does not identify those wells as highly vulnerable (these wells are separately identified in the tables by footnotes). It should be emphasized that, like all vulnerability categories (for example, "high," "moderate," and "low") that are not specifically defined in terms of quantitative probabilities of contamination, the vulnerability designations assigned in the present study have somewhat subjective boundaries (National Research Council, 1993). In addition, alternative methods of combining and categorizing the significant vulnerability factors or the incorporation of additional factors not tested in the present study would likely result in different wells being identified as more or less vulnerable to contamination. Additional data are presented in tables 14 through 18 (at back of report), such that alternative ranking schemes could be readily implemented. For these reasons, and because of the many sources of uncertainty discussed previously, the relative vulnerability designations provided in this section should be considered as a preliminary assessment, which could be refined, improved, and verified with additional data collection, analysis, and testing.

Factors significantly associated with elevated concentrations of nutrients (or nitrate) were aquifer type and the area in the WHPA of residential land use, of the urban land use that includes parks and golf courses; the area of forest cover in the WHPA was inversely associated with elevated concentrations of nutrients. These factors were consistently significant for threshold criteria of nitrate concentrations greater than 1 and 5 mg/L as N and are tabulated for all the wells in table 14. Wells expected to be most vulnerable to contamination by nutrients ("A" wells) are sand-and-gravel wells with a high percentage of their WHPA occupied by residential land use and (or) with any amount of the urban land use with parks and golf courses in their WHPA. Wells expected to be least vulnerable to contamination by nutrients ("D" wells) are bedrock wells without high percentages of residential land use or without the urban land use with parks and golf courses in the WHPA. Bedrock wells with these high-risk land uses in the WHPA or sand-and-gravel wells without these land uses are assigned to the "B" and "C" vulnerability categories, respectively (table 14). For the purposes of this assessment, residential land use occupying more than 20 percent of the WHPA was considered "high;" this value is based on the percentile distributions (fig. 9*A*) and contingency tests of residential land use in affected and unaffected WHPAs. Any amount of the urban land use with parks and golf courses was considered important because the presence or absence of this land use also was significant for elevated nitrate concentrations and because areas of this land use generally were low relative to the total WHPA. Forest cover was not included as a separate vulnerability factor because it is correlated (inversely) with residential land use (*p*-value less than 0.001, Kendall's tau correlation coefficient). Similarly, the presence or absence of sewers in the WHPA was not used, because sewers also were correlated with residential land use.

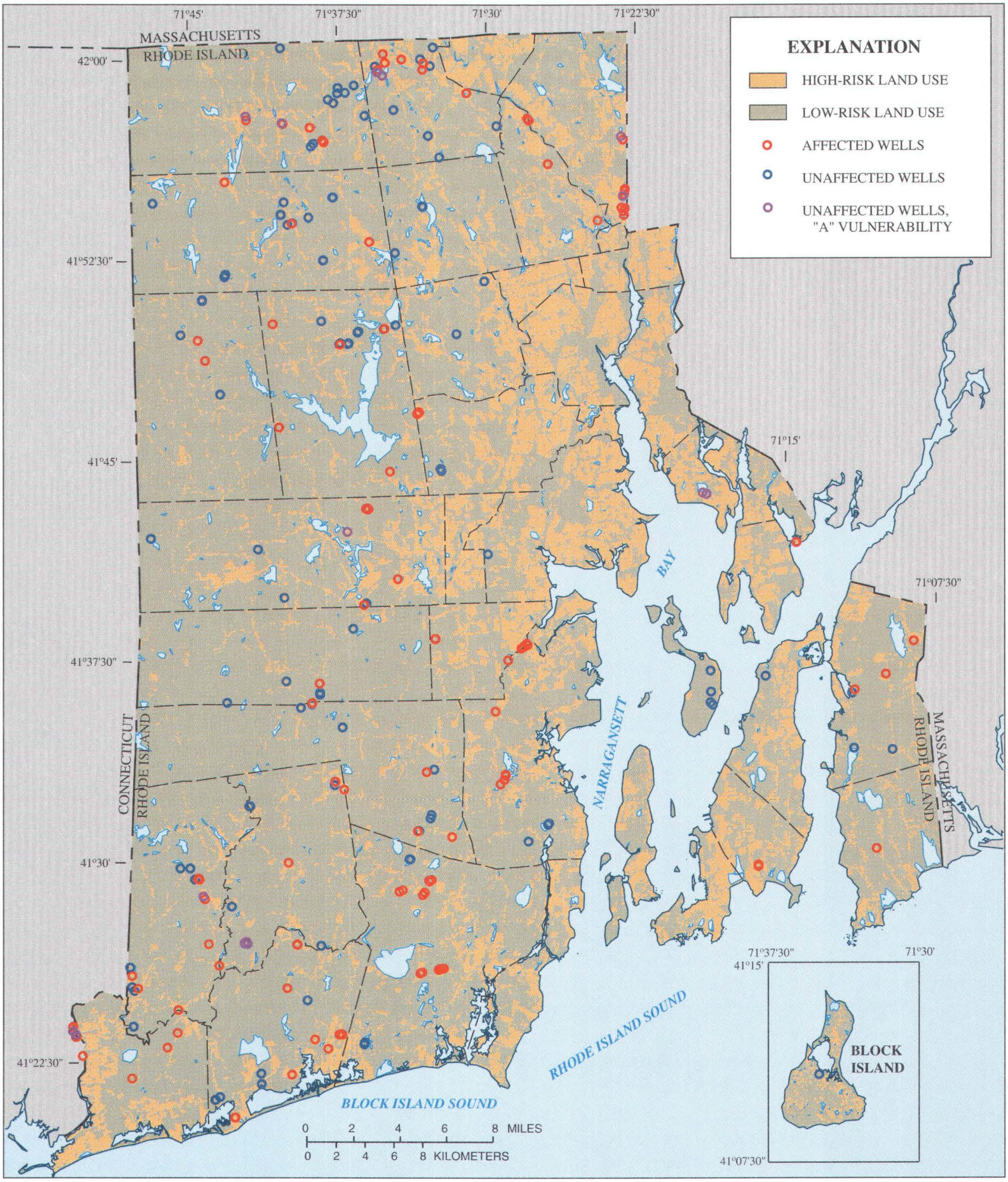
Factors significantly associated with detections of pesticides were aquifer type, the area of the urban land use with parks and golf courses and institutional urban land uses in the WHPA, the area of high-yield ground-water reservoirs (for sand-and-gravel wells) in the WHPA, and the median nitrate concentration at the well. These factors are tabulated in table 15. Wells expected to be most vulnerable to contamination by pesticides ("A" wells) are sand-and-gravel wells with any amount of the urban land use with parks and golf courses or institutional land use in their WHPAs. Sand-and-gravel wells without these land uses in their WHPAs but with high median nitrate concentration, or bedrock wells with these land uses in their WHPAs, were grouped in an intermediate vulnerability category ("B"). Wells without these land uses and generally with low nitrate concentrations were expected to be least vulnerable to contamination by pesticides ("C" wells; nine bedrock wells with high median nitrate concentrations were included in this group). For this designation, a median nitrate concentration was considered "high" if it was greater than 1.8 mg/L as N, which is the 50th percentile value for median nitrate concentrations in wells with detections of pesticides (fig. 12). Areas of ground-water reservoirs in the WHPAs were not considered, because it is unclear how these features are related to the occurrence of the contaminants. The area of ground-water reservoirs in the WHPA may be a surrogate for some other characteristic, such as supply-system size. Large supply systems and wells, which tend to be in high-yield areas, may be more likely to be affected for some reason unrelated to aquifer characteristics, or they simply may be tested more often. Because of these uncertainties, ground-water reservoirs were not used to designate vulnerability categories for pesticides or for the other contaminant classes for which they were significant.

It should be re-emphasized that, as with the other contaminant classes, there are multiple ways of combining and prioritizing the vulnerability factors that were identified for the pesticide contaminant class, and additional factors could be included in the vulnerability designations. These considerations are particularly important for the pesticide group. Because it was based on a small number of affected wells and did not distinguish between various pesticide sources, the data analysis was limited in its ability to identify significant indicators of vulnerability to pesticide contamination. Thus, on the basis of the available data, the areas of agricultural land uses in the WHPA were not significant in the present study. A vulnerability assessment of supply wells to contamination by pesticides, however, should incorporate some factor(s) representing pesticide applications for agricultural or domestic uses, which might vary for different pesticide groups according to their uses in specific applications (Pepper, 1998). The areal percentage of agricultural land use in the WHPA is included in table 15 for information purposes, but additional data and further investigation would be needed to incorporate this or other information on pesticide-application activities into the vulnerability designations. Soil characteristics, such as the area of hydrologic group A, or the area-weighted, soil-leaching potential rank also could be incorporated into an alternative approach to the vulnerability assessment for pesticides.

Factors significantly associated with detections of solvents and other industrial organic chemicals were aquifer type and the area in the WHPA of industrial land use, of brushland cover, of an agricultural land use that includes orchards and nurseries (inversely associated with contamination); ground-water reservoirs are omitted here for reasons discussed previously. Some of these factors are tabulated in table 16, along with the area of all urban land uses in the WHPA, which might be expected from literature sources to influence contamination by VOCs (Eckhardt and Stackelberg, 1995; Grady and Mullaney, 1998). Wells expected to be most vulnerable to contamination by solvents ("A" wells) are sand-and-gravel wells with any amount of industrial land use in their WHPAs. Wells with more than 50 percent of their WHPA occupied by urban land uses also were given the "A" designation. Wells expected to be least vulnerable ("D" wells) are bedrock wells without industrial land use or with less than 50 percent urban land use in their WHPAs. Bedrock wells with industrial land use or with more than 50 percent urban land use in their WHPAs and sand-and-gravel wells without these land-use characteristics were grouped in intermediate vulnerability categories ("B" and "C" wells, respectively). The brushland land use and agricultural land use with orchards and nurseries were not used in assigning vulnerability designations, but alternative approaches could incorporate these land uses, following further investigation of how they could be systematically related to the occurrence of solvents across the State.

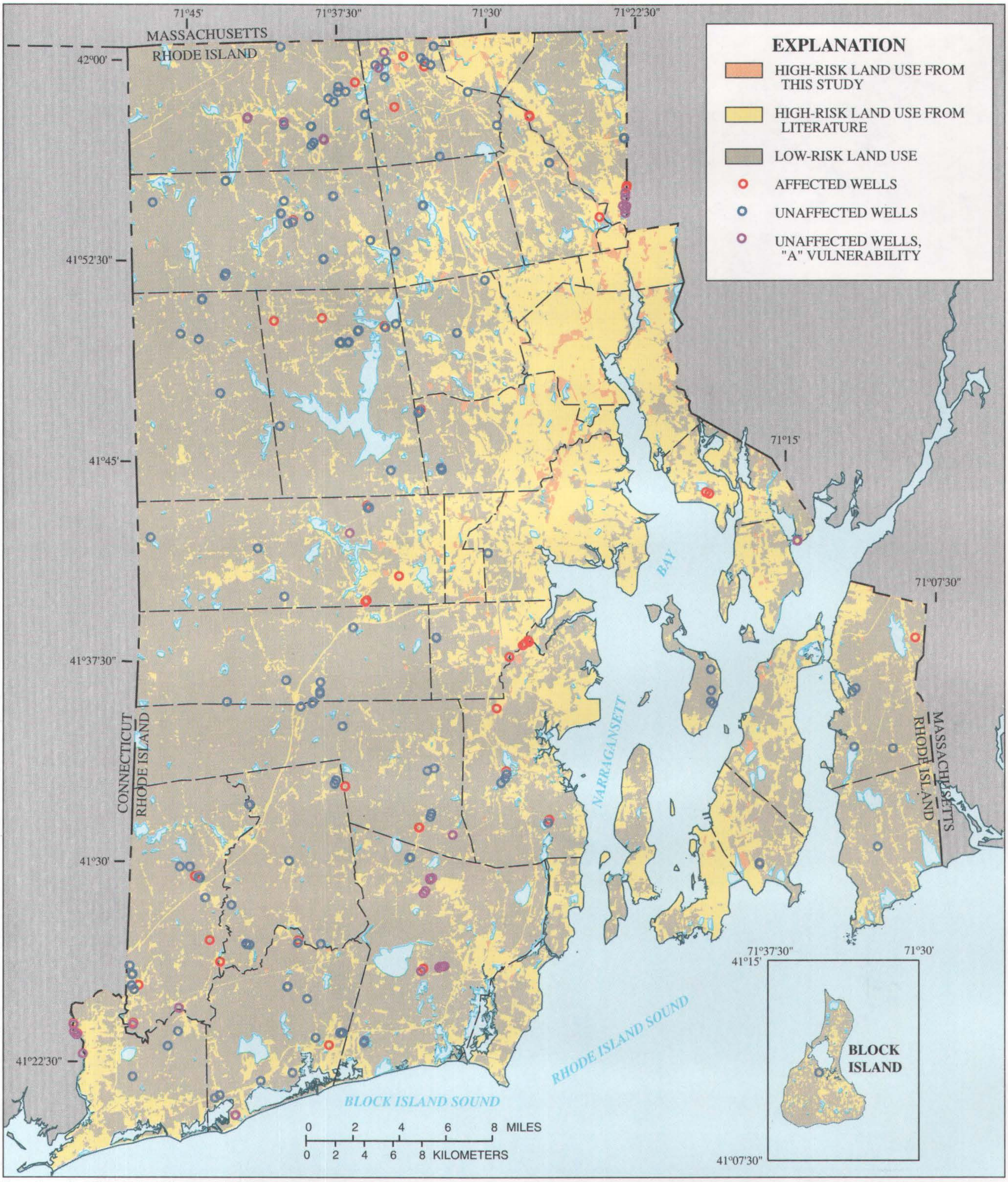
Significant land use or other factors were not identified in the present study for contamination for detections of fuel hydrocarbons, and vulnerability is not specifically assessed for this contaminant class. However, fuel hydrocarbons, along with other VOCs, have been found more frequently in shallow ground water in urban areas in several studies, as described previously (Eckhardt and Stackelberg, 1995; Squillace and others, 1995; Grady and Mullaney, 1998). Thus, the vulnerability of wells to contamination by these chemicals could be assessed in terms of the areal percentage of urban land use in their WHPAs, as tabulated for solvents (table 16). Wells with a high percentage of urban land use in their WHPAs would be expected to be more vulnerable to contamination by fuel hydrocarbons than wells in areas of less urban land use.

The spatial distribution of contaminated wells and of the land uses used in the designations of relative vulnerability to contamination ("high-risk" land uses) by nitrate, pesticides, and solvents suggests that regional or statewide mapping of relative vulnerability to these contaminants may be problematic. The high-risk land uses for nitrate contamination—residential land use and the urban land use with parks and golf courses—are prevalent in the northeast and east-central parts of the State. (fig. 28). Nitrate-affected wells (using the threshold criterion of 1 mg/L as N) and unaffected wells given the "A" vulnerability designation, however, are distributed throughout the State. Similarly, some wells in all parts of the State where supply wells are present are affected by and are expected to be most vulnerable to contamination by solvents (fig. 29). Pesticide-affected wells also are scattered throughout the State, but appear at least partly clustered in the southwest (fig. 30), one of the more active agricultural areas in Rhode Island (E. Pepper, RIDEM, personal commun., 1999). This pattern supports the hypothesis that agricultural land use should be considered an important vulnerability factor for pesticide contamination, as found by many studies (for example, Grady and Mullaney, 1998) although it was not identified as a significant factor in the present study. In general, however, the patchy distribution of high-risk land uses and scattered distributions of affected and "A" vulnerability wells suggests that relative vulnerability may be assessed most effectively by close evaluation of land uses and other characteristics in the areas contributing water to the supply wells.



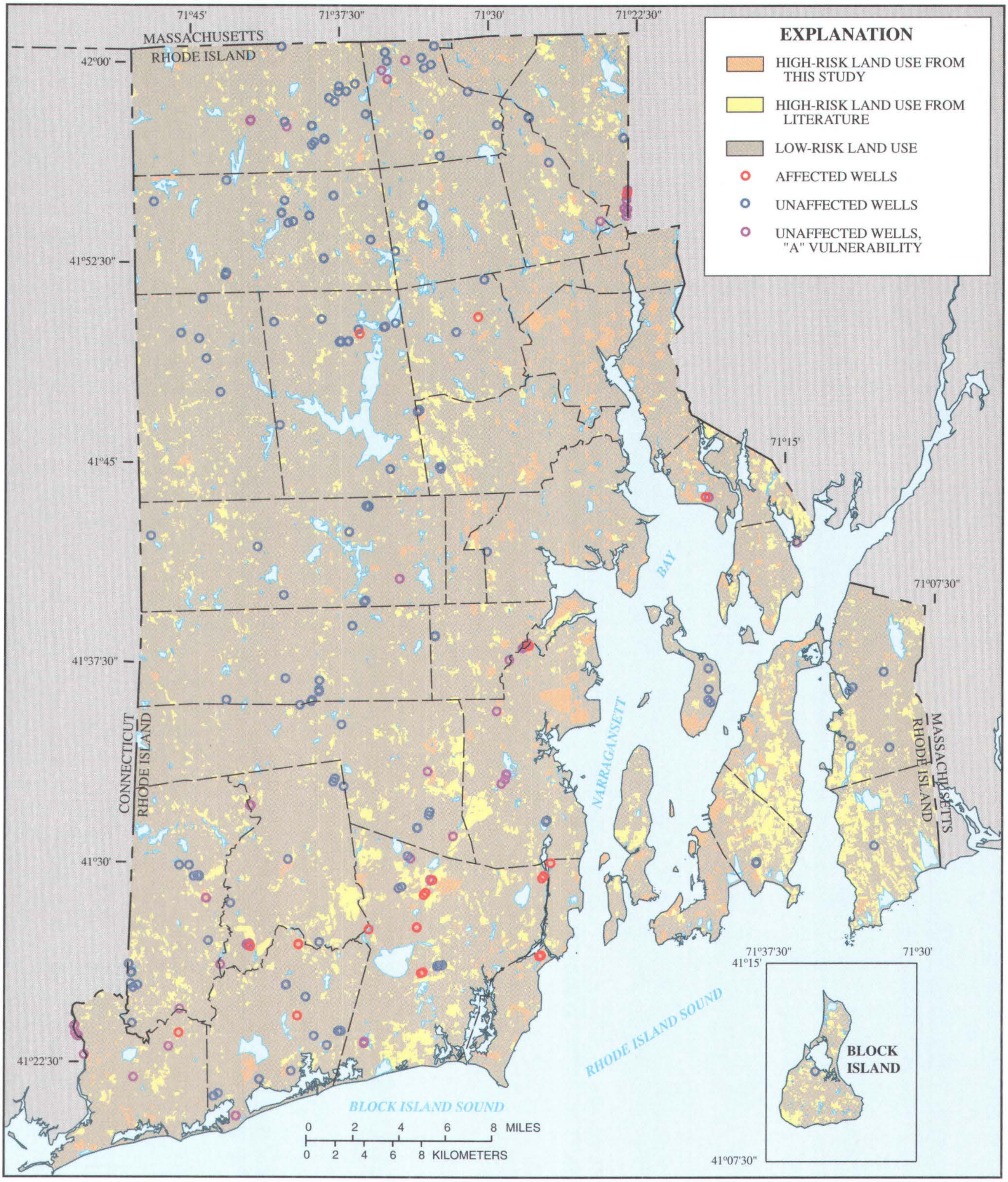

Base from the Rhode Island Geographic Information System (RIGIS)
of the Rhode Island Board of Governors for Higher Education,
State base map, 1:24,000, 1989,
Based on Rhode Island coordinate system

**Figure 28.** Distribution of high- and low-risk land use and community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected for nutrients. Affected wells are wells in which measured nitrate concentrations exceeded 1 milligram per liter as nitrogen.




Base from the Rhode Island Geographic Information System (RIGIS)
of the Rhode Island Board of Governors for Higher Education,
State base map, 1:24,000, 1989,
Based on Rhode Island coordinate system

**Figure 29.** Distribution of high- and low-risk land use and community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected for solvents and other industrial organic chemicals.




Base from the Rhode Island Geographic Information System (RIGIS)
of the Rhode Island Board of Governors for Higher Education,
State base map, 1:24,000, 1989,
Based on Rhode Island coordinate system

**Figure 30.** Distribution of high- and low-risk land use and community and non-community, non-transient supply wells in Rhode Island that are affected and unaffected for pesticides.

Factors significantly associated with elevated concentrations of road-deicing chemicals (or sodium) were aquifer type and the area of urban and residential land uses, the area of forest cover (inversely related to road-deicing chemicals), soil characteristics, and road density in the WHPA. Most of these characteristics are tabulated in table 17. The density of all paved roads and the rank of soil-leaching potential risk were used to designate vulnerability categories. Paved-road density was considered to represent contamination sources from all urban land-use activities and from the road-salt application, because paved-road density and urban land use were correlated closely. The leaching potential rank was used rather than the area of soil hydrologic group A in the WHPA, because the difference in the area-weighted leaching potential rank between affected and unaffected groups yielded a lower *p*-value than the difference between areas of soil group A. Aquifer type was given less weight for road-deicing chemicals than for the other contaminant classes because the *p*-value for the test of aquifer type, although less than 0.05, was relatively high. Sand-and-gravel and bedrock wells for which the density of paved roads in the WHPA was greater than or equal to 8 $mi/mi^2$ (high road density) and for which the area-weighted leaching potential rank was greater than or equal to 4 (high soil rank) were expected to be most vulnerable to contamination by sodium ("A" wells); these values were based on the percentile values of road density and soil-leaching potential rank in affected and unaffected WHPAs (fig. 18). Wells with high road density but low soil rank were given an intermediate vulnerability designation ("B"). Wells with low road density and any soil rank were given the "C" designation, as they were expected to be least vulnerable to sodium contamination.

Nutrients, solvents, pesticides, and road-deicing chemicals all are contaminants with primarily anthropogenic sources. In addition, land use and other factors likely to contribute to the wells' vulnerability to these contaminants are similar. Thus, the distribution of vulnerability ranks among the supply wells for these four contaminant classes is similar (fig. 31), and, in many cases, wells that are ranked as most vulnerable to contamination by one of these classes are ranked as most vulnerable to the other classes. This suggests that an overall vulnerability ranking could be developed that might serve as an index of vulnerability to contamination by anthropogenic sources, although factors used for more than one contaminant class (for example, the urban land use with parks and golf courses) would be weighted more heavily in such an index. As an example, a overall vulnerability ranking was calculated by representing the vulnerability categories with numerical values (4, 3, 2, and 1 for categories "A," "B," "C," and "D" for nutrients and solvents, and 4, 2.5, and 1 for categories "A," "B," and "C" for pesticides and road-deicing chemicals) and summing these values for each well. Following this procedure, 53 wells are identified as most vulnerable to contamination (sum of numerical values greater than 12), and 33 wells are identified as least vulnerable (sum of numerical value less than or equal to 4), with the remaining 170 wells ranked as moderately vulnerable (sum of numerical values greater than 4 but less than or equal to 12; fig. 31).

Elevated concentrations of fluoride were found in bedrock wells and in wells located in areas of felsic and mafic crystalline rocks. Aquifer type, bedrock lithologic type at the wells, and median fluoride concentration at the wells are tabulated in table 18. Bedrock wells in the crystalline rock types are expected to be most vulnerable to fluoride contamination ("A" wells); sand-and-gravel wells located in these rock types are assigned to an intermediate vulnerability category ("B"); and wells of any aquifer type located in any other lithologic rock type are expected to be least vulnerable to fluoride contamination ("C" wells). Although correlated with median fluoride concentration, well depth was not used to assign vulnerability designations because of uncertainty in defining depth categories based on the available data. Unlike the distribution of high-risk land uses for other contaminant classes, the distribution of the "high-" and "low-risk" lithologic rock types for fluoride contamination lends itself well to statewide mapping of more and less vulnerable areas (fig. 32).

Aquifer type was the only factor significantly related to elevated activities of radionuclides (or gross alpha and beta radioactivity) in the present study, with bedrock wells more likely to be affected than sand-and-gravel wells. Fluoride concentrations, pH, and alkalinity also were significantly higher in affected wells, but, because they were higher in all bedrock wells, these geochemical factors were not used separately to assess vulnerability for radionuclides. Lithologic rock type or other categories of bedrock formations were not identified as significant factors

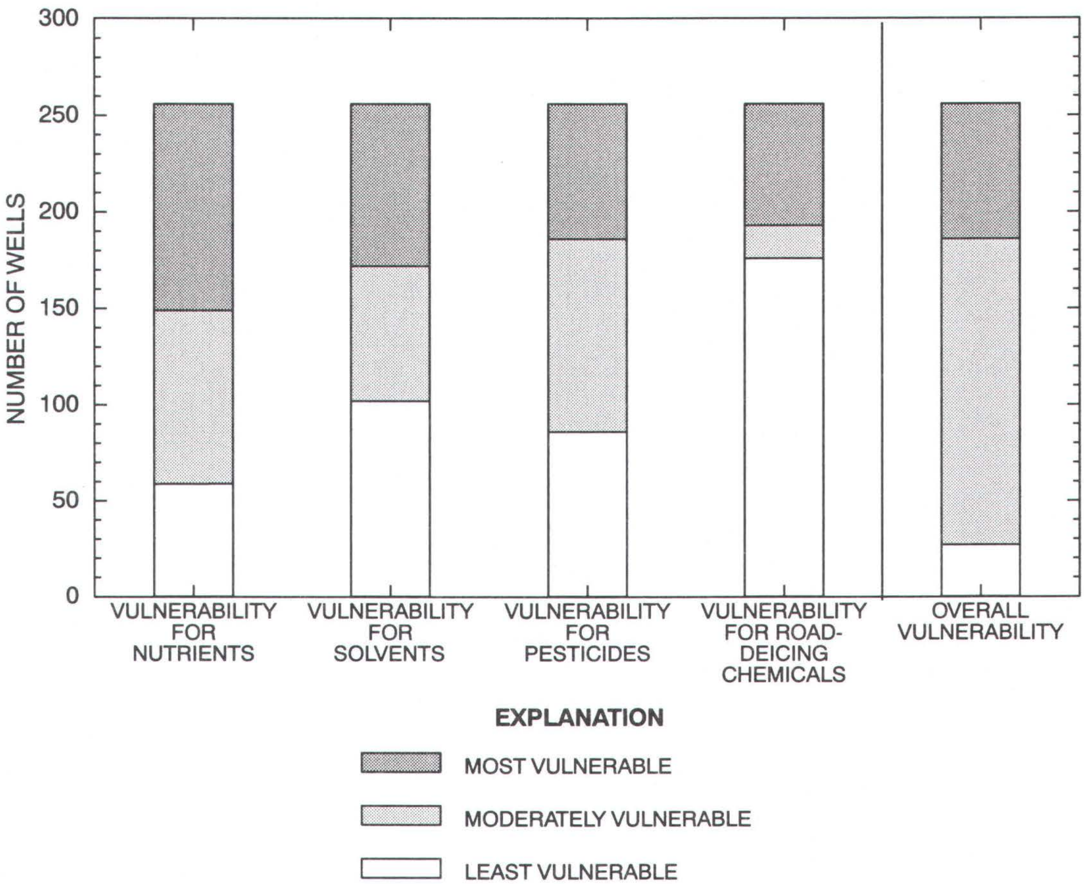
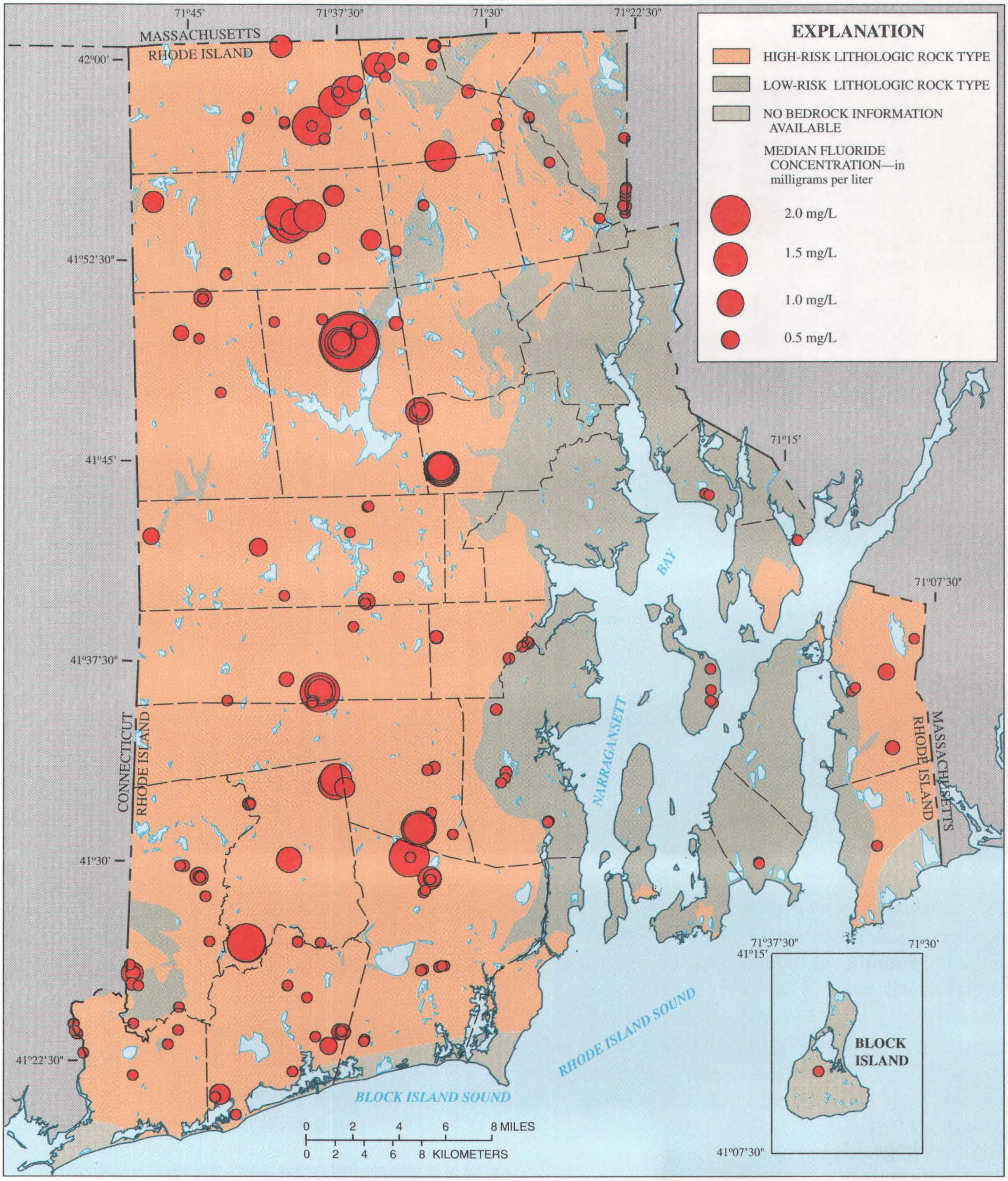



**Figure 31.** Distribution of relative vulnerability ranks among community and non-community, non-transient supply wells in Rhode Island for nutrients, solvents and other industrial organic chemicals, pesticides, and road-deicing chemicals. See text for definitions of vulnerability categories.

based on the data analysis of the present study. Literature sources indicate that bedrock geology, however, in terms of uranium content and other characteristics, is important for the distribution of radionuclides in ground water. Thus, bedrock formations identified in Gundersen and Schumann (1993) and Veeger and Ruderman (1998) as associated with the potential for high radon production in air (based on uranium content, surface radioactivity, and other factors) and high dissolved radon concentrations in ground water are used, along with aquifer type, to identify wells that would be expected to be more vulnerable to contamination by radionuclides ("A" wells, table 18). These bedrock formations are rocks of the Scituate Igneous Suite, the Hope Valley Group (Sterling Plutonic Group), the Narragansett Pier Plutonic Suite, and granites of southeastern Rhode Island (although no supply wells were located this bedrock unit, the alkalic granites of Cumberland also would be in this category). Bedrock wells at locations in other bedrock formations are assigned to an intermediate vulnerability category ("B" wells), and sand-and-gravel wells (in any bedrock formation), which would be expected to be least vulnerable to contamination by radionuclides, are designated as "C" wells. It should be noted that use of the specified bedrock formations to categorize some wells as more vulnerable to contamination by radionuclides than other wells represents a hypothesis based on limited available information, which would have to be tested by further data analysis.




Base from the Rhode Island Geographic Information System (RIGIS) of the Rhode Island Board of Governors for Higher Education, State base map, 1:24,000, 1989, Based on Rhode Island coordinate system

**Figure 32.** Distribution of high- and low-risk lithologic rock types for elevated fluoride and median fluoride concentrations at community and non-community, non-transient supply wells in Rhode Island.

## CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDY

Knowledge of the degree to which ground-water supplies are vulnerable to contamination and of the factors that influence their vulnerability is necessary for the management and protection of these resources. Methods of vulnerability assessment range from simple mapping exercises to complex statistical models, and vary with the purpose, scale, and resources available. In the present study, existing data that could be used for a statewide vulnerability assessment of public-supply wells in Rhode Island was compiled and a water-quality-based assessment method was developed. This method was used to investigate the relative vulnerability to contamination of 256 public-supply wells in the State.

Relative vulnerability was investigated for all community and non-community, non-transient public-supply wells that were active as of December 1996. Water-quality data for the 256 wells consisted of monitoring results for compliance with Safe Drinking Water Act regulations for 1988 to 1996 and were obtained, along with ancillary data for the wells, from the Rhode Island Department of Health. Spatial data include digital data layers of well locations, wellhead-protection areas (WHPAs), surficial and bedrock geology, soil type, land use, roads, surface-water hydrography, and known waste sites. These data layers were obtained and, in some cases, modified from the Geographic Information System of the Rhode Island Board of Governors for Higher Education (RIGIS). Relative vulnerability was investigated separately with respect to 10 classes of monitored drinking-water contaminants: nutrients, pesticides, solvents and other industrial organic chemicals, fuel hydrocarbons, road-deicing chemicals, fluoride, iron and manganese, trace inorganic chemicals (such as metals), radionuclides, and microbial contaminants. Wells were categorized as "affected" or "unaffected" for each class of contaminants on the basis of the historical water quality at the well and a threshold criterion or concentration that was specified for each class. Statistical tests were used to identify hydrogeologic, land-use, and other factors that were significantly different between affected and unaffected groups. These factors were considered indicators of a well's likelihood of being contaminated and thus potential contributors to a well's vulnerability to contamination.

Vulnerability factors were identified successfully for six contaminant classes: nutrients, pesticides, solvents and other industrial organic chemicals, road-deicing chemicals, fluoride, and radionuclides. Land use in the area contributing water to the well, represented by the WHPA, and aquifer type were the best indicators of potential contamination for contaminants with primarily anthropogenic sources, that is, nutrients, pesticides, solvents, and road-deicing chemicals. Significant land uses for different classes were: residential land use and an urban land use that includes parks and golf courses, for nutrients (tested using nitrate concentrations); the urban land use with parks and golf courses and institutional land use, for pesticides; industrial land use, for solvents; and urban land use for road-deicing chemicals (tested using sodium concentrations). Wells screened in stratified-drift aquifers (sand-and-gravel wells) were more likely than bedrock wells to be affected for all four of these contaminant classes. Factors representing soil characteristics and the density of paved roads in the WHPA also were significant for road-deicing chemicals. Soil characteristics and agricultural land use were likely to be important for pesticides also, although these factors were not statistically significant in the present study. The patchy distribution of these high-risk land uses suggests that regional or statewide mapping of vulnerability to the contaminants in these classes would be difficult. For fluoride, which occurs naturally in ground water, lithologic rock type and aquifer type were indicators of vulnerability. Elevated fluoride concentrations were more likely to occur in areas of felsic, intermediate, mafic, and mixed igneous and metamorphic rocks than in areas of other lithologic rock types. Areas more or less vulnerable to fluoride contamination are more readily mapped on a statewide basis. Aquifer type was the only factor found to be significant for radionuclides (tested using gross alpha and beta radioactivity), with higher activities more likely to occur in bedrock than in sand-and-gravel wells.

Factors on which to base a vulnerability assessment could not be identified for fuel hydrocarbons, iron and manganese, trace inorganic chemicals, and microbial contaminants. For fuel hydrocarbons, this finding may reflect the inadequacy of the available land-use data at the statewide scale for characterizing potential contaminant sources. Although not specifically assessed in the present study, vulnerability to contamination by fuel hydrocarbons could be assessed on the basis of the amount of urban land use near the well or in its contributing area; in several studies, urban land use has been related generally to contamination by VOCs, including fuel hydrocarbons.

For iron and manganese and trace inorganic chemicals (mostly metals), the approach used in the present study was unable to identify factors related to contaminant occurrence for several probable reasons. Iron, manganese, and other metals occur naturally in the environment, although some metals also have anthropogenic sources. Thus, land-use data and spatial data characterizing the surficial deposits are less effective in explaining the distribution of these contaminants than they are for primarily anthropogenic contaminants. In addition, the occurrence and mobility of iron, manganese, and many other metals in ground water are controlled by subsurface geochemical conditions, by interaction with sediments, and, under some conditions, by microbial processes, in addition to the distribution of natural sources. Data were not available, however, to describe relevant subsurface geochemical conditions, such as dissolved-oxygen concentrations, at the well and in the aquifer from which water is withdrawn. The use of available water-quality data, collected from the supply wells for regulatory purposes, also presented greater problems for these contaminant classes than for others for which the data analysis was more successful. Samples for analyses of iron, manganese, and other metals that are sensitive to redox conditions or are related to suspended particle concentrations may be easily altered during sample collection and processing. Sampling effects could introduce unknown sources of variability that would tend to obscure relations between contaminant concentrations in the source water and potential explanatory variables. Finally, many of the trace inorganic chemicals were detected in small numbers of wells and at concentrations at or near the reported method detection limits. The resulting small sample sizes and low concentrations limited the possible threshold criteria that could be used or made the approach of the present study impossible for some constituents. The potential for contamination of samples from contact with metallic well or distribution-system materials also is an important limitation for the use of the available water-quality data in a vulnerability assessment for these contaminants.

Results of the data analysis for microbial contaminants suggested that vulnerability to these contaminants may be related to well characteristics in some cases, such as depth to the top of the screened or open interval of the well. The available data on relevant well characteristics, however, were limited. In addition, well-construction and maintenance procedures may be more important than environmental or hydrogeologic characteristics for microbial contaminants in the supply wells. Thus, a weak correlation of microbial contaminants with the environmental or hydrogeologic factors would be obscured.

Results of the present study should be considered a preliminary assessment of relative vulnerability of supply wells in Rhode Island. The assessment could be improved and tested by further investigation in several ways. Better definition of the areas contributing water to wells would allow for more accurate assessment of land areas likely to affect water quality at the wells. This is especially important for bedrock wells, for which WHPAs were based on less site-specific hydrogeologic information than for sand-and-gravel wells. Better-defined contributing areas could result in more accurately identified vulnerability factors for all wells, and in more appropriately designated vulnerability categories for individual wells. Present-day risks for individual supply wells might be more accurately depicted with more recent land-use data than the 1988 data used in the present study. Analysis of changes in land uses and time trends in water-quality conditions might be used to investigate the role of times-of-travel in the vulnerability assessment. For example, bedrock wells may have appeared less vulnerable to contamination by anthropogenic chemicals than sand-and-gravel wells because of longer times-of-travel from the land surface to some bedrock wells, or because water from bedrock wells, which tend to be open throughout their length, may be a mixture of older and younger water.

Further studies of the relative vulnerability of supply wells in Rhode Island could include the collection of additional data. Water-quality data, collected from randomly chosen locations with a consistent sampling frequency and with closely controlled sampling procedures, could support more rigorous analytical approaches or be used to test the results of the present study. More complete data sets for well characteristics would allow a more robust analysis of the relation of these factors to well vulnerability. Further investigation of how sand-and-gravel and bedrock wells differ with respect to relative vulnerability could be made with larger water-quality sample sizes, or through data-collection programs that target one aquifer type. Newly collected water-quality data, or perhaps subsampling of existing data, might support the use of multivariate statistical techniques. Multivariate analysis would yield more objective methods of combining multiple significant factors into a vulnerability ranking scheme and more quantitative, predictive models of vulnerability. Such approaches also could allow for the uncertainty associated with the assessment to be quantified. Finally, data collection and analysis at the spatial scale of individual wells and WHPAs could define better the relations between land-use activities and the occurrence of specific contaminants at the supply wells, thereby yielding a better understanding of how these activities contribute to the vulnerability of supply wells to contamination.

In conclusion, results of the present study provide a preliminary assessment of the factors that affect the relative vulnerability of the community and non-community, non-transient supply wells in Rhode Island to monitored drinking-water contaminants. Because of the limitations of land-use, hydrogeologic, and other spatial data at the statewide scale and because of the complexities of ground-water flow paths to specific supply wells, site-specific studies are needed for the determination of the susceptibility of wells to specific contaminant sources in their contributing areas. Results of the present study, however, may be used in several ways to support water-supply and source-water management and protection in Rhode Island. The vulnerability designations developed in this study (or as modified by resource managers) may be used as a screening tool at the statewide scale to identify and prioritize supply wells and systems for more detailed and extensive susceptibility assessments. Relations between specific land uses and the historical occurrence of contaminants at the wells identified in the present study may be used to identify, among multiple potential contamination sources in WHPAs, those types of sources that should be considered significant. Data on land use in WHPAs also could be used to create a large-scale inventory of potential contamination sources. Finally, results of this study could be used to design data-collection and analysis approaches for more detailed or quantitative vulnerability assessments.

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# TABLES

**Table 12**. Community and non-community, non-transient public supply systems and wells in Rhode Island and available well data

[**Supply type:** C, community; P, non-community, non-transient. **Source identifier:** Combines the public-water system identifier (PWSID) and the source number assigned by the Rhode Island Department of Health. **USGS-ID:** identifier used in figures 2 and 3. **WHPA:** Wellhead-protection area. **Aquifer type:** BD, bedrock; D, dug well of undetermined aquifer type; SD, sand and gravel; U, drilled well of undetermined aquifer type. no., number; --, not available]

| Supply type | Source identifier | System name | Source name | USGS-ID | WHPA | Aquifer type | Well depth, in feet | Depth to water, in feet | Depth to bedrock, in feet |
|---|---|---|---|---|---|---|---|---|---|
| C | 1000009-1 | Abbey Lane Community Association, Inc. | Drilled well no. 2 | 63 | C23 | BD | 617 | 3 | -- |
| C | 1000009-4 | Abbey Lane Community Association, Inc. | Drilled well no. 3 | 178 | C23 | BD | 440 | -- | 13 |
| C | 1000020-1 | Scituate Housing for the Elderly/Rockland Oaks | Drilled well no. 1 | 68 | C27 | BD | 630 | 20 | 6 |
| C | 1000020-2 | Scituate Housing for the Elderly/Rockland Oaks | Well no. 2 | 67 | C27 | BD | 705 | 20 | 6 |
| C | 1000020-3 | Scituate Housing for the Elderly/Rockland Oaks | Drilled well no. 3 | 69 | C27 | BD | -- | -- | -- |
| C | 1000035-3 | Castle Rock Condominiums | Well no. 4 | 150 | C63 | BD | 125 | 25 | 20 |
| C | 1000035-4 | Castle Rock Condominiums | Well no. 5 | 152 | C63 | BD | 400 | 40 | 16 |
| C | 1000035-5 | Castle Rock Condominiums | Well no. 6 | 151 | C63 | BD | 500 | 30 | 18 |
| C | 1000040-1 | Richmond Water Supply Board | Gravel-packed well no. 1 | 113 | C50 | SD | 65 | -- | -- |
| C | 1000040-2 | Richmond Water Supply Board | Gravel-packed well no. 2 | 180 | C50 | SD | 54 | -- | -- |
| C | 1000043-2 | Canonchet Cliffs I/Hopkinton Housing | Well no. 2 | 124 | C55 | BD | 510 | 15 | 13 |
| C | 1000043-3 | Canonchet Cliffs I/Hopkinton Housing | Well no. 4 | 125 | C55 | BD | 600 | | 12 |
| C | 1000045-1 | Bethel Village Water Association | Well no. 1 | 141 | C59 | BD | 167 | 10 | 74 |
| C | 1000045-2 | Bethel Village Water Association | Well no. 2 | 142 | C59 | BD | 230 | 20 | 68 |
| C | 1000098-1 | Green Fairways Golf Partners, L.C., DBA Lindhbrook Water System | Gravel-developed well no. 1 | 133 | C55 | SD | 43 | 2.5 | -- |
| C | 1000098-2 | Green Fairways Golf Partners, L.C., DBA Lindhbrook Water System | Gravel-developed well no. 2 | 132 | C55 | SD | 42 | 2 | -- |
| C | 1559511-1 | Kent County Water Authority | E. Green well no. 1 | 90 | C38 | SD | 118 | -- | -- |
| C | 1559511-2 | Kent County Water Authority | Spring Lake well | 82 | C34 | SD | 79 | -- | -- |
| C | 1559511-3 | Kent County Water Authority | Mishnock well no. 1 | 85 | C36 | SD | 75 | -- | -- |
| C | 1559511-4 | Kent County Water Authority | Mishnock well no. 2 | 84 | C36 | SD | 88 | -- | -- |
| C | 1559512-1 | Westerly Water Department | Well no. 1A | 153 | C61 | SD | 71 | 1.5 | -- |
| C | 1559512-10 | Westerly Water Department | Noyes Ave. well | 159 | C66 | SD | 65 | 4 | -- |
| C | 1559512-11 | Westerly Water Department | Crandall well | 161 | C67 | SD | 82 | -- | -- |
| C | 1559512-2 | Westerly Water Department | Well no. 1B | 155 | C61 | SD | 71 | 3 | -- |
| C | 1559512-3 | Westerly Water Department | Well no. 1C | 154 | C61 | SD | 74 | 11 | -- |

**Table 12.** Community and non-community, non-transient public supply systems and wells in Rhode Island and available well data—*Continued*

| Supply type | Source identifier | System name | Source name | USGS-ID | WHPA | Aquifer type | Well depth, in feet | Depth to water, in feet | Depth to bedrock, in feet |
|---|---|---|---|---|---|---|---|---|---|
| C | 1559512-4 | Westerly Water Department | Well no. 2A | 147 | C61 | SD | 73 | 11 | -- |
| C | 1559512-5 | Westerly Water Department | Well no. 2B | 145 | C61 | SD | 75 | 14 | -- |
| C | 1559512-6 | Westerly Water Department | Well no. 2C | 146 | C61 | SD | 75 | -- | -- |
| C | 1559512-7 | Westerly Water Department | Well no. 3 | 149 | C61 | SD | 73 | 5 | -- |
| C | 1559512-8 | Westerly Water Department | Bradford well no. 2 | 148 | C65 | SD | 82 | 8 | -- |
| C | 1559512-9 | Westerly Water Department | Bradford well no. 3 | 158 | C65 | SD | 69 | 7 | -- |
| C | 1559513-1 | Shady Harbor Fire District | Gravel-developed well no. 3 | 166 | C69 | SD | 27 | 4 | 27 |
| C | 1559513-2 | Shady Harbor Fire District | Gravel-developed well no. 4 | 164 | C69 | SD | 45 | -- | 45 |
| C | 1559513-4 | Shady Harbor Fire District | Drilled well no. 6 | 165 | C69 | BD | 265 | 1.5 | 30 |
| C | 1559513-5 | Shady Harbor Fire District | Drilled well no. 7 | 163 | C69 | BD | 265 | -- | 19 |
| C | 1559517-1 | Town of North Kingstown | Well no. 1 | 106 | C47 | SD | 50 | 7 | -- |
| C | 1559517-10 | Town of North Kingstown | Drilled well no. 8 | 118 | C52 | SD | -- | -- | -- |
| C | 1559517-2 | Town of North Kingstown | Well no. 2 | 107 | C47 | SD | 56 | 15 | -- |
| C | 1559517-3 | Town of North Kingstown | Well no. 3 | 116 | C52 | SD | 66 | 6 | -- |
| C | 1559517-4 | Town of North Kingstown | Well no. 4 | 108 | C47 | SD | 68 | -- | -- |
| C | 1559517-5 | Town of North Kingstown | Well no. 5 | 110 | C47 | SD | 72 | -- | -- |
| C | 1559517-6 | Town of North Kingstown | Well no. 6 | 104 | C46 | SD | 85 | -- | -- |
| C | 1559517-7 | Town of North Kingstown | Well no. 9 | 91 | C38 | SD | 118 | -- | -- |
| C | 1559517-8 | Town of North Kingstown | Well no. 10 | 92 | C38 | SD | 107 | -- | -- |
| C | 1559517-9 | Town of North Kingstown | Drilled well no. 7 | 117 | C52 | SD | -- | -- | -- |
| C | 1559519-1 | Mohegan Water Association, Inc. | Well no. 1 | 28 | C5 | BD | 650 | 50 | 6.5 |
| C | 1559519-2 | Mohegan Water Association, Inc. | Well no. 4 | 27 | C5 | BD | 505 | 40 | 8 |
| C | 1583825-1 | Glendale Water Association | Drilled rock well | 29 | C6 | BD | 417 | -- | -- |
| C | 1592012-2 | State-Operated Facilities DDD/MHRH (Ladd School) | Well no. 2 | 105 | C48 | SD | 55 | 6.2 | -- |
| C | 1592019-1 | Oakland Water Association | Drilled rock well | 38 | C10 | BD | 150 | 30 | -- |
| C | 1592019-2 | Oakland Water Association | New drilled well | 176 | C10 | BD | 280 | 20 | 21 |
| C | 1592020-1 | Pascoag Fire District | Well no. 2 | 32 | C11 | SD | 41 | -- | -- |
| C | 1592020-2 | Pascoag Fire District | Well no. 3 | 34 | C11 | SD | 57 | -- | -- |
| C | 1592021-2 | City of Pawtucket | Well no. 2 | 56 | C16 | SD | 69 | -- | -- |
| C | 1592021-3 | City of Pawtucket | Well no. 3 | 55 | C16 | SD | 43 | -- | -- |

**Table 12**. Community and non-community, non-transient public supply systems and wells in Rhode Island and available well data—*Continued*

| Supply type | Source identifier | System name | Source name | USGS-ID | WHPA | Aquifer type | Well depth, in feet | Depth to water, in feet | Depth to bedrock, in feet |
|---|---|---|---|---|---|---|---|---|---|
| C | 1592021-4 | City of Pawtucket | Well no. 4 | 54 | C16 | SD | 82 | -- | -- |
| C | 1592021-5 | City of Pawtucket | Well no. 5 | 53 | C16 | SD | 62 | -- | -- |
| C | 1592021-6 | City of Pawtucket | Well no. 6 | 50 | C16 | SD | 55 | -- | -- |
| C | 1592021-7 | City of Pawtucket | Well no. 7 | 47 | C16 | SD | 49 | -- | -- |
| C | 1592021-8 | City of Pawtucket | Well no. 8 | 46 | C16 | SD | 89 | -- | -- |
| C | 1592021-9 | City of Pawtucket | Well no. 9 | 45 | C16 | SD | 56 | -- | -- |
| C | 1592023-1 | Prudence Island Utility Corporation | Bristol Colony | 102 | C39 | BD | 105 | 38 | -- |
| C | 1592023-5 | Prudence Island Utility Corporation | Broadway well no. 1 | 100 | C39 | BD | 180 | 25 | -- |
| C | 1592023-7 | Prudence Island Utility Corporation | Army well | 98 | C39 | BD | 322 | 30 | -- |
| C | 1592023-8 | Prudence Island Utility Corporation | Indian Spring well no. 1 | 94 | C39 | BD | 464 | 5 | 12 |
| C | 1592023-9 | Prudence Island Utility Corporation | Indian Spring well no. 4 | 179 | C39 | BD | 464 | 5 | 12 |
| C | 1615614-1 | Slatersville Public Supply | Driven wellfield | 26 | C2 | SD | -- | -- | -- |
| C | 1615614-2 | Slatersville Public Supply | Pacheco Park well | 25 | C2 | BD | -- | -- | -- |
| C | 1615614-5 | Slatersville Public Supply | Well no. 6 | 24 | C3 | SD | -- | -- | -- |
| C | 1615623-1 | South Kingstown–South Shore | Well no. 1 | 157 | C62 | SD | 57 | 34 | -- |
| C | 1615623-2 | South Kingstown–South Shore | Well no. 2 | 156 | C62 | SD | 56 | 26 | -- |
| C | 1615624-1 | United Water Rhode Island | Gravel-packed well no. 2 | 137 | C58 | SD | 55 | 8 | -- |
| C | 1615624-2 | United Water Rhode Island | Gravel-packed well no. 3 | 138 | C58 | SD | 55 | 3 | -- |
| C | 1615624-3 | United Water Rhode Island | Gravel-packed well no. 4 | 136 | C58 | SD | 55 | 5 | -- |
| C | 1615624-4 | United Water Rhode Island | Gravel-packed well no. 5 | 139 | C58 | SD | 98 | 8.5 | -- |
| C | 1615624-5 | United Water Rhode Island | Gravel-packed well no. 6 | 140 | C58 | SD | 84 | 12.5 | -- |
| C | 1615624-7 | United Water Rhode Island | Gravel-packed well no. 1 | 135 | C58 | SD | 66 | 3 | -- |
| C | 1615626-1 | Touisset Point Water Trust | Coggeshall well | 80 | C33 | SD | 40 | 33 | -- |
| C | 1615626-2 | Touisset Point Water Trust | George St. well | 81 | C33 | SD | 46 | -- | -- |
| C | 1647512-1 | Central Beach Fire District | Well no. 1 | 167 | C70 | SD | 20 | -- | -- |
| C | 1647512-2 | Central Beach Fire District | Well no. 2 | 168 | C70 | SD | 28 | 4 | -- |
| C | 1647515-5 | Bristol County Water Authority | Well no. 1A | 77 | C30 | SD | -- | -- | -- |
| C | 1647515-6 | Bristol County Water Authority | Well no. 2 | 76 | C30 | SD | 84.5 | -- | -- |
| C | 1647526-1 | Brandy Acres | Drilled rock well | 44 | C17 | BD | 200 | 50 | 70 |
| C | 1647529-1 | Shannock Cooperative Water Association | Well no. 1 | 134 | C57 | BD | 85 | 12 | 30 |

**Table 12**. Community and non-community, non-transient public supply systems and wells in Rhode Island and available well data—*Continued*

| Supply type | Source identifier | System name | Source name | USGS-ID | WHPA | Aquifer type | Well depth, in feet | Depth to water, in feet | Depth to bedrock, in feet |
|---|---|---|---|---|---|---|---|---|---|
| C | 1647530-1 | Town of Cumberland | Manville well no. 2 | 33 | C7 | SD | 55 | 28 | -- |
| C | 1647530-3 | Town of Cumberland | Abbott Run no. 2 | 40 | C14 | SD | 50 | 26 | -- |
| C | 1647530-4 | Town of Cumberland | Abbott Run no. 3 | 39 | C14 | SD | 50 | 29 | -- |
| C | 1647530-5 | Town of Cumberland | Manville well no. 1 | 31 | C7 | SD | 86 | 28 | -- |
| C | 1858411-1 | Harrisville Fire District | Well no. 2 | 35 | C12 | SD | 34 | -- | -- |
| C | 1858411-2 | Harrisville Fire District | Well no. 3 | 37 | C13 | SD | 36 | -- | -- |
| C | 1858421-1 | Kingston Water District | Well no. 1 | 130 | C56 | SD | 64 | 9 | -- |
| C | 1858421-2 | Kingston Water District | Well no. 2 | 131 | C56 | SD | 65 | 10 | -- |
| C | 1858422-1 | University of Rhode Island | Well no. 2 | 128 | C56 | SD | 132 | 8 | -- |
| C | 1858422-2 | University of Rhode Island | Well no. 3 | 129 | C56 | SD | 138 | 21 | -- |
| C | 1858422-3 | University of Rhode Island | Well no. 4 | 127 | C56 | SD | 95 | 27 | -- |
| C | 1858423-5 | Town of Lincoln | Well no. 4–Lonsdale | 59 | C20 | SD | -- | -- | -- |
| C | 1858435-1 | Hemlock Village | Drilled well | 70 | C28 | BD | 445 | 28 | 108 |
| C | 1900020-1 | Woodland Homeowner's Association | Gravel-packed well | 78 | C32 | SD | 65 | -- | -- |
| C | 1900023-1 | Lippitt Hill Estates | Well no. 4 | 74 | C29 | BD | -- | -- | -- |
| C | 1900023-2 | Lippitt Hill Estates | Well no. 5 | 75 | C29 | BD | -- | -- | -- |
| C | 1900023-3 | Lippitt Hill Estates | Well no. 1 | 71 | C29 | BD | -- | -- | -- |
| C | 1900023-4 | Lippitt Hill Estates | Well no. 2 | 72 | C29 | BD | -- | -- | -- |
| C | 1900023-5 | Lippitt Hill Estates | Well no. 3 | 73 | C29 | BD | -- | -- | -- |
| C | 1900025-2 | Canonchet Cliffs II/Hopkinton Village, Inc. | Drilled well no. 5 | 126 | C55 | BD | 600 | -- | -- |
| C | 1900029-1 | Crescent Club | Drilled well | 160 | C68 | BD | -- | -- | -- |
| C | 1900034-1 | Nasonville Water District | Well field A | 30 | C8 | SD | 40 | -- | -- |
| C | 1900034-2 | Nasonville Water District | Well field B | 181 | C8 | SD | 40 | -- | -- |
| C | 1900036-1 | Slater Village Condominium | Drilled well no. 1 | 170 | C4 | U | -- | -- | -- |
| C | 1900036-2 | Slater Village Condominium | Drilled well no. 2 | 171 | C4 | U | -- | -- | -- |
| C | 1900039-1 | Eastern Passage Trust Development | Rock well | 174 | C41 | BD | -- | -- | -- |
| C | 1900048-2 | Canonchet Cliffs III | Well no. 6 | 123 | C55 | BD | 300 | 10 | 10 |
| C | 1900049-1 | Tuspani Water Company | Gravel-packed well | 183 | C74 | SD | -- | -- | -- |
| C | 2000004-2 | Woodpecker Hill Nursing Home | Drilled well no. 1 | 79 | C31 | BD | 90 | 10 | -- |
| C | 2000059-1 | Harmony Hill School, Inc. | Drilled well no. 1 | 49 | C18 | BD | -- | -- | -- |

**Table 12**. Community and non-community, non-transient public supply systems and wells in Rhode Island and available well data—*Continued*

| Supply type | Source identifier | System name | Source name | USGS-ID | WHPA | Aquifer type | Well depth, in feet | Depth to water, in feet | Depth to bedrock, in feet |
|---|---|---|---|---|---|---|---|---|---|
| C | 2000059-2 | Harmony Hill School, Inc. | Drilled well no. 2 | 48 | C18 | BD | 600 | -- | -- |
| C | 2000083-1 | Hebert Nursing Home, Inc. | Drilled well no. 1 | 52 | C19 | BD | 180 | -- | -- |
| C | 2000083-2 | Hebert Nursing Home, Inc. | Drilled well no. 2 | 51 | C19 | BD | 410 | -- | -- |
| C | 2000084-1 | Waterman Heights Nursing Home | Drilled well no. 1 | 62 | C22 | BD | 165 | 50 | 12 |
| C | 2000165-1 | Shady Acres Rest Home | Drilled well no. 2 | 112 | C49 | BD | 435 | -- | -- |
| C | 2051311-1 | Heritage Park | Drilled well no. 1 | 97 | C43 | BD | 170 | 15 | -- |
| C | 2415415-1 | Oak Crest Manor, Inc. | Drilled well no. 1 | 64 | C24 | BD | 254 | 20 | 80 |
| C | 2519424-1 | Davis Mobile Homes Parks, Inc. | Drilled well no. 2 | 60 | C21 | BD | 180 | -- | 30 |
| C | 2519424-3 | Davis Mobile Homes Parks, Inc. | Drilled well no. 3 | 177 | C21 | BD | 500 | -1 | 7 |
| C | 2519426-1 | Alpine Nursing Home | Drilled well no. 1 | 83 | C35 | BD | 278 | 20 | -- |
| C | 2585312-1 | Split Rock Corporation | Dug well no. 2 | 115 | C51 | DG | -- | -- | -- |
| C | 2585312-2 | Split Rock Corporation | Drilled well no. 1 | 114 | C51 | BD | -- | -- | -- |
| C | 2585313-1 | Mobile Village Park, Inc. | Drilled well no. 1 | 103 | C45 | BD | 60 | -- | -- |
| C | 2674924-1 | Border Hill Mobile Home Park | Drilled well no. 2 (north) | 182 | C64 | SD | 146 | -- | -- |
| C | 2674925-1 | Indian Cedar Mobile Home Park | Drilled well no. 1 | 144 | C60 | BD | 50 | 22 | -- |
| C | 2674925-2 | Indian Cedar Mobile Home Park | Drilled well no. 2 | 143 | C60 | BD | 60 | -- | -- |
| C | 2674928-1 | Ninigret Realty Company (Land Harbor) | Drilled well no. 1 | 162 | C68 | BD | 60 | 25 | -- |
| C | 2753326-1 | Meadowlark Mobile Home Park, Inc. | Drilled no. 1 (pumphouse) | 121 | C54 | BD | 136 | 21 | -- |
| C | 2753326-3 | Meadowlark Mobile Home Park, Inc. | Drilled no. 2 (laundry) | 122 | C54 | BD | 135 | 21 | -- |
| C | 2788012-1 | Nancy Ann Nursing Home, Inc. | Drilled well no. 1 | 66 | C26 | BD | 120 | -- | 18 |
| C | 2814410-3 | Blueberry Heights Mobile Park | Drilled well no. 3 | 96 | C42 | BD | 300 | -- | 36 |
| C | 2882117-3 | Allen's Health Center, DBA Allen's Nursing Home | Gravel-pack well no. 3 | 120 | C53 | SD | 32 | -- | -- |
| C | 2882117-4 | Allen's Health Center, DBA Allen's Nursing Home | Drilled well no. 2 | 119 | C53 | BD | 364 | -- | -- |
| C | 2942518-1 | Woodland Convalescent Center | Drilled well no. 1 | 36 | C9 | BD | 1,180 | 30 | -- |
| C | 2942525-1 | Hillsdale Housing Cooperative, Inc. | Drilled well no. 2 | 111 | C49 | BD | 520 | 20 | 4.5 |
| C | 2942525-3 | Hillsdale Housing Cooperative, Inc. | Drilled well no. 1A | 109 | C49 | BD | 550 | 20 | 5.5 |
| C | 2943224-8 | Hemlock Estates | Drilled well no. 7 | 61 | C21 | BD | -- | -- | -- |
| C | 2973130-1 | Maplehill Mobile Home Village | Gravel-pack no. 1 | 42 | C15 | SD | -- | -- | -- |
| C | 2973130-2 | Maplehill Mobile Home Village | Gravel-pack no. 2 | 43 | C15 | SD | -- | -- | -- |
| C | 2973130-3 | Maplehill Mobile Home Village | Gravel-pack no. 3 | 41 | C15 | SD | -- | -- | -- |

**Table 12**. Community and non-community, non-transient public supply systems and wells in Rhode Island and available well data—*Continued*

| Supply type | Source identifier | System name | Source name | USGS-ID | WHPA | Aquifer type | Well depth, in feet | Depth to water, in feet | Depth to bedrock, in feet |
|---|---|---|---|---|---|---|---|---|---|
| C | 2980001-1 | Four Seasons Mobile Home Park | Drilled well no. 1 | 95 | C40 | BD | -- | -- | -- |
| C | 2980003-1 | Lawrence Sunset Cove Association | Drilled well no. 1 | 99 | C43 | BD | 90 | -- | -- |
| C | 2980145-1 | Camp E-Hun-Tee | Drilled well no. 1 | 101 | C44 | BD | 450 | -- | -- |
| C | 2980146-1 | Laurel Crest Housing | Drilled well no. 1 (old) | 58 | C21 | BD | 200 | 20 | 90 |
| C | 2980146-3 | Laurel Crest Housing | Drilled well no. 2 (new) | 57 | C21 | BD | 300 | 20 | 92 |
| C | 2980196-2 | E. Searles Ball Memorial Housing | Gravel pack | 169 | C71 | SD | 91 | 29 | -- |
| C | 2980258-1 | Deerfield Commons/North Smithfield Properties, L.L.C. | Drilled well no. 1 | 22 | C1 | BD | 800 | -- | -- |
| C | 2980258-2 | Deerfield Commons/North Smithfield Properties, L.L.C. | Drilled well no. 2 | 23 | C1 | BD | 800 | -- | -- |
| C | 2980258-5 | Deerfield Commons/North Smithfield Properties, L.L.C. | Drilled well no. 5 | 173 | C1 | BD | 800 | -- | -- |
| C | 2980264-1 | Marathon House (Exeter) | Drilled well | 186 | C72 | BD | -- | -- | -- |
| C | 2980276-1 | Pheasant Ridge Homeowners Association | Drilled well no. 1 | 86 | C37 | BD | 200 | 12 | -- |
| C | 2980276-2 | Pheasant Ridge Homeowners Association | Drilled well no. 2 | 87 | C37 | BD | 575 | 14 | 10 |
| C | 2980323-1 | Scituate Commons | Drilled well | 65 | C25 | BD | 240 | -- | -- |
| C | 2980340-1 | Apple Creek at Windwood Apartments | Drilled well | 185 | C73 | BD | 110 | -- | -- |
| P | 1000007-1 | Fogarty Memorial School | Well no. 3 | 102 | P20 | BD | 250 | 30 | 3 |
| P | 1000007-2 | Fogarty Memorial School | Well no. 4 | 103 | P20 | BD | 205 | 55 | 5 |
| P | 1000025-1 | Crest Manufacturing Company. | Drilled well no. 1 | 17 | P14 | BD | 125 | 0 | 20 |
| P | 1000039-1 | University of Rhode Island–Liberty Lane | Gravel-developed well | 72 | P49 | SD | 70 | -- | -- |
| P | 1000042-1 | Branch River Industrial Park | Drilled well | 5 | P4 | BD | 300 | -- | 7 |
| P | 1559510-1 | Mildred E. Lineham School | Drilled rock well | 50 | P37 | BD | 220 | -- | 28 |
| P | 1559516-1 | Imperial Wallcoverings, Inc. | Well no. 2 | 92 | P59 | SD | 80 | 8.5 | -- |
| P | 1559516-2 | Imperial Wallcoverings, Inc. | Well no. 3 | 104 | P59 | SD | 75 | 5 | -- |
| P | 1583819-3 | Metcalf Elementary School | Well no. 1 (ballfield) | 56 | P39 | BD | 120 | -- | 15 |
| P | 1583819-4 | Metcalf Elementary School | Well no. 2 (garage) | 55 | P39 | BD | 120 | 29 | 25 |
| P | 1583820-1 | Wawaloam School | Drilled rock well no. 1 | 57 | P40 | BD | 355 | 20 | 10 |
| P | 1583823-1 | Captain Isaac Paine School | Drilled rock well | 36 | P29 | BD | 160 | -- | -- |
| P | 1583827-1 | Chepachet School/Town Buildings | Drilled rock well | 18 | P15 | BD | 250 | -- | -- |
| P | 1583829-4 | Ponaganset High School | Well no. 4 | 26 | P19 | BD | 745 | -- | 1 |
| P | 1583829-5 | Ponaganset High School | Well no. 5 | 25 | P19 | BD | 560 | -- | 3 |

**Table 12.** Community and non-community, non-transient public supply systems and wells in Rhode Island and available well data—*Continued*

| Supply type | Source identifier | System name | Source name | USGS-ID | WHPA | Aquifer type | Well depth, in feet | Depth to water, in feet | Depth to bedrock, in feet |
|---|---|---|---|---|---|---|---|---|---|
| P | 1583829-6 | Ponaganset High School | Well no. 6 | 24 | P19 | BD | 400 | -- | 5 |
| P | 1583829-7 | Ponaganset High School | Drilled well no. 7 (new) | 27 | P19 | BD | -- | -- | -- |
| P | 1592014-1 | ATP Manufacturing | Well no. 3 | 3 | P4 | BD | 480 | -- | -- |
| P | 1592015-1 | Industrial Park Water Company, Inc. | Tifft Road well | 6 | P6 | SD | 64 | 6 | -- |
| P | 1592017-1 | North Smithfield Jr./Sr. High School | Drilled rock well | 13 | P12 | BD | 458 | 15 | 27 |
| P | 1592025-1 | Quonset Point/Davisville Industrial Park | Well no. 9 | 88 | C38 | SD | 61 | -- | -- |
| P | 1592025-2 | Quonset Point/Davisville Industrial Park | Well no. 3 | 93 | C38 | SD | 97 | -- | -- |
| P | 1592025-3 | Quonset Point/Davisville Industrial Park | Well no. 14A | 89 | C38 | SD | 80 | -- | -- |
| P | 1592027-2 | Richmond School | Drilled rock well no. 1 | 66 | P46 | BD | 595 | 23 | 22 |
| P | 1592027-3 | Richmond School | Drilled rock well no. 2 | 67 | P46 | BD | 100 | -- | 20 |
| P | 1592028-1 | Chariho Vocational School | Gravel-developed | 79 | P51 | SD | 70 | 18 | -- |
| P | 1592030-1 | Chariho Regional High School | Gravel-developed well | 75 | P51 | SD | 70 | 23 | -- |
| P | 1615611-1 | Clayville School | Drilled rock well | 41 | P31 | BD | 101 | -- | -- |
| P | 1615612-4 | Scituate High and Trimtown School | Drilled rock well 1 | 34 | P28 | BD | 395 | -- | 117 |
| P | 1615612-5 | Scituate High and Trimtown School | Drilled rock well 2 | 35 | P28 | BD | 450 | -- | 75 |
| P | 1615612-6 | Scituate High and Trimtown School | Drilled rock well 3 | 33 | P28 | BD | 300 | -- | -- |
| P | 1615613-1 | North Scituate Elementary | Drilled rock well | 30 | P24 | BD | 300 | 20 | 30 |
| P | 1615617-1 | American Power Conversion | Gravel-developed well | 71 | P49 | SD | 68 | 9 | -- |
| P | 1647513-3 | Bradford Dyeing Association, Inc. | Drilled well | 91 | P58 | SD | 63 | 6 | -- |
| P | 1647517-1 | Turex, Inc. | Drilled rock well | 10 | P9 | BD | 270 | -- | -- |
| P | 1647525-3 | Charlestown Elementary School | Well no. 2 | 76 | P52 | BD | 120 | 35 | -- |
| P | 1647525-4 | Charlestown Elementary School | Well no. 3 | 73 | P52 | BD | 292 | 55 | 8 |
| P | 1647527-1 | Western Coventry Elementary School | Drilled rock well | 47 | P34 | BD | 155 | 23 | 0 |
| P | 1858414-1 | Greene Plastics Corporation, Industrial Supply | Drilled well | 68 | P47 | BD | 210 | 15 | 10 |
| P | 1858415-1 | Ashaway Line & Twine Manufacturing Company–Lower Mill | Drilled rock well | 87 | P56 | BD | 150 | 3 | -- |
| P | 1858417-1 | Ashaway Elementary School | Drilled rock well | 89 | P56 | BD | 400 | -- | -- |
| P | 1858425-2 | Josephine Wilbur School | Drilled well no. 1 | 65 | P45 | BD | 200 | 24 | 36 |
| P | 1858431-1 | Alton Operating Corporation | Dug well | 83 | P54 | DG | 18 | 7 | -- |
| P | 1900003-1 | Coventry Air National Guard | Well no. 2 (north of P15) | 45 | P33 | BD | 610 | -- | -- |
| P | 1900003-2 | Coventry Air National Guard | Well no. 1 (south of P14) | 46 | P33 | BD | 550 | -- | -- |

**Table 12**. Community and non-community, non-transient public supply systems and wells in Rhode Island and available well data—*Continued*

| Supply type | Source identifier | System name | Source name | USGS-ID | WHPA | Aquifer type | Well depth, in feet | Depth to water, in feet | Depth to bedrock, in feet |
|---|---|---|---|---|---|---|---|---|---|
| P | 1900003-3 | Coventry Air National Guard | Well no. 3 (near pumphouse) | 43 | P33 | BD | -- | -- | -- |
| P | 1900003-4 | Coventry Air National Guard | Well no. 4 (near building P4) | 44 | P33 | BD | -- | -- | -- |
| P | 1900004-1 | North Smithfield Air National Guard Base | Well no. 1 | 101 | P1 | U | -- | -- | -- |
| P | 1900004-2 | North Smithfield Air National Guard Base | Well no. 2 | 105 | P1 | U | -- | -- | -- |
| P | 1900024-1 | Exeter-West Greenwich Jr./Sr. High School | Well no. 3 | 52 | P38 | BD | -- | -- | -- |
| P | 1900024-2 | Exeter-West Greenwich Jr./Sr. High School | Well no. 1 | 54 | P38 | BD | 500 | 5 | 50 |
| P | 1900024-3 | Exeter-West Greenwich Jr./Sr. High School | Well no. 2 | 53 | P38 | BD | 600 | 4 | 48 |
| P | 1900026-1 | North Smithfield Elementary School | Drilled well | 16 | P62 | BD | 300 | -- | 10 |
| P | 1900027-3 | Charlestown Municipal Offices/Public Works Department | New drilled well | 90 | P57 | BD | 360 | 12 | 28 |
| P | 1900028-1 | Burrillville Middle School | Drilled well | 11 | P10 | BD | 280 | -- | -- |
| P | 1900035-1 | Greene Plastics Corporation–Warehouse | Rock well | 69 | P47 | BD | 300 | 20 | 14 |
| P | 1900038-1 | Pinewood Park School | Drilled well | 20 | P17 | BD | 365 | -- | -- |
| P | 1900040-2 | Ocean State Power | New drilled well no. 2 | 1 | P2 | BD | 500 | -- | 8 |
| P | 1900041-1 | West Glocester Elementary School | Drilled well no. 1 | 19 | P16 | BD | -- | -- | -- |
| P | 1900044-1 | Scituate Early Learning Center | Drilled well | 29 | P22 | BD | 125 | -- | -- |
| P | 2000090-1 | Firehouse Pizza Shop II, Inc. | Drilled well no. 1 | 97 | P4 | BD | 180 | 25 | -- |
| P | 2000110-1 | Camp Sunrise Academy | Drilled well no. 1 | 42 | P32 | BD | -- | -- | -- |
| P | 2000133-1 | Wood River Health Services | Drilled well no. 1 | 70 | P48 | BD | -- | -- | -- |
| P | 2000135-1 | Greenwich Village Nursery School | Drilled well no. 1 | 49 | P36 | BD | 70 | 6 | -- |
| P | 2000142-4 | Chicken by Chickadee Farms, Inc. | Gravel-developed | 74 | P53 | SD | 35 | -- | -- |
| P | 2000145-1 | Crandal House–Senior Citizens | Drilled well no. 1 | 88 | P56 | BD | 98 | 10 | -- |
| P | 2000176-1 | Y's Owl Nursery (Kent YMCA) | Drilled well no. 1 | 48 | P35 | BD | 120 | 30 | -- |
| P | 2051719-1 | Alpine Country Club | Drilled well no. 4 | 37 | P30 | BD | -- | -- | -- |
| P | 2051719-2 | Alpine Country Club | Drilled well no. 3 | 38 | P30 | BD | -- | -- | -- |
| P | 2051719-3 | Alpine Country Club | Drilled well no. 2 | 39 | P30 | BD | -- | -- | -- |
| P | 2051719-4 | Alpine Country Club | Drilled well no. 1 | 40 | P30 | BD | -- | -- | -- |
| P | 2051729-1 | Ski Pro, Inc. | Dug well no. 1 | 64 | P44 | DG | 20 | -- | -- |
| P | 2788010-1 | North Foster Day Care | Drilled well | 32 | P27 | BD | 400 | -- | -- |
| P | 2942515-1 | Park Square Medical Center | Drilled well no. 1 | 9 | P8 | BD | 380 | 50 | -- |
| P | 2973119-4 | Wright's Farm | Drilled well no. 4 | 7 | P7 | BD | 600 | 9 | 26 |

**Table 12.** Community and non-community, non-transient public supply systems and wells in Rhode Island and available well data—*Continued*

| Supply type | Source identifier | System name | Source name | USGS-ID | WHPA | Aquifer type | Well depth, in feet | Depth to water, in feet | Depth to bedrock, in feet |
|---|---|---|---|---|---|---|---|---|---|
| P | 2980017-1 | Church of the Holy Spirit | Drilled well | 94 | P60 | BD | -- | -- | -- |
| P | 2980019-1 | Charlestown Senior Citizen Center | Drilled well | 96 | P61 | BD | 64 | 16.5 | 18 |
| P | 2980030-1 | Scituate Village Shopping Center | Drilled well no. 1 | 99 | P23 | BD | 184 | -- | -- |
| P | 2980036-1 | Slaterville Plaza, Inc. | Drilled well no. 1 | 2 | P3 | BD | 535 | -- | -- |
| P | 2980084-2 | Johnston Child Care Center | Drilled well no. 2 (house) | 31 | P26 | BD | 185 | 25 | 17 |
| P | 2980127-1 | Trinity Lutheran Pre-School | Drilled well no. 1 | 84 | P55 | BD | 67 | 36 | -- |
| P | 2980134-1 | Northwest Community Nursing and Health Service | Drilled well no. 1 | 21 | P18 | BD | 320 | -- | -- |
| P | 2980135-1 | Pied Piper Nursery School | Drilled well no. 1 | 28 | P21 | BD | 75 | -- | -- |
| P | 2980138-1 | Sakonnet Day Care Learning Center | Drilled well no. 1 | 60 | P42 | BD | 170 | -- | 23 |
| P | 2980154-1 | Rhode Island State Police, Investigative Support and Services Building | Drilled well | 98 | P25 | BD | -- | -- | -- |
| P | 2980185-2 | Chariho Regional Middle School | Well no. 2 north | 77 | P51 | SD | 135 | 55 | -- |
| P | 2980185-3 | Chariho Regional Middle School | Well no. 3 south | 78 | P51 | SD | 135 | 55 | -- |
| P | 2980192-1 | Carbon Technology | Well no. 1 | 62 | P43 | BD | 400 | -- | -- |
| P | 2980192-2 | Carbon Technology | Well no. 2 | 63 | P43 | BD | 500 | -- | -- |
| P | 2980265-1 | Nonquit School | Drilled well | 59 | P41 | BD | 114 | -- | -- |
| P | 2980270-1 | Richmond Country Club, Inc. | Drilled well (new) | 100 | P50 | BD | -- | -- | -- |
| P | 2980277-1 | Boliden Metech, Inc., Plant 1 | Drilled well | 14 | P13 | BD | 260 | -- | -- |
| P | 2980278-1 | Boliden Metech, Inc., Plant 2 | Drilled well | 15 | P13 | BD | -- | -- | -- |
| P | 2980301-1 | Branch Village Professional Building | Drilled well | 4 | P4 | BD | 620 | -- | -- |
| P | 2980311-1 | Bruin Plastics, Inc. | Drilled well no. 1 | 12 | P11 | BD | 550 | 24 | 15 |
| P | 2980330-1 | Rhode Island State Police Headquarters (new) | Drilled well | 106 | P25 | BD | -- | -- | -- |
| P | 2980346-1 | Fleming School | Drilled | 107 | P5 | U | -- | -- | -- |

**Table 13.** Available water-quality data for community and non-community, non-transient supply wells in Rhode Island

[Water-quality data from the Rhode Island Department of Health. Water-quality constituents and properties grouped by contaminant classes defined for the vulnerability assessment. **MDL:** method detection limit, in milligrams per liter unless otherwise indicated. MDLs associated with less than 10 percent of samples are not listed; mL, milliliter; --, undetermined]

| Water-quality constituent or property | Total number of analyses | Number of wells with data | Number of analyses above MDL | MDL |
|---|---|---|---|---|
| **Nutrients** | | | | |
| Nitrate as N | 1,342 | 246 | 1,041 | 0.1 |
| Nitrite as N | 1,270 | 245 | 17 | 0.02 |
| Nitrogen, ammonia as N | 558 | 189 | 82 | 0.05 |
| **Pesticides[1]** | | | | |
| Aciflourfen | 13 | 6 | 0 | 13 |
| Alachlor | 725 | 220 | 1 | 0.1, 0.2, 0.25, 0.267 |
| Aldicarb | 475 | 217 | 0 | 0.35, 0.5, 1 |
| Aldicarb, total | 334 | 188 | 2 | 0.9, 3 |
| Aldicarb sulfone | 475 | 217 | 6 | 0.16, 0.5, 0.6, 1 |
| Aldicarb sulfoxide | 475 | 217 | 6 | 0.38, 0.5, 1 |
| Aldrin | 1,028 | 238 | 0 | 0.09, 0.1, 0.2, 0.28 |
| Atrazine | 725 | 220 | 0 | 0.1, 0.2, 0.26, 1.1 |
| Baygon | 114 | 114 | 0 | 1 |
| Benazon | 13 | 6 | 0 | 2 |
| Bromomethane | 1,769 | 243 | 0 | 1, 5 |
| Butachlor (Machete) | 720 | 220 | 0 | 0.024, 0.09, 0.1, 0.11 |
| Captan | 112 | 83 | 0 | 0.5 |
| Carbaryl (Sevin) | 475 | 217 | 1 | 0.5, 1, 2 |
| Carbofuran | 475 | 217 | 1 | 0.16, 0.9, 1 |
| Chlordane | 756 | 237 | 0 | 0.18, 0.2, 0.41, 0.2 |
| α-Chlordane | 405 | 152 | 0 | 0.006, 0.1 |
| γ-Chlordane | 405 | 152 | 0 | 0.012, 0.1 |
| Chlorothalonil (Bravo) | 117 | 83 | 0 | 0.5 |
| Chlorpyriphos (Dursban) | 112 | 83 | 0 | 0.7 |
| Dalapon | 255 | 69 | 0 | 0.52, 5 |
| DDD | 116 | 87 | 0 | 0.2 |
| DDE | 116 | 87 | 0 | 0.2 |
| DDT | 327 | 168 | 0 | 0.2, 1 |
| Diazinon (Spectracide) | 112 | 83 | 0 | 0.51 |
| 1,2-Dibromo-3-chloropropane | 2,084 | 250 | 1 | 0.01, 1, 10 |
| 1,2-Dibromoethane (same as EDB) | 1,640 | 243 | 0 | 1, 5 |
| Dicamba | 478 | 218 | 0 | 0.4, 0.5, 2.1 |
| 2-4-Diclorophenoxyacetic acid (2,4-D) | 700 | 236 | 0 | 0.05, 0.2, 0.9, 1 |
| Dieldrin | 1,009 | 238 | 3 | 0.001, 0.06, 0.07, 0.1, 0.3 |
| Dinoseb | 478 | 218 | 1 | 0.1, 0.2, 0.4 |
| Endosulfan I | 116 | 87 | 0 | 0.9 |
| Endosulfan II | 116 | 87 | 0 | 1 |
| Endosulfan sulfate | 116 | 87 | 0 | 0.5 |
| Endothall | 291 | 68 | 0 | 1.07, 4.47 |

**Table 13**. Available water-quality data for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Water-quality constituent or property | Total number of analyses | Number of wells with data | Number of analyses above MDL | MDL |
|---|---|---|---|---|
| **Pesticides[1]—*Continued*** | | | | |
| Endrin | 971 | 237 | 0 | 0.001, 0.2, 0.5 |
| Ethylene dibromide (EDB) | 443 | 213 | 1 | 0.01, 0.02 |
| Garlon | 13 | 6 | 0 | 2 |
| Heptachlor | 961 | 237 | 0 | 0.015, 0.04, 0.08, 0.1 |
| Heptachlor epoxide | 961 | 237 | 0 | 0.017, 0.02, 0.05, 0.1 |
| α-Hexachlorocyclohexane (α-BHC) | 116 | 87 | 0 | 0.7 |
| β-Hexachlorocyclohexane (β-BHC) | 116 | 87 | 0 | 0.15 |
| δ-Hexachlorocyclohexane (δ-BHC) | 116 | 87 | 0 | 0.7 |
| 3-Hydroxycarbofuran | 475 | 217 | 0 | 0.5, 1, 2 |
| Lindane (γ-BHC) | 971 | 237 | 0 | 0.001, 0.02, 1 |
| Methiocarb | 114 | 114 | 0 | 0.5 |
| Methomyl | 475 | 217 | 1 | 0.5, 1 |
| Methoxychlor | 1,038 | 238 | 0 | 0.003, 0.1, 0.17, 0.2, 3 |
| Metolachlor | 720 | 220 | 16 | 0.067, 0.08, 0.1, 1.2 |
| Metribuzin (Sencor) | 725 | 220 | 0 | 0.16, 0.2, 0.235, 0.53 |
| *cis*-Nonachlor | 204 | 148 | 0 | 0.027 |
| *trans*-Nonachlor | 404 | 151 | 0 | 0.011, 0.1 |
| Oxamyl (Vydate) | 475 | 217 | 0 | 0.196, 0.5, 0.1 |
| Pentachlorophenol | 842 | 220 | 1 | 0.1, 0.2, 0.3, 0.4 |
| Picloram | 478 | 218 | 0 | 0.5, 0.8, 1 |
| Propachlor (Ramrod) | 720 | 220 | 1 | 0.06, 0.07, 0.1 |
| Simazine | 725 | 220 | 0 | 0.07, 0.1, 1 |
| 2,4,5-Trichlorophenoxy-acetic acid (2,4,5-T) | 13 | 6 | 0 | 2 |
| 2-(2,4,5-Trichlorophenoxy)-propionic acid (2,4,5-TP, or Silvex) | 700 | 236 | 0 | 0.005, 0.1, 0.4, 0.6 |
| Toxaphene | 766 | 237 | 0 | 0.4, 1, 1.2, 2.1, 5 |
| **Solvents and Other Industrial Organic Chemicals[1]** | | | | |
| Bromobenzene | 1,641 | 243 | 0 | 1 |
| Carbon tetrachloride | 2,047 | 244 | 0 | 0.5, 1 |
| Chlorobenzene | 1,770 | 243 | 0 | 0.5, 1 |
| Chloroethane | 1,769 | 243 | 0 | 1, 5.0 |
| 2-Chlorotoluene | 1,640 | 243 | 0 | 1 |
| 4-Chlorotoluene | 1,641 | 243 | 0 | 1 |
| Dibromochloromethane | 1,773 | 243 | 4 | 1 |
| Dibromomethane | 1,641 | 243 | 0 | 1 |
| 1,2-Dichlorobenzene | 1,641 | 243 | 2 | 0.5, 1 |
| 1,3-Dichlorobenzene | 1,640 | 243 | 1 | 1 |
| 1,4-Dichlorobenzene | 1,919 | 244 | 2 | 0.5, 1 |
| Dichlorodifluoromethane | 1,641 | 243 | 2 | 1 |
| 1,1-Dichloroethane | 1,770 | 243 | 38 | 0.5, 1 |
| 1,2-Dichloroethane | 2,046 | 244 | 0 | 0.5, 1 |
| 1,1-Dichloroethene | 2,048 | 244 | 37 | 1 |

**Table 13.** Available water-quality data for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Water-quality constituent or property | Total number of analyses | Number of wells with data | Number of analyses above MDL | MDL |
|---|---|---|---|---|
| **Solvents and Other Industrial Organic Chemicals[1]—*Continued*** | | | | |
| 1,2-Dichloroethene | 128 | 9 | 0 | 1 |
| *cis*-1,2-Dichloroethene | 1,642 | 243 | 5 | 0.5, 1 |
| *trans*-1,2-Dichloroethene | 1,641 | 243 | 1 | 0.5, 1 |
| 1,2-Dichloropropane | 1,770 | 243 | 0 | 0.5, 1 |
| 2,4-Dinitrotoluene | 163 | 86 | 0 | 0.09 |
| 2,6-Dinitrotoluene | 163 | 86 | 0 | 0.07 |
| Hexachlorobenzene | 725 | 220 | 0 | 0.017, 0.1, 0.13, 0.2 |
| Hexachlorobutadiene | 1,640 | 243 | 0 | 1 |
| Hexachlorocyclopentadiene | 719 | 214 | 0 | 0.082, 0.1, 0.2, 1.1 |
| Isophorone | 163 | 86 | 0 | 0.05 |
| Methylene chloride | 1,770 | 243 | 1 | 0.05, 1 |
| Naphthalene | 1,642 | 243 | 3 | 1 |
| 1-Naphthol | 234 | 123 | 0 | 0.2, 1 |
| Pyrene | 369 | 91 | 0 | 0.1 |
| 1,1,1,2-Tetrachloroethane | 1,641 | 243 | 1 | 1 |
| 1,1,2,2-Tetrachloroethane | 1,770 | 243 | 0 | 1 |
| Tetrachloroethene | 1,771 | 243 | 52 | 0.5, 1 |
| 1,2,4-Trichlorobenzene | 1,641 | 243 | 0 | 0.5, 1 |
| 1,1,1-Trichloroethane | 2,048 | 244 | 158 | 0.5, 1 |
| 1,1,2-Trichloroethane | 1,770 | 243 | 1 | 0.5, 1 |
| Trichloroethene (TCE) | 2,048 | 244 | 25 | 0.5, 1 |
| Trichlorofluoromethane | 1,641 | 243 | 1 | 0.5 |
| Vinyl chloride | 2,047 | 244 | 0 | 0.5, 1, 2 |
| **Fuel Hydrocarbons[1]** | | | | |
| Benzene | 2,047 | 244 | 8 | 0.5, 1 |
| *n*-Butylbenzene | 1,641 | 243 | 1 | 1 |
| *sec*-Butylbenzene | 1,641 | 243 | 0 | 1 |
| *tert*-Butylbenzene | 1,641 | 243 | 0 | 1 |
| 1,1-Dichloropropene | 1,640 | 243 | 0 | 1 |
| 1,3-Dichloropropane | 1,641 | 243 | 1 | 1 |
| 1,3-Dichloropropene | 1,641 | 243 | 0 | 1 |
| *cis*- and *trans*-1,3-Dichloropropene | 128 | 9 | 0 | 1 |
| 2,2-Dichloropropane | 1,641 | 243 | 0 | 1 |
| Ethylbenzene | 1,770 | 243 | 6 | 0.5, 1 |
| Hexane | 1,324 | 238 | 4 | 1 |
| Isopropylbenzene | 1,641 | 243 | 2 | 1 |
| *p*-Isopropyltoluene | 1,322 | 242 | 0 | 1 |
| *p*-Isopropyltoluene (P-Cymene) | 319 | 46 | 1 | 1 |
| Methyl *tert*-butyl ether | 1,528 | 240 | 45 | 1 |

**Table 13.** Available water-quality data for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Water-quality constituent or property | Total number of analyses | Number of wells with data | Number of analyses above MDL | MDL |
|---|---|---|---|---|
| **Fuel Hydrocarbons[1]—*Continued*** | | | | |
| *n*-Propylbenzene | 1,641 | 243 | 1 | 1 |
| Toluene | 1,770 | 243 | 22 | 0.5, 1 |
| 1,2,3-Trichlorobenzene | 1,641 | 243 | 0 | 1 |
| 1,2,3-Trichloropropane | 1,641 | 243 | 0 | 1 |
| 1,2,4-Trimethylbenzene | 1,641 | 243 | 4 | 1 |
| 1,3,5-Trimethylbenzene | 1,641 | 243 | 3 | 1 |
| *m*-Xylene | 83 | 63 | 1 | 1 |
| *o*-Xylene | 74 | 59 | 1 | 1 |
| Xylene | 1,769 | 243 | 12 | 0.5, 1 |
| **Road-Deicing Chemicals** | | | | |
| Sodium | 1,072 | 202 | 1,071 | 2 |
| Potassium | 563 | 190 | 563 | -- |
| Chloride | 600 | 191 | 595 | 2 |
| Specific conductance | 126 | 66 | 126 | -- |
| **Fluoride** | | | | |
| Fluoride | 832 | 220 | 272 | 0.2 |
| **Iron and Manganese** | | | | |
| Iron | 592 | 190 | 404 | 0.02 |
| Manganese | 601 | 190 | 291 | 0.02 |
| pH | 1,196 | 186 | -- | -- |
| **Trace Inorganic Chemicals** | | | | |
| Antimony | 143 | 70 | 3 | 0.003, 0.005 |
| Arsenic | 1,188 | 245 | 29 | 0.005 |
| Barium | 808 | 222 | 195 | 0.02 |
| Beryllium | 116 | 70 | 18 | 0.0002 |
| Cadmium | 807 | 222 | 12 | 0.001 |
| Chromium | 807 | 222 | 6 | 0.005 |
| Copper | 648 | 207 | 247 | 0.02 |
| Cyanide | 106 | 67 | 1 | 0.01 |
| Lead | 660 | 207 | 150 | 0.005 |
| Mercury | 808 | 222 | 1 | 0.001 |
| Nickel | 598 | 192 | 6 | 0.02 |
| Selenium | 807 | 222 | 4 | 0.005 |
| Silver | 585 | 191 | 1 | 0.001 |
| Thallium | 143 | 70 | 5 | 0.001, 0.005 |
| Zinc | 582 | 191 | 289 | 0.02 |
| **Radionuclides** | | | | |
| Gross alpha radioactivity | 460 | 179 | 220 | variable |
| Gross beta radioactivity | 404 | 179 | 353 | variable |
| Radium 226 | 26 | 24 | 26 | variable |
| Radium 228 | 26 | 24 | 26 | variable |

**Table 13.** Available water-quality data for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Water-quality constituent or property | Total number of analyses | Number of wells with data | Number of analyses above MDL | MDL |
|---|---|---|---|---|
| **Microbial Contaminants[2]** | | | | |
| Total coliform bacteria | 2,102 | 209 | 124 | 1 colony-forming unit per 100 mL |
| Fecal coliform bacteria | 192 | 90 | 3 | -- |
| **Constituents Related to Hardness** | | | | |
| Alkalinity, total | 690 | 206 | 690 | -- |
| Calcium | 716 | 206 | 714 | 2.5 |
| Hardness, total | 561 | 190 | 561 | -- |
| Magnesium | 591 | 190 | 589 | 0.5 |
| **Polycyclic Aromatic Hydrocarbons[1]** | | | | |
| Acenaphthalene | 368 | 91 | 0 | 0.1, 0.2 |
| Acenaphthene | 1 | 1 | 0 | 1 |
| Acenaphthylene | 1 | 1 | 0 | 1 |
| Anthracene | 369 | 91 | 0 | 0.1 |
| Benz (A) Anthracene | 369 | 91 | 0 | 0.05, 0.1 |
| Benzo (A) Pyrene | 410 | 100 | 0 | 0.08, 0.1, 0.15 |
| Benzo (B) Fluoranthene | 369 | 91 | 0 | 0.1 |
| Benzo (G,H,I) Perylene | 369 | 91 | 0 | 0.5, 0.05 |
| Benzo (K) Fluoranthene | 369 | 91 | 0 | 0.1 |
| Chrysene | 369 | 91 | 0 | 0.05, 0.1 |
| Dibenzo (A,H) Anthracene | 369 | 91 | 0 | 0.05, 0.5 |
| Fluoranthene | 6 | 6 | 0 | 0.05, 0.1 |
| Fluorene | 369 | 91 | 0 | 0.1, 0.2 |
| Ideno (1,2,3) Pyrene | 1 | 1 | 0 | 2 |
| Indeno (1,2,3,C,D) Pyrene | 368 | 91 | 0 | 0.05, 0.5 |
| Phenanthrene | 369 | 91 | 0 | 0.1 |
| **Polychlorinated Biphenyls (PCBs)[1]** | | | | |
| 2-Chlorobiphenyl | 205 | 56 | 0 | 0.1 |
| 2,3-Dichlorobiphenyl | 205 | 56 | 0 | 0.1 |
| 2,2,3,3,4,4,6-Heptachlorobiphenyl | 200 | 51 | 0 | 0.2 |
| 2,2,4,4,5,6-Hexachlorobiphenyl | 200 | 51 | 0 | 0.1 |
| 2,2,3,3,4,5,6,6-Octachlorobiphenyl | 200 | 51 | 0 | 0.2 |
| 2,2,3,4,6-Pentachlorobiphenyl | 200 | 51 | 0 | 0.1 |
| 2,4,5-Trichlorobiphenyl | 200 | 51 | 0 | 0.1 |
| PCB Alochlor 1016 | 473 | 218 | 0 | 0.08, 0.25, 0.4, 0.5 |
| PCB Alochlor 1221 | 473 | 218 | 0 | 0.4, 0.72, 15, 20 |
| PCB Alochlor 1232 | 473 | 218 | 0 | 0.4, 0.48, 0.5, 0.65 |
| PCB Alochlor 1242 | 473 | 218 | 0 | 0.3, 0.31, 0.4, 0.75 |
| PCB Alochlor 1248 | 473 | 218 | 0 | 0.10, 0.13, 0.25, 0.4 |
| PCB Alochlor 1254 | 473 | 218 | 0 | 0.10, 0.25, 0.37, 0.4 |
| PCB Alochlor 1260 | 473 | 218 | 0 | 0.19, 0.22, 0.25, 0.4 |

**Table 13**. Available water-quality data for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Water-quality constituent or property | Total number of analyses | Number of wells with data | Number of analyses above MDL | MDL |
|---|---|---|---|---|
| **Synthethic Organic Chemicals Related to Chlorination[1]** | | | | |
| Bromochloromethane | 1,649 | 243 | 0 | 1 |
| Bromodichloromethane | 1,781 | 243 | 3 | 1 |
| Bromoform | 1,781 | 243 | 1 | 1 |
| Chloroform | 1,781 | 243 | 13 | 1 |
| Residual Chlorine | 571 | 151 | 9 | -- |
| **Synthetic Organic Chemicals Related to Analytical Methods** | | | | |
| Butylbenzylphthalate | 369 | 91 | 0 | 0.1, 2 |
| Di-*n*-butylphthalate | 369 | 91 | 0 | 2 |
| Di (2-ethylhexyl) adipate | 410 | 100 | 24 | 0.15, 0.2, 2 |
| Di (2-ethylhexyl) phthalate | 410 | 100 | 38 | 0.2, 2 |
| Diethylphthalate | 369 | 91 | 2 | 2 |
| Dimethylphthalate | 368 | 91 | 1 | 2 |

[1]MDLs given in micrograms per liter.

[2]Total number of analyses for bacterial contaminants represent the number of sample-collection dates, which may include multiple analyses by different methods.

**Table 14**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by nutrients based on aquifer type and land use

[**Supply type:** C, community; P, non-community, non-transient. **Source identifier:** Combines the public-water system identifier (PWSID) and the source number assigned by the Rhode Island Department of Health. **USGS-ID:** Identifier used in figures 2 and 3. **Aquifer type:** BD, bedrock; D, dug well of undetermined aquifer type; SD, sand and gravel; U, drilled well of undetermined aquifer type. WHPA, wellhead-protection area. **Affected or unaffected:** Y, affected, N, unaffected. **Relative vulnerability:** A, most vulnerable; D, least vulnerable. Shading indicates values used in designating A, B, and C vulnerability categories. mg/L as N, milligrams per liter as nitrogen; >, actual value is greater than value shown]

| Supply type | Source identifier | USGS-ID | Vulnerability factor: Aquifer type | Vulnerability factor: Area in WHPA, as percentage of total area: Residential land use | Vulnerability factor: Area in WHPA, as percentage of total area: Urban land use with parks and golf courses | Affected or unaffected for three threshold criteria: Nitrate > 1 mg/L as N | Affected or unaffected for three threshold criteria: Nitrate > 2 mg/L as N | Affected or unaffected for three threshold criteria: Nitrate > 5 mg/L as N | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|
| C | 1000009-1 | 63 | BD | 13.3 | 0 | N | N | N | D |
| C | 1000009-4 | 178 | BD | 13.3 | 0 | N | N | N | D |
| C | 1000020-1 | 68 | BD | 16.1 | 1.2 | N | N | N | B |
| C | 1000020-2 | 67 | BD | 16.1 | 1.2 | N | N | N | B |
| C | 1000020-3 | 69 | BD | 16.1 | 1.2 | N | N | N | B |
| C | 1000035-3 | 150 | BD | 38.7 | 0 | Y | Y | N | A[1] |
| C | 1000035-4 | 152 | BD | 38.7 | 0 | Y | N | N | B |
| C | 1000035-5 | 151 | BD | 38.7 | 0 | Y | N | N | B |
| C | 1000040-1 | 113 | SD | 4.4 | 0 | N | N | N | C |
| C | 1000040-2 | 180 | SD | 4.4 | 0 | N | N | N | C |

**Table 14**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by nutrients based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Affected or unaffected for three threshold criteria | | | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | | |
| | | | | Residential land use | Urban land use with parks and golf courses | Nitrate > 1 mg/L as N | Nitrate > 2 mg/L as N | Nitrate > 5 mg/L as N | |
| C | 1000043-2 | 124 | BD | 6.2 | 7.8 | Y | N | N | B |
| C | 1000043-3 | 125 | BD | 6.2 | 7.8 | Y | N | N | B |
| C | 1000045-1 | 141 | BD | 22.0 | 0 | Y | Y | N | A[1] |
| C | 1000045-2 | 142 | BD | 22.0 | 0 | N | N | N | B |
| C | 1000098-1 | 133 | SD | 6.2 | 7.8 | Y | Y | N | A |
| C | 1000098-2 | 132 | SD | 6.2 | 7.8 | N | N | N | A |
| C | 1559511-1 | 90 | SD | 27.2 | 5.2 | Y | Y | N | A |
| C | 1559511-2 | 82 | SD | 32.9 | 0 | Y | Y | Y | A |
| C | 1559511-3 | 85 | SD | 18.5 | 0 | Y | N | N | B |
| C | 1559511-4 | 84 | SD | 18.5 | 0 | N | N | N | B |
| C | 1559512-1 | 153 | SD | 20.4 | 4.0 | Y | Y | N | A |
| C | 1559512-10 | 159 | SD | 49.2 | 0 | Y | Y | Y | A |
| C | 1559512-11 | 161 | SD | 12.5 | 1.0 | Y | N | N | A |
| C | 1559512-2 | 155 | SD | 20.4 | 4.0 | N | N | N | A |
| C | 1559512-3 | 154 | SD | 20.4 | 4.0 | Y | N | N | A |
| C | 1559512-4 | 147 | SD | 20.4 | 4.0 | Y | N | N | A |
| C | 1559512-5 | 145 | SD | 20.4 | 4.0 | Y | N | N | A |
| C | 1559512-6 | 146 | SD | 20.4 | 4.0 | Y | Y | N | A |
| C | 1559512-7 | 149 | SD | 20.4 | 4.0 | N | N | N | A |
| C | 1559512-8 | 148 | SD | 16.7 | 0 | Y | Y | N | A[1] |
| C | 1559512-9 | 158 | SD | 16.7 | 0 | Y | N | N | C |
| C | 1559513-1 | 166 | SD | 14.4 | 0 | N | N | N | C |
| C | 1559513-2 | 164 | SD | 14.4 | 0 | N | N | N | C |
| C | 1559513-4 | 165 | BD | 14.4 | 0 | N | N | N | D |
| C | 1559513-5 | 163 | BD | 14.4 | 0 | N | N | N | D |
| C | 1559517-1 | 106 | SD | 9.9 | .1 | Y | Y | N | A |
| C | 1559517-10 | 118 | SD | 2.3 | 0 | N | N | N | C |
| C | 1559517-2 | 107 | SD | 9.9 | .1 | Y | N | N | A |
| C | 1559517-3 | 116 | SD | 2.3 | 0 | N | N | N | C |
| C | 1559517-4 | 108 | SD | 9.9 | .1 | Y | Y | N | A |
| C | 1559517-5 | 110 | SD | 9.9 | .1 | Y | Y | N | A |
| C | 1559517-6 | 104 | SD | 39.0 | 0 | Y | N | N | A |
| C | 1559517-7 | 91 | SD | 27.2 | 5.2 | Y | Y | N | A |
| C | 1559517-8 | 92 | SD | 27.2 | 5.2 | Y | Y | Y | A |
| C | 1559517-9 | 117 | SD | 2.3 | 0 | N | N | N | C |
| C | 1559519-1 | 28 | BD | 14.2 | 0 | N | N | N | D |
| C | 1559519-2 | 27 | BD | 14.2 | 0 | N | N | N | D |
| C | 1583825-1 | 29 | BD | 17.1 | 0 | N | N | N | D |
| C | 1592012-2 | 105 | SD | 11.1 | 0 | Y | N | N | C |
| C | 1592019-1 | 38 | BD | 22.0 | 0 | Y | N | N | B |

**Table 14**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by nutrients based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor: Aquifer type | Area in WHPA, as percentage of total area: Residential land use | Area in WHPA, as percentage of total area: Urban land use with parks and golf courses | Affected or unaffected for three threshold criteria: Nitrate > 1 mg/L as N | Nitrate > 2 mg/L as N | Nitrate > 5 mg/L as N | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|
| C | 1592019-2 | 176 | BD | 22.0 | 0 | Y | N | N | B |
| C | 1592020-1 | 32 | SD | 46.3 | 0 | N | N | N | A |
| C | 1592020-2 | 34 | SD | 46.3 | 0 | Y | N | N | A |
| C | 1592021-2 | 56 | SD | 49.3 | .6 | Y | N | N | A |
| C | 1592021-3 | 55 | SD | 49.3 | .6 | Y | Y | N | A |
| C | 1592021-4 | 54 | SD | 49.3 | .6 | Y | Y | Y | A |
| C | 1592021-5 | 53 | SD | 49.3 | .6 | Y | Y | Y | A |
| C | 1592021-6 | 50 | SD | 49.3 | .6 | N | N | N | A |
| C | 1592021-7 | 47 | SD | 49.3 | .6 | Y | N | N | A |
| C | 1592021-8 | 46 | SD | 49.3 | .6 | Y | Y | N | A |
| C | 1592021-9 | 45 | SD | 49.3 | .6 | Y | Y | Y | A |
| C | 1592023-1 | 102 | BD | 13.9 | .4 | N | N | N | B |
| C | 1592023-5 | 100 | BD | 13.9 | .4 | N | N | N | B |
| C | 1592023-7 | 98 | BD | 13.9 | .4 | N | N | N | B |
| C | 1592023-8 | 94 | BD | 13.9 | .4 | N | N | N | B |
| C | 1592023-9 | 179 | BD | 13.9 | .4 | N | N | N | B |
| C | 1592025-1 | 88 | SD | 27.2 | 5.2 | Y | Y | Y | A |
| C | 1592025-2 | 93 | SD | 27.2 | 5.2 | Y | Y | N | A |
| C | 1592025-3 | 89 | SD | 27.2 | 5.2 | Y | N | N | A |
| C | 1615614-1 | 26 | SD | 34.1 | 1.3 | Y | N | N | A |
| C | 1615614-2 | 25 | BD | 34.1 | 1.3 | Y | Y | N | A[1] |
| C | 1615614-5 | 24 | SD | 40.4 | 0 | Y | Y | N | A |
| C | 1615623-1 | 157 | SD | 15.8 | 0 | N | N | N | C |
| C | 1615623-2 | 156 | SD | 15.8 | 0 | N | N | N | C |
| C | 1615624-1 | 137 | SD | 9.1 | 0 | Y | N | N | C |
| C | 1615624-2 | 138 | SD | 9.1 | 0 | Y | N | N | C |
| C | 1615624-3 | 136 | SD | 9.1 | 0 | Y | Y | N | A[1] |
| C | 1615624-4 | 139 | SD | 9.1 | 0 | Y | Y | N | A[1] |
| C | 1615624-5 | 140 | SD | 9.1 | 0 | Y | Y | N | A[1] |
| C | 1615624-7 | 135 | SD | 9.1 | 0 | Y | Y | Y | A[1] |
| C | 1615626-1 | 80 | SD | 73.0 | 4.5 | Y | Y | Y | A |
| C | 1615626-2 | 81 | SD | 73.0 | 4.5 | Y | Y | Y | A |
| C | 1647512-1 | 167 | SD | 52.1 | 2.7 | Y | Y | N | A |
| C | 1647512-2 | 168 | SD | 52.1 | 2.7 | Y | Y | Y | A |
| C | 1647515-5 | 77 | SD | 43.8 | 3.1 | N | N | N | A |
| C | 1647515-6 | 76 | SD | 43.8 | 3.1 | N | N | N | A |
| C | 1647526-1 | 44 | BD | 18.3 | 0 | Y | Y | N | A[1] |
| C | 1647529-1 | 134 | BD | 9.6 | 0 | N | N | N | D |
| C | 1647530-1 | 33 | SD | 33.6 | 0 | Y | N | N | A |
| C | 1647530-3 | 40 | SD | 39.2 | 0 | Y | Y | N | A |

**Table 14**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by nutrients based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Affected or unaffected for three threshold criteria | | | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | | |
| | | | | Residential land use | Urban land use with parks and golf courses | Nitrate > 1 mg/L as N | Nitrate > 2 mg/L as N | Nitrate > 5 mg/L as N | |
| C | 1647530-4 | 39 | SD | 39.2 | 0 | N | N | N | A |
| C | 1647530-5 | 31 | SD | 33.6 | 0 | Y | N | N | A |
| C | 1858411-1 | 35 | SD | 58.5 | 0 | Y | N | N | A |
| C | 1858411-2 | 37 | SD | 22.1 | 0 | N | N | N | A |
| C | 1858421-1 | 130 | SD | 14.4 | 12.1 | Y | Y | N | A |
| C | 1858421-2 | 131 | SD | 14.4 | 12.1 | Y | Y | Y | A |
| C | 1858422-1 | 128 | SD | 14.4 | 12.1 | Y | Y | N | A |
| C | 1858422-2 | 129 | SD | 14.4 | 12.1 | Y | Y | N | A |
| C | 1858422-3 | 127 | SD | 14.4 | 12.1 | Y | N | N | A |
| C | 1858423-5 | 59 | SD | 32.4 | 4.1 | Y | N | N | A |
| C | 1858435-1 | 70 | BD | 10.2 | 0 | N | N | N | D |
| C | 1900020-1 | 78 | SD | 66.5 | 0 | N | N | N | A |
| C | 1900023-1 | 74 | BD | 8.2 | 0 | N | N | N | D |
| C | 1900023-2 | 75 | BD | 8.2 | 0 | N | N | N | D |
| C | 1900023-3 | 71 | BD | 8.2 | 0 | N | N | N | D |
| C | 1900023-4 | 72 | BD | 8.2 | 0 | N | N | N | D |
| C | 1900023-5 | 73 | BD | 8.2 | 0 | N | N | N | D |
| C | 1900025-2 | 126 | BD | 6.2 | 7.8 | N | N | N | B |
| C | 1900029-1 | 160 | BD | 12.3 | 14.0 | N | N | N | B |
| C | 1900034-1 | 30 | SD | 15.9 | 0 | N | N | N | C |
| C | 1900034-2 | 181 | SD | 15.9 | 0 | N | N | N | C |
| C | 1900036-1 | 170 | U | 38.1 | 0 | N | N | N | B |
| C | 1900036-2 | 171 | U | 38.1 | 0 | N | N | N | B |
| C | 1900039-1 | 174 | BD | 10.6 | 0 | N | N | N | D |
| C | 1900048-2 | 123 | BD | 6.2 | 7.8 | Y | Y | N | A[1] |
| C | 1900049-1 | 183 | SD | 8.8 | 6.4 | N | N | N | A |
| C | 2000004-2 | 79 | BD | 0.6 | 0 | N | N | N | D |
| C | 2000059-1 | 49 | BD | 6.2 | .2 | N | N | N | B |
| C | 2000059-2 | 48 | BD | 6.2 | .2 | N | N | N | B |
| C | 2000083-1 | 52 | BD | 9.4 | 0 | N | N | N | D |
| C | 2000083-2 | 51 | BD | 9.4 | 0 | N | N | N | D |
| C | 2000084-1 | 62 | BD | 6.7 | 0 | N | N | N | D |
| C | 2000165-1 | 112 | BD | 20.2 | .7 | Y | Y | N | A[1] |
| C | 2051311-1 | 97 | BD | 6.6 | 0 | Y | Y | N | A[1] |
| C | 2415415-1 | 64 | BD | 16.2 | 0 | Y | N | N | D |
| C | 2519424-1 | 60 | BD | 28.5 | 0 | Y | N | N | B |
| C | 2519424-3 | 177 | BD | 28.5 | 0 | N | N | N | B |
| C | 2519426-1 | 83 | BD | 17.7 | 0 | N | N | N | D |
| C | 2585312-1 | 115 | DG | 11.7 | 0 | N | N | N | C |
| C | 2585312-2 | 114 | BD | 11.7 | 0 | N | N | N | D |

**Table 14.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by nutrients based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor: Aquifer type | Vulnerability factor: Area in WHPA, as percentage of total area: Residential land use | Vulnerability factor: Area in WHPA, as percentage of total area: Urban land use with parks and golf courses | Affected or unaffected for three threshold criteria: Nitrate > 1 mg/L as N | Affected or unaffected for three threshold criteria: Nitrate > 2 mg/L as N | Affected or unaffected for three threshold criteria: Nitrate > 5 mg/L as N | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|
| C | 2585313-1 | 103 | BD | 5.2 | 1.1 | N | N | N | B |
| C | 2674924-1 | 182 | SD | 12.1 | 0 | Y | N | N | C |
| C | 2674925-1 | 144 | BD | 9.0 | 0 | N | N | N | D |
| C | 2674925-2 | 143 | BD | 9.0 | 0 | Y | N | N | D |
| C | 2674928-1 | 162 | BD | 12.3 | 14.0 | N | N | N | B |
| C | 2753326-1 | 121 | BD | 39.8 | 3.1 | Y | Y | N | A[1] |
| C | 2753326-3 | 122 | BD | 39.8 | 3.1 | Y | Y | Y | A[1] |
| C | 2788012-1 | 66 | BD | 9.5 | 0 | Y | Y | N | A[1] |
| C | 2814410-3 | 96 | BD | 17.6 | 0 | N | N | N | D |
| C | 2882117-3 | 120 | SD | 14.7 | 0 | N | N | N | C |
| C | 2882117-4 | 119 | BD | 14.7 | 0 | N | N | N | D |
| C | 2942518-1 | 36 | BD | 17.5 | 2.9 | N | N | N | B |
| C | 2942525-1 | 111 | BD | 20.2 | .7 | N | N | N | B |
| C | 2942525-3 | 109 | BD | 20.2 | .7 | Y | Y | N | A[1] |
| C | 2943224-8 | 61 | BD | 28.5 | 0 | N | N | N | B |
| C | 2973130-1 | 42 | SD | 73.1 | 0 | Y | N | N | A |
| C | 2973130-2 | 43 | SD | 73.1 | 0 | Y | N | N | A |
| C | 2973130-3 | 41 | SD | 73.1 | 0 | Y | N | N | A |
| C | 2980001-1 | 95 | BD | 19.9 | 0 | Y | Y | N | A[1] |
| C | 2980003-1 | 99 | BD | 6.6 | 0 | N | N | N | D |
| C | 2980145-1 | 101 | BD | 6.4 | 0 | N | N | N | D |
| C | 2980146-1 | 58 | BD | 28.5 | 0 | N | N | N | B |
| C | 2980146-3 | 57 | BD | 28.5 | 0 | N | N | N | B |
| C | 2980196-2 | 169 | SD | 11.9 | 0 | Y | N | N | C |
| C | 2980258-1 | 22 | BD | 45.3 | 0 | N | N | N | B |
| C | 2980258-2 | 23 | BD | 45.3 | 0 | N | N | N | B |
| C | 2980258-5 | 173 | BD | 45.3 | 0 | N | N | N | B |
| C | 2980264-1 | 186 | BD | 10.3 | 0 | N | N | N | D |
| C | 2980276-1 | 86 | BD | 10.2 | 0 | Y | Y | N | A[1] |
| C | 2980276-2 | 87 | BD | 10.2 | 0 | Y | Y | N | A[1] |
| C | 2980323-1 | 65 | BD | 20.1 | .6 | Y | Y | N | A[1] |
| C | 2980340-1 | 185 | BD | 37.2 | 0 | Y | Y | N | A[1] |
| P | 1000007-1 | 102 | BD | 3.8 | 0 | N | N | N | D |
| P | 1000007-2 | 103 | BD | 3.8 | 0 | N | N | N | D |
| P | 1000025-1 | 17 | BD | 9.0 | 9.8 | Y | N | N | B |
| P | 1000039-1 | 72 | SD | 8.6 | 0 | Y | Y | N | A[1] |
| P | 1000042-1 | 5 | BD | 23.7 | 0 | Y | N | N | B |
| P | 1559510-1 | 50 | BD | 5.1 | .8 | Y | N | N | B |
| P | 1559516-1 | 92 | SD | 6.6 | 0 | N | N | N | C |
| P | 1559516-2 | 104 | SD | 6.6 | 0 | N | N | N | C |

**Table 14**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by nutrients based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor: Aquifer type | Vulnerability factor: Area in WHPA, as percentage of total area: Residential land use | Vulnerability factor: Area in WHPA, as percentage of total area: Urban land use with parks and golf courses | Affected or unaffected for three threshold criteria: Nitrate > 1 mg/L as N | Affected or unaffected for three threshold criteria: Nitrate > 2 mg/L as N | Affected or unaffected for three threshold criteria: Nitrate > 5 mg/L as N | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|
| P | 1583819-3 | 56 | BD | 0.7 | 2.0 | N | N | N | B |
| P | 1583819-4 | 55 | BD | .7 | 2.0 | Y | Y | N | A[1] |
| P | 1583820-1 | 57 | BD | 1.4 | 3.2 | N | N | N | B |
| P | 1583823-1 | 36 | BD | 10.4 | 0 | Y | N | N | D |
| P | 1583827-1 | 18 | BD | 18.0 | 0 | N | N | N | D |
| P | 1583829-4 | 26 | BD | 3.8 | 1.3 | N | N | N | B |
| P | 1583829-5 | 25 | BD | 3.8 | 1.3 | N | N | N | B |
| P | 1583829-6 | 24 | BD | 3.8 | 1.3 | N | N | N | B |
| P | 1583829-7 | 27 | BD | 3.8 | 1.3 | N | N | N | B |
| P | 1592014-1 | 3 | BD | 23.7 | 0 | N | N | N | B |
| P | 1592015-1 | 6 | SD | 11.9 | 14.0 | N | N | N | A |
| P | 1592017-1 | 13 | BD | 16.3 | 2.1 | N | N | N | B |
| P | 1592027-2 | 66 | BD | 7.0 | 22.0 | Y | Y | N | A[1] |
| P | 1592027-3 | 67 | BD | 7.0 | 22.0 | Y | Y | N | A[1] |
| P | 1592028-1 | 79 | SD | 9.0 | 2.9 | N | N | N | A |
| P | 1592030-1 | 75 | SD | 9.0 | 2.9 | N | N | N | A |
| P | 1615611-1 | 41 | BD | 16.3 | 0 | Y | Y | N | A[1] |
| P | 1615612-4 | 34 | BD | 22.4 | 1.4 | Y | N | N | B |
| P | 1615612-5 | 35 | BD | 22.4 | 1.4 | N | N | N | B |
| P | 1615612-6 | 33 | BD | 22.4 | 1.4 | N | N | N | B |
| P | 1615613-1 | 30 | BD | 28.1 | 1.1 | N | N | N | B |
| P | 1615617-1 | 71 | SD | 8.6 | 0 | Y | Y | Y | A[1] |
| P | 1647513-3 | 91 | SD | 19.7 | .6 | Y | N | N | A |
| P | 1647517-1 | 10 | BD | 13.1 | 0 | N | N | N | D |
| P | 1647525-3 | 76 | BD | 15.3 | .9 | Y | N | N | B |
| P | 1647525-4 | 73 | BD | 15.3 | .9 | Y | Y | N | A[1] |
| P | 1647527-1 | 47 | BD | 16.5 | 0 | N | N | N | D |
| P | 1858414-1 | 68 | BD | 6.6 | 0 | N | N | N | D |
| P | 1858415-1 | 87 | BD | 38.4 | 5.9 | N | N | N | B |
| P | 1858417-1 | 89 | BD | 38.4 | 5.9 | N | N | N | B |
| P | 1858425-2 | 65 | BD | 11.4 | 3.2 | Y | Y | N | A[1] |
| P | 1858431-1 | 83 | DG | 33.9 | 0 | Y | N | N | A |
| P | 1900003-1 | 45 | BD | 3.5 | 0 | Y | Y | N | A[1] |
| P | 1900003-2 | 46 | BD | 3.5 | 0 | Y | Y | N | A[1] |
| P | 1900003-3 | 43 | BD | 3.5 | 0 | Y | Y | N | A[1] |
| P | 1900003-4 | 44 | BD | 3.5 | 0 | Y | Y | N | A[1] |
| P | 1900004-1 | 101 | U | 4.4 | 0 | N | N | N | D |
| P | 1900004-2 | 105 | U | 4.4 | 0 | N | N | N | D |
| P | 1900024-1 | 52 | BD | 1.0 | 0 | N | N | N | D |
| P | 1900024-2 | 54 | BD | 1.0 | 0 | N | N | N | D |

**Table 14**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by nutrients based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Affected or unaffected for three threshold criteria | | | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area: Residential land use | Area in WHPA, as percentage of total area: Urban land use with parks and golf courses | Nitrate > 1 mg/L as N | Nitrate > 2 mg/L as N | Nitrate > 5 mg/L as N | |
| P | 1900024-3 | 53 | BD | 1.0 | 0 | N | N | N | D |
| P | 1900026-1 | 16 | BD | 6.8 | 0 | N | N | N | D |
| P | 1900027-3 | 90 | BD | 7.4 | 2.4 | N | N | N | B |
| P | 1900028-1 | 11 | BD | 12.8 | 0 | N | N | N | D |
| P | 1900035-1 | 69 | BD | 6.6 | 0 | N | N | N | D |
| P | 1900038-1 | 20 | BD | 18.7 | 0 | N | N | N | D |
| P | 1900040-2 | 1 | BD | 7.1 | 0 | N | N | N | D |
| P | 1900041-1 | 19 | BD | 3.1 | 0 | N | N | N | D |
| P | 1900044-1 | 29 | BD | 22.2 | 0 | N | N | N | B |
| P | 2000090-1 | 97 | BD | 23.7 | 0 | Y | Y | Y | A[1] |
| P | 2000110-1 | 42 | BD | 8.9 | 2.4 | Y | N | N | B |
| P | 2000133-1 | 70 | BD | 4.1 | 0 | Y | Y | N | A[1] |
| P | 2000135-1 | 49 | BD | 8.6 | 0 | N | N | N | D |
| P | 2000142-4 | 74 | SD | 5.2 | 0 | Y | Y | N | A[1] |
| P | 2000145-1 | 88 | BD | 38.4 | 5.9 | Y | Y | Y | A[1] |
| P | 2000176-1 | 48 | BD | 11.6 | 0 | N | N | N | D |
| P | 2051719-1 | 37 | BD | .3 | 50.7 | Y | Y | Y | A[1] |
| P | 2051719-2 | 38 | BD | .3 | 50.7 | Y | Y | Y | A[1] |
| P | 2051719-3 | 39 | BD | .3 | 50.7 | Y | Y | Y | A[1] |
| P | 2051719-4 | 40 | BD | .3 | 50.7 | Y | Y | Y | A[1] |
| P | 2051729-1 | 64 | DG | 9.4 | 13.3 | Y | Y | N | A |
| P | 2788010-1 | 32 | BD | 16.7 | 0 | N | N | N | D |
| P | 2942515-1 | 9 | BD | 29.7 | 2.1 | Y | N | N | B |
| P | 2973119-4 | 7 | BD | 8.3 | 0 | N | N | N | D |
| P | 2980017-1 | 94 | BD | 46.8 | 0 | Y | N | N | B |
| P | 2980019-1 | 96 | BD | 17.7 | 22.8 | Y | N | N | B |
| P | 2980030-1 | 99 | BD | 17.0 | 0 | N | N | N | D |
| P | 2980036-1 | 2 | BD | 55.1 | .2 | Y | N | N | B |
| P | 2980084-2 | 31 | BD | .5 | 0 | N | N | N | D |
| P | 2980127-1 | 84 | BD | 18.0 | 0 | N | N | N | D |
| P | 2980134-1 | 21 | BD | 43.6 | 10.7 | Y | N | N | B |
| P | 2980135-1 | 28 | BD | 56.7 | .7 | N | N | N | B |
| P | 2980138-1 | 60 | BD | 30.9 | 0 | N | N | N | B |
| P | 2980154-1 | 98 | BD | 4.2 | 4.6 | N | N | N | B |
| P | 2980185-2 | 77 | SD | 9.0 | 2.9 | N | N | N | A |
| P | 2980185-3 | 78 | SD | 9.0 | 2.9 | N | N | N | A |
| P | 2980192-1 | 62 | BD | 15.1 | 0 | N | N | N | D |
| P | 2980192-2 | 63 | BD | 15.1 | 0 | Y | N | N | D |
| P | 2980265-1 | 59 | BD | 12.8 | 0 | N | N | N | D |
| P | 2980270-1 | 100 | BD | 15.7 | 0 | N | N | N | D |

**Table 14.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by nutrients based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Aquifer type | Vulnerability factor: Area in WHPA, as percentage of total area: Residential land use | Urban land use with parks and golf courses | Affected or unaffected for three threshold criteria: Nitrate > 1 mg/L as N | Nitrate > 2 mg/L as N | Nitrate > 5 mg/L as N | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|
| P | 2980277-1 | 14 | BD | 29.8 | 2.3 | N | N | N | B |
| P | 2980278-1 | 15 | BD | 29.8 | 2.3 | N | N | N | B |
| P | 2980301-1 | 4 | BD | 23.7 | 0 | N | N | N | B |
| P | 2980311-1 | 12 | BD | 25.7 | 0 | N | N | N | B |
| P | 2980330-1 | 106 | BD | 4.2 | 4.6 | N | N | N | B |
| P | 2980346-1 | 107 | U | 9.7 | 0 | N | N | N | D |

[1]Well is designated with "A" vulnerability category based on historical water quality (measured nitrate concentration greater than 2 mg/L as N) rather than on tabulated vulnerability factors.

**Table 15.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by pesticides based on aquifer type, land use, and median nitrate concentrations

[**Supply type:** C, community; P, non-community, non-transient. **Source identifier:** Combines the public-water system identifier (PWSID) and the source number assigned by the Rhode Island Department of Health. **USGS-ID:** Identifier used in figures 2 and 3. **Aquifer type:** BD, bedrock; D, dug well of undetermined aquifer type; SD, sand and gravel; U, drilled well of undetermined aquifer type. WHPA, wellhead-protection area. **Agricultural land use:** Not significant in the present study but included on the basis of literature sources—see text for discussion. **Affected or unaffected:** Y, affected, N, unaffected. **Relative vulnerability:** A, most vulnerable; C, least vulnerable; --, not assessed. Shading indicates values used in designating A and B vulnerability categories. mg/L as N, milligrams per liter as nitrogen; <, actual value is less than value shown]

| Supply type | Source identifier | USGS-ID | Vulnerability factor: Aquifer type | Area in WHPA, as percentage of total area: Urban land use with parks and golf courses | Institutional land use | Agricultural land use | Hydrologic group A soils | Median nitrate concentration, in mg/L as N | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|---|
| C | 1000009-1 | 63 | BD | 0.0 | 0.9 | 1.4 | 0.0 | 0.3 | N | B |
| C | 1000009-4 | 178 | BD | 0 | .9 | 1.4 | 0 | .6 | N | B |
| C | 1000020-1 | 68 | BD | 1.2 | 3.2 | 6.3 | 12.4 | <.1 | N | B |
| C | 1000020-2 | 67 | BD | 1.2 | 3.2 | 6.3 | 12.4 | <.1 | N | B |
| C | 1000020-3 | 69 | BD | 1.2 | 3.2 | 6.3 | 12.4 | <.1 | N | B |
| C | 1000035-3 | 150 | BD | 0 | 0 | .3 | 73.0 | .8 | N | C |
| C | 1000035-4 | 152 | BD | 0 | 0 | .3 | 73.0 | 1.0 | N | C |
| C | 1000035-5 | 151 | BD | 0 | 0 | .3 | 73.0 | .9 | N | C |
| C | 1000040-1 | 113 | SD | 0 | .7 | 7.8 | 27.9 | -- | N | A |
| C | 1000040-2 | 180 | SD | 0 | .7 | 7.8 | 27.9 | <.1 | N | A |
| C | 1000043-2 | 124 | BD | 7.8 | 0 | 10.1 | 3.5 | .8 | N | B |
| C | 1000043-3 | 125 | BD | 7.8 | 0 | 10.1 | 3.5 | 1.5 | N | B |
| C | 1000045-1 | 141 | BD | 0 | .3 | 5.6 | 48.1 | 1.7 | N | B |
| C | 1000045-2 | 142 | BD | 0 | .3 | 5.6 | 48.1 | <.1 | N | B |
| C | 1000098-1 | 133 | SD | 7.8 | 0 | 10.1 | 3.5 | .3 | N | A |

**Table 15**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by pesticides based on aquifer type, land use, and median nitrate concentrations—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | | | Affected or unaffected | Relative vulnera-bility |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | Median nitrate concen-tration, in mg/L as N | | |
| | | | | Urban land use with parks and golf courses | Institu-tional land use | Agricul-tural land use | Hydro-logic group A soils | | | |
| C | 1000098-2 | 132 | SD | 7.8 | 0.0 | 10.1 | 3.5 | 0.2 | N | A |
| C | 1559511-1 | 90 | SD | 5.2 | .2 | .4 | 54.8 | 2.2 | N | A |
| C | 1559511-2 | 82 | SD | 0 | 0 | 6.4 | 69.8 | 4.6 | N | A |
| C | 1559511-3 | 85 | SD | 0 | 0 | 0 | 20.2 | 1.1 | N | C |
| C | 1559511-4 | 84 | SD | 0 | 0 | 0 | 20.2 | .3 | N | C |
| C | 1559512-1 | 153 | SD | 4.0 | .7 | 11.6 | 22.5 | 1.8 | N | A |
| C | 1559512-10 | 159 | SD | 0 | 0 | 0 | 25.9 | 4.1 | N | A |
| C | 1559512-11 | 161 | SD | 1.0 | .02 | 6.0 | 8.4 | 1.2 | N | A |
| C | 1559512-2 | 155 | SD | 4.0 | .7 | 11.6 | 22.5 | .5 | N | A |
| C | 1559512-3 | 154 | SD | 4.0 | .7 | 11.6 | 22.5 | .8 | N | A |
| C | 1559512-4 | 147 | SD | 4.0 | .7 | 11.6 | 22.5 | 1.1 | N | A |
| C | 1559512-5 | 145 | SD | 4.0 | .7 | 11.6 | 22.5 | 1.2 | N | A |
| C | 1559512-6 | 146 | SD | 4.0 | .7 | 11.6 | 22.5 | 1.7 | N | A |
| C | 1559512-7 | 149 | SD | 4.0 | .7 | 11.6 | 22.5 | .6 | N | A |
| C | 1559512-8 | 148 | SD | 0 | .2 | 9.6 | 17.6 | 2.8 | Y | A |
| C | 1559512-9 | 158 | SD | 0 | .2 | 9.6 | 17.6 | .9 | N | A |
| C | 1559513-1 | 166 | SD | 0 | 0 | 1.6 | 48.5 | .9 | N | C |
| C | 1559513-2 | 164 | SD | 0 | 0 | 1.6 | 48.5 | .04 | N | C |
| C | 1559513-4 | 165 | BD | 0 | 0 | 1.6 | 48.5 | .6 | N | C |
| C | 1559513-5 | 163 | BD | 0 | 0 | 1.6 | 48.5 | .1 | N | C |
| C | 1559517-1 | 106 | SD | .1 | .1 | 25.3 | 25.2 | .7 | N | A |
| C | 1559517-10 | 118 | SD | 0 | 0 | 0 | 36.6 | <.1 | N | C |
| C | 1559517-2 | 107 | SD | .1 | .1 | 25.3 | 25.2 | 1.4 | N | A |
| C | 1559517-3 | 116 | SD | 0 | 0 | 0 | 36.6 | <.1 | N | C |
| C | 1559517-4 | 108 | SD | .1 | .1 | 25.3 | 25.2 | 2.5 | N | A |
| C | 1559517-5 | 110 | SD | .1 | .1 | 25.3 | 25.2 | 2.4 | N | A |
| C | 1559517-6 | 104 | SD | 0 | .7 | 3.8 | 55.2 | 1.8 | N | A |
| C | 1559517-7 | 91 | SD | 5.2 | .2 | .4 | 54.8 | 3.1 | N | A |
| C | 1559517-8 | 92 | SD | 5.2 | .2 | .4 | 54.8 | 4.3 | N | A |
| C | 1559517-9 | 117 | SD | 0 | 0 | 0 | 36.6 | <.1 | N | C |
| C | 1559519-1 | 28 | BD | 0 | 1.0 | 10.6 | 18.9 | <.1 | N | B |
| C | 1559519-2 | 27 | BD | 0 | 1.0 | 10.6 | 18.9 | <.1 | N | B |
| C | 1583825-1 | 29 | BD | 0 | .3 | 5.3 | 4.4 | .2 | N | B |
| C | 1592012-2 | 105 | SD | 0 | 13.1 | 7.6 | 15.3 | .5 | N | A |
| C | 1592019-1 | 38 | BD | 0 | .1 | 3.8 | 41.2 | 1.7 | N | B |
| C | 1592019-2 | 176 | BD | 0 | .1 | 3.8 | 41.2 | .9 | N | B |
| C | 1592020-1 | 32 | SD | 0 | 5.5 | 0 | 17.2 | .2 | N | A |
| C | 1592020-2 | 34 | SD | 0 | 5.5 | 0 | 17.2 | 1.4 | N | A |
| C | 1592021-2 | 56 | SD | .6 | 1.2 | 3.3 | 43.1 | 1.1 | N | A |
| C | 1592021-3 | 55 | SD | .6 | 1.2 | 3.3 | 43.1 | 1.8 | N | A |

**Table 15.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by pesticides based on aquifer type, land use, and median nitrate concentrations—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area: Urban land use with parks and golf courses | Institutional land use | Agricultural land use | Hydrologic group A soils | Median nitrate concentration, in mg/L as N | | |
| C | 1592021-4 | 54 | SD | 0.6 | 1.2 | 3.3 | 43.1 | 2.9 | N | A |
| C | 1592021-5 | 53 | SD | .6 | 1.2 | 3.3 | 43.1 | 3.7 | N | A |
| C | 1592021-6 | 50 | SD | .6 | 1.2 | 3.3 | 43.1 | .4 | N | A |
| C | 1592021-7 | 47 | SD | .6 | 1.2 | 3.3 | 43.1 | 1.6 | N | A |
| C | 1592021-8 | 46 | SD | .6 | 1.2 | 3.3 | 43.1 | 2.8 | Y | A |
| C | 1592021-9 | 45 | SD | .6 | 1.2 | 3.3 | 43.1 | 3.1 | N | A |
| C | 1592023-1 | 102 | BD | .4 | .4 | 3.3 | 8.4 | <.1 | N | B |
| C | 1592023-5 | 100 | BD | .4 | .4 | 3.3 | 8.4 | <.1 | N | B |
| C | 1592023-7 | 98 | BD | .4 | .4 | 3.3 | 8.4 | .2 | N | B |
| C | 1592023-8 | 94 | BD | .4 | .4 | 3.3 | 8.4 | <.1 | N | B |
| C | 1592023-9 | 179 | BD | .4 | .4 | 3.3 | 8.4 | <.1 | N | B |
| C | 1592025-1 | 88 | SD | 5.2 | .2 | .4 | 54.8 | 4.2 | N | A |
| C | 1592025-2 | 93 | SD | 5.2 | .2 | .4 | 54.8 | 1.5 | N | A |
| C | 1592025-3 | 89 | SD | 5.2 | .2 | .4 | 54.8 | .8 | Y | A |
| C | 1615614-1 | 26 | SD | 1.3 | 2.1 | 4.8 | 33.2 | .9 | N | A |
| C | 1615614-2 | 25 | BD | 1.3 | 2.1 | 4.8 | 33.2 | 2.5 | N | B |
| C | 1615614-5 | 24 | SD | 0 | 8.8 | 0 | 60.4 | 2.6 | N | A |
| C | 1615623-1 | 157 | SD | 0 | .4 | 8.3 | 67.7 | .3 | N | A |
| C | 1615623-2 | 156 | SD | 0 | .4 | 8.3 | 67.7 | .3 | N | A |
| C | 1615624-1 | 137 | SD | 0 | 0 | 20.5 | 29.1 | .9 | N | C |
| C | 1615624-2 | 138 | SD | 0 | 0 | 20.5 | 29.1 | .8 | N | C |
| C | 1615624-3 | 136 | SD | 0 | 0 | 20.5 | 29.1 | 2.0 | N | B |
| C | 1615624-4 | 139 | SD | 0 | 0 | 20.5 | 29.1 | 2.4 | Y | A[1] |
| C | 1615624-5 | 140 | SD | 0 | 0 | 20.5 | 29.1 | 1.8 | Y | A[1] |
| C | 1615624-7 | 135 | SD | 0 | 0 | 20.5 | 29.1 | 4.5 | N | B |
| C | 1615626-1 | 80 | SD | 4.5 | 0 | 2.9 | 81.0 | 8.2 | N | A |
| C | 1615626-2 | 81 | SD | 4.5 | 0 | 2.9 | 81.0 | 6.7 | N | A |
| C | 1647512-1 | 167 | SD | 2.7 | 0 | 0 | 0 | 2.8 | N | A |
| C | 1647512-2 | 168 | SD | 2.7 | 0 | 0 | 0 | 4.0 | N | A |
| C | 1647515-5 | 77 | SD | 3.1 | 2.5 | 2.3 | 36.6 | .3 | N | A |
| C | 1647515-6 | 76 | SD | 3.1 | 2.5 | 2.3 | 36.6 | <.1 | Y | A |
| C | 1647526-1 | 44 | BD | 0 | 0 | 1.6 | 16.2 | 1.8 | N | C |
| C | 1647529-1 | 134 | BD | 0 | 1.0 | 16.7 | 23.9 | <.1 | N | B |
| C | 1647530-1 | 33 | SD | 0 | 0 | 0 | 0 | .5 | N | C |
| C | 1647530-3 | 40 | SD | 0 | 0 | 9.6 | 49.2 | 1.0 | N | C |
| C | 1647530-4 | 39 | SD | 0 | 0 | 9.6 | 49.2 | .9 | N | C |
| C | 1647530-5 | 31 | SD | 0 | 0 | 0 | 0 | 1.5 | N | C |
| C | 1858411-1 | 35 | SD | 0 | 0 | 0 | 89.9 | 1.3 | N | C |
| C | 1858411-2 | 37 | SD | 0 | 1.8 | .9 | 36.4 | .7 | N | A |
| C | 1858421-1 | 130 | SD | 12.1 | 36.8 | 15.1 | 9.2 | 3.9 | Y | A |

**Table 15.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by pesticides based on aquifer type, land use, and median nitrate concentrations—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor: Aquifer type | Area in WHPA, as percentage of total area: Urban land use with parks and golf courses | Institutional land use | Agricultural land use | Hydrologic group A soils | Median nitrate concentration, in mg/L as N | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|---|
| C | 1858421-2 | 131 | SD | 12.1 | 36.8 | 15.1 | 9.2 | 4.0 | Y | A |
| C | 1858422-1 | 128 | SD | 12.1 | 36.8 | 15.1 | 9.2 | 1.1 | N | A |
| C | 1858422-2 | 129 | SD | 12.1 | 36.8 | 15.1 | 9.2 | 2.0 | N | A |
| C | 1858422-3 | 127 | SD | 12.1 | 36.8 | 15.1 | 9.2 | 1.8 | Y | A |
| C | 1858423-5 | 59 | SD | 4.1 | 2.9 | 26.4 | 36.8 | .7 | N | A |
| C | 1858435-1 | 70 | BD | 0 | 0 | 2.5 | 19.0 | .4 | N | C |
| C | 1900020-1 | 78 | SD | 0 | 0 | 26.3 | 70.8 | .5 | N | C |
| C | 1900023-1 | 74 | BD | 0 | 0 | 18.9 | 0 | <.1 | N | C |
| C | 1900023-2 | 75 | BD | 0 | 0 | 18.9 | 0 | <.1 | N | C |
| C | 1900023-3 | 71 | BD | 0 | 0 | 18.9 | 0 | .2 | N | C |
| C | 1900023-4 | 72 | BD | 0 | 0 | 18.9 | 0 | <.1 | N | C |
| C | 1900023-5 | 73 | BD | 0 | 0 | 18.9 | 0 | .1 | N | C |
| C | 1900025-2 | 126 | BD | 7.8 | 0 | 10.1 | 3.5 | <.1 | N | B |
| C | 1900029-1 | 160 | BD | 14.0 | 0 | 3.4 | 64.4 | -- | -- | B |
| C | 1900034-1 | 30 | SD | 0 | 0 | 0 | 17.9 | <.1 | N | C |
| C | 1900034-2 | 181 | SD | 0 | 0 | 0 | 17.9 | <.1 | N | C |
| C | 1900036-1 | 170 | U | 0 | 0 | 1.2 | 35.4 | .4 | -- | C |
| C | 1900036-2 | 171 | U | 0 | 0 | 1.2 | 35.4 | -- | -- | C |
| C | 1900039-1 | 174 | BD | 0 | 0 | 26.1 | 19.5 | -- | -- | C |
| C | 1900048-2 | 123 | BD | 7.8 | 0 | 10.1 | 3.5 | 1.9 | N | B |
| C | 1900049-1 | 183 | SD | 6.4 | 1.2 | 0 | 43.1 | -- | -- | A |
| C | 2000004-2 | 79 | BD | 0 | 0 | 4.2 | 14.0 | .4 | N | C |
| C | 2000059-1 | 49 | BD | .2 | .8 | 4.8 | 14.3 | <.1 | N | B |
| C | 2000059-2 | 48 | BD | .2 | .8 | 4.8 | 14.3 | <.1 | N | B |
| C | 2000083-1 | 52 | BD | 0 | 1.9 | 20.3 | 15.8 | <.1 | N | B |
| C | 2000083-2 | 51 | BD | 0 | 1.9 | 20.3 | 15.8 | <.1 | N | B |
| C | 2000084-1 | 62 | BD | 0 | .1 | 23.6 | .5 | <.1 | N | B |
| C | 2000165-1 | 112 | BD | .7 | 0 | 1.4 | 1.3 | 2.0 | N | B |
| C | 2051311-1 | 97 | BD | 0 | 0 | 4.2 | 0 | 1.3 | N | C |
| C | 2415415-1 | 64 | BD | 0 | 0 | 8.5 | 0 | .8 | N | C |
| C | 2519424-1 | 60 | BD | 0 | 0 | 3.5 | 21.6 | .8 | N | C |
| C | 2519424-3 | 177 | BD | 0 | 0 | 3.5 | 21.6 | <.1 | N | C |
| C | 2519426-1 | 83 | BD | 0 | 0 | 1.0 | 0 | .3 | N | C |
| C | 2585312-1 | 115 | DG | 0 | 0 | 2.9 | 0 | <.1 | N | C |
| C | 2585312-2 | 114 | BD | 0 | 0 | 2.9 | 0 | <.1 | N | C |
| C | 2585313-1 | 103 | BD | 1.1 | .5 | 3.6 | 0 | <.1 | N | B |
| C | 2674924-1 | 182 | SD | 0 | 0 | 0 | 86.4 | 1.1 | N | C |
| C | 2674925-1 | 144 | BD | 0 | 0 | 1.9 | 25.0 | .5 | N | C |
| C | 2674925-2 | 143 | BD | 0 | 0 | 1.9 | 25.0 | 1.0 | N | C |
| C | 2674928-1 | 162 | BD | 14.0 | 0 | 3.4 | 64.4 | .3 | N | B |

**Table 15**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by pesticides based on aquifer type, land use, and median nitrate concentrations—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | | | Affected or unaffected | Relative vulnera-bility |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | Median nitrate concen-tration, in mg/L as N | | |
| | | | | Urban land use with parks and golf courses | Institu-tional land use | Agricul-tural land use | Hydro-logic group A soils | | | |
| C | 2753326-1 | 121 | BD | 3.1 | 1.4 | 42.0 | 0.0 | 2.3 | N | B |
| C | 2753326-3 | 122 | BD | 3.1 | 1.4 | 42.0 | 0 | 4.1 | N | B |
| C | 2788012-1 | 66 | BD | 0 | .8 | 3.8 | 6.1 | 2.0 | N | B |
| C | 2814410-3 | 96 | BD | 0 | 0 | 0 | 5.3 | <.1 | N | C |
| C | 2882117-3 | 120 | SD | 0 | 1.4 | 1.9 | 8.7 | .5 | N | A |
| C | 2882117-4 | 119 | BD | 0 | 1.4 | 1.9 | 8.7 | .9 | N | B |
| C | 2942518-1 | 36 | BD | 2.9 | 0 | 9.6 | 11.5 | .4 | N | B |
| C | 2942525-1 | 111 | BD | .7 | 0 | 1.4 | 1.3 | <.1 | N | B |
| C | 2942525-3 | 109 | BD | .7 | 0 | 1.4 | 1.3 | <.1 | N | B |
| C | 2943224-8 | 61 | BD | 0 | 0 | 3.5 | 21.6 | .4 | N | C |
| C | 2973130-1 | 42 | SD | 0 | 0 | 0 | 41.0 | .8 | N | C |
| C | 2973130-2 | 43 | SD | 0 | 0 | 0 | 41.0 | .4 | N | C |
| C | 2973130-3 | 41 | SD | 0 | 0 | 0 | 41.0 | .6 | N | C |
| C | 2980001-1 | 95 | BD | 0 | .3 | 4.5 | 0 | 2.2 | N | B |
| C | 2980003-1 | 99 | BD | 0 | 0 | 4.2 | 0 | .4 | N | C |
| C | 2980145-1 | 101 | BD | 0 | 0 | 1.4 | 19.1 | .1 | N | C |
| C | 2980146-1 | 58 | BD | 0 | 0 | 3.5 | 21.6 | .1 | N | C |
| C | 2980146-3 | 57 | BD | 0 | 0 | 3.5 | 21.6 | .1 | N | C |
| C | 2980196-2 | 169 | SD | 0 | 0 | 10.8 | 77.6 | 1.8 | N | B |
| C | 2980258-1 | 22 | BD | 0 | 0 | 1.2 | 15.4 | <.1 | N | C |
| C | 2980258-2 | 23 | BD | 0 | 0 | 1.2 | 15.4 | -- | N | C |
| C | 2980258-5 | 173 | BD | 0 | 0 | 1.2 | 15.4 | <.1 | N | C |
| C | 2980264-1 | 186 | BD | 0 | 10.6 | 5.2 | 20.9 | .2 | -- | B |
| C | 2980276-1 | 86 | BD | 0 | 0 | 4.1 | .4 | 2.3 | N | C |
| C | 2980276-2 | 87 | BD | 0 | 0 | 4.1 | .4 | 2.3 | N | C |
| C | 2980323-1 | 65 | BD | .6 | 4.2 | .8 | 31.8 | 4.1 | N | B |
| C | 2980340-1 | 185 | BD | 0 | 0 | 13.7 | 0 | 4.2 | -- | C |
| P | 1000007-1 | 102 | BD | 0 | 4.7 | 3.9 | 0 | .4 | N | B |
| P | 1000007-2 | 103 | BD | 0 | 4.7 | 3.9 | 0 | .2 | N | B |
| P | 1000025-1 | 17 | BD | 9.8 | 7.0 | 8.0 | 0 | 1.2 | N | B |
| P | 1000039-1 | 72 | SD | 0 | 0 | 29.0 | 7.5 | 4.1 | N | B |
| P | 1000042-1 | 5 | BD | 0 | 0 | 1.5 | 10.7 | 1.5 | N | C |
| P | 1559510-1 | 50 | BD | .8 | 1.9 | 12.1 | 1.3 | 1.9 | N | B |
| P | 1559516-1 | 92 | SD | 0 | 0 | 3.7 | 35.2 | .2 | N | C |
| P | 1559516-2 | 104 | SD | 0 | 0 | 3.7 | 35.2 | .2 | N | C |

**Table 15.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by pesticides based on aquifer type, land use, and median nitrate concentrations—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor: Aquifer type | Area in WHPA, as percentage of total area: Urban land use with parks and golf courses | Institutional land use | Agricultural land use | Hydrologic group A soils | Median nitrate concentration, in mg/L as N | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|---|
| P | 1583819-3 | 56 | BD | 2.0 | 3.8 | 6.7 | 0.0 | 0.6 | N | B |
| P | 1583819-4 | 55 | BD | 2.0 | 3.8 | 6.7 | 0 | 1.6 | N | B |
| P | 1583820-1 | 57 | BD | 3.2 | 1.4 | 0 | 16.8 | .2 | N | B |
| P | 1583823-1 | 36 | BD | 0 | 2.9 | 4.0 | 49.6 | 1.8 | N | B |
| P | 1583827-1 | 18 | BD | 0 | 2.6 | 10.3 | 14.6 | <.1 | N | B |
| P | 1583829-4 | 26 | BD | 1.3 | 1.8 | 7.2 | 2.3 | <.1 | N | B |
| P | 1583829-5 | 25 | BD | 1.3 | 1.8 | 7.2 | 2.3 | .2 | N | B |
| P | 1583829-6 | 24 | BD | 1.3 | 1.8 | 7.2 | 2.3 | <.1 | N | B |
| P | 1583829-7 | 27 | BD | 1.3 | 1.8 | 7.2 | 2.3 | <.1 | N | B |
| P | 1592014-1 | 3 | BD | 0 | 0 | 1.5 | 10.7 | .1 | N | C |
| P | 1592015-1 | 6 | SD | 14.0 | 2.0 | 5.8 | 63.0 | .1 | N | A |
| P | 1592017-1 | 13 | BD | 2.1 | 1.4 | 14.7 | 23.1 | .8 | N | B |
| P | 1592027-2 | 66 | BD | 22.0 | 5.4 | 16.7 | 30.2 | .4 | N | B |
| P | 1592027-3 | 67 | BD | 22.0 | 5.4 | 16.7 | 30.2 | .2 | N | B |
| P | 1592028-1 | 79 | SD | 2.9 | 4.2 | 37.4 | 23.9 | -- | Y | A[1] |
| P | 1592030-1 | 75 | SD | 2.9 | 4.2 | 37.4 | 23.9 | -- | N | A |
| P | 1615611-1 | 41 | BD | 0 | 1.4 | 7.5 | 4.4 | 4.7 | N | B |
| P | 1615612-4 | 34 | BD | 1.4 | 4.3 | 5.4 | .4 | 1.0 | N | B |
| P | 1615612-5 | 35 | BD | 1.4 | 4.3 | 5.4 | .4 | .8 | N | B |
| P | 1615612-6 | 33 | BD | 1.4 | 4.3 | 5.4 | .4 | .7 | N | B |
| P | 1615613-1 | 30 | BD | 1.1 | 8.0 | .9 | 41.6 | -- | N | B |
| P | 1615617-1 | 71 | SD | 0 | 0 | 29.0 | 7.5 | 6.7 | N | B |
| P | 1647513-3 | 91 | SD | .6 | .1 | 9.4 | 13.8 | 1.9 | N | A |
| P | 1647517-1 | 10 | BD | 0 | 1.5 | 12.3 | 48.9 | <.1 | N | B |
| P | 1647525-3 | 76 | BD | .9 | 3.6 | 6.2 | 29.0 | 1.2 | Y | A[1] |
| P | 1647525-4 | 73 | BD | .9 | 3.6 | 6.2 | 29.0 | 1.6 | Y | A[1] |
| P | 1647527-1 | 47 | BD | 0 | 2.1 | 12.1 | 0 | <.1 | N | B |
| P | 1858414-1 | 68 | BD | 0 | 0 | 7.0 | 0 | .6 | N | C |
| P | 1858415-1 | 87 | BD | 5.9 | 2.9 | 10.4 | 50.4 | .9 | N | B |
| P | 1858417-1 | 89 | BD | 5.9 | 2.9 | 10.4 | 50.4 | <.1 | N | B |
| P | 1858425-2 | 65 | BD | 3.2 | 2.7 | 29.9 | 0 | 2.6 | N | B |
| P | 1858431-1 | 83 | DG | 0 | .8 | 4.9 | 57.1 | 1.3 | N | A |
| P | 1900003-1 | 45 | BD | 0 | 0 | 0 | 0 | 2.9 | N | B |
| P | 1900003-2 | 46 | BD | 0 | 0 | 0 | 0 | 2.4 | N | B |
| P | 1900003-3 | 43 | BD | 0 | 0 | 0 | 0 | 2.1 | N | B |

**Table 15.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by pesticides based on aquifer type, land use, and median nitrate concentrations—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor: Aquifer type | Area in WHPA, as percentage of total area: Urban land use with parks and golf courses | Institutional land use | Agricultural land use | Hydrologic group A soils | Median nitrate concentration, in mg/L as N | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|---|
| P | 1900003-4 | 44 | BD | 0.0 | 0.0 | 0.0 | 0.0 | 3.4 | N | B |
| P | 1900004-1 | 101 | U | 0 | 0 | 0 | 0 | -- | -- | C |
| P | 1900004-2 | 105 | U | 0 | 0 | 0 | 0 | -- | -- | C |
| P | 1900024-1 | 52 | BD | 0 | 0 | 0 | 0 | <.1 | N | C |
| P | 1900024-2 | 54 | BD | 0 | 0 | 0 | 0 | <.1 | N | C |
| P | 1900024-3 | 53 | BD | 0 | 0 | 0 | 0 | .1 | N | C |
| P | 1900026-1 | 16 | BD | 0 | 0 | 12.2 | 0 | <.1 | N | C |
| P | 1900027-3 | 90 | BD | 2.4 | 2.0 | 0 | 37.3 | .5 | N | B |
| P | 1900028-1 | 11 | BD | 0 | 0 | 8.3 | 23.2 | <.1 | N | C |
| P | 1900035-1 | 69 | BD | 0 | 0 | 7.0 | 0 | <.1 | N | C |
| P | 1900038-1 | 20 | BD | 0 | 0 | 4.0 | 25.0 | <.1 | N | C |
| P | 1900040-2 | 1 | BD | 0 | 0 | 6.5 | 3.0 | -- | N | C |
| P | 1900041-1 | 19 | BD | 0 | 0 | 0 | .4 | -- | N | C |
| P | 1900044-1 | 29 | BD | 0 | 0 | 14.4 | 0 | <.1 | N | C |
| P | 2000090-1 | 97 | BD | .0 | 0 | 1.5 | 10.7 | 7.6 | -- | C |
| P | 2000110-1 | 42 | BD | 2.4 | 0 | 4.7 | 27.0 | 1.6 | N | B |
| P | 2000133-1 | 70 | BD | 0 | 0 | 15.3 | 0 | 2.8 | N | C |
| P | 2000135-1 | 49 | BD | 0 | 0 | 2.1 | 21.9 | <.1 | N | C |
| P | 2000142-4 | 74 | SD | 0 | 0 | 10.9 | 6.9 | 2.9 | N | B |
| P | 2000145-1 | 88 | BD | 5.9 | 2.9 | 10.4 | 50.4 | 8.1 | N | B |
| P | 2000176-1 | 48 | BD | 0 | 8.4 | 2.5 | 12.2 | <.1 | N | B |
| P | 2051719-1 | 37 | BD | 50.7 | 0 | 2.2 | 0 | 5.9 | N | B |
| P | 2051719-2 | 38 | BD | 50.7 | 0 | 2.2 | 0 | 5.6 | N | B |
| P | 2051719-3 | 39 | BD | 50.7 | 0 | 2.2 | 0 | 3.7 | N | B |
| P | 2051719-4 | 40 | BD | 50.7 | 0 | 2.2 | 0 | 4.9 | N | B |
| P | 2051729-1 | 64 | DG | 13.3 | 0 | 26.3 | 1.4 | 2.1 | N | A |
| P | 2788010-1 | 32 | BD | 0 | .9 | .2 | 14.4 | <.1 | N | B |
| P | 2942515-1 | 9 | BD | 2.1 | 3.4 | 0 | 21.2 | 1.2 | N | B |
| P | 2973119-4 | 7 | BD | 0 | 8.7 | 25.1 | 45.0 | <.1 | N | B |
| P | 2980017-1 | 94 | BD | 0 | 0 | 10.3 | 71.4 | 1.2 | N | C |
| P | 2980019-1 | 96 | BD | 22.8 | 0 | 0 | 5.5 | 1.2 | N | B |
| P | 2980030-1 | 99 | BD | 0 | 0 | 8.0 | 14.2 | .3 | N | C |
| P | 2980036-1 | 2 | BD | .2 | .8 | 5.0 | 26.5 | 1.8 | N | B |
| P | 2980084-2 | 31 | BD | 0 | 0 | 0 | 0 | <.1 | N | C |
| P | 2980127-1 | 84 | BD | 0 | .9 | 9.2 | 42.7 | 1.0 | N | B |
| P | 2980134-1 | 21 | BD | 10.7 | 1.3 | 5.8 | 6.4 | 1.6 | N | B |
| P | 2980135-1 | 28 | BD | .7 | .1 | 0 | 25.6 | .1 | N | B |
| P | 2980138-1 | 60 | BD | 0 | .5 | 14.6 | 0 | .1 | N | B |
| P | 2980154-1 | 98 | BD | 4.6 | 11.7 | 3.7 | 40.2 | <.1 | N | B |
| P | 2980185-2 | 77 | SD | 2.9 | 4.2 | 37.4 | 23.9 | <.1 | N | A |

**Table 15.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by pesticides based on aquifer type, land use, and median nitrate concentrations—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | Median nitrate concentration, in mg/L as N | | |
| | | | | Urban land use with parks and golf courses | Institutional land use | Agricultural land use | Hydrologic group A soils | | | |
| P | 2980185-3 | 78 | SD | 2.9 | 4.2 | 37.4 | 23.9 | <0.1 | N | A |
| P | 2980192-1 | 62 | BD | 0 | 0 | 0 | 2.2 | .2 | N | C |
| P | 2980192-2 | 63 | BD | 0 | 0 | 0 | 2.2 | .2 | N | C |
| P | 2980265-1 | 59 | BD | 0 | 3.1 | 21.1 | 0 | <.1 | N | B |
| P | 2980270-1 | 100 | BD | 0 | 0 | .7 | 51.8 | <.1 | N | C |
| P | 2980277-1 | 14 | BD | 2.3 | .5 | 3.1 | 56.5 | .2 | N | B |
| P | 2980278-1 | 15 | BD | 2.3 | .5 | 3.1 | 56.5 | .5 | N | B |
| P | 2980301-1 | 4 | BD | 0 | 0 | 1.5 | 10.7 | .6 | N | C |
| P | 2980311-1 | 12 | BD | 0 | .8 | 9.3 | 3.4 | <.1 | N | C |
| P | 2980330-1 | 106 | BD | 4.6 | 11.7 | 3.7 | 40.2 | <.1 | Y | A[1] |
| P | 2980346-1 | 107 | U | 0 | 0 | 25.1 | 0 | -- | -- | C |

[1]Well is designated with "A" vulnerability category based on historical water quality (pesticide detections) rather than on tabulated vulnerability factors.

**Table 16.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by solvents and other industrial organic chemicals based on aquifer type and land use

[**Supply type:** C, community; P, non-community, non-transient. **Source identifier:** Combines the public-water system identifier (PWSID) and the source number assigned by the Rhode Island Department of Health. **USGS-ID:** Identifier used in figures 2 and 3. **Aquifer type:** BD, bedrock; D, dug well of undetermined aquifer type; SD, sand and gravel; U, drilled well of undetermined aquifer type. WHPA, wellhead-protection area. **All urban land uses**: Not significant in the present study but included on the basis of literature sources—see text for discussion. **Affected or unaffected:** Y, affected, N, unaffected. **Relative vulnerability:** A, most vulnerable; D, least vulnerable. Shading indicates values used in designating A, B, and C vulnerability categories. --, not assessed]

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | |
| | | | | Industrial land use | All urban land uses | Brushland cover | | |
| C | 1000009-1 | 63 | BD | 0 | 15.8 | 1.5 | N | D |
| C | 1000009-4 | 178 | BD | 0 | 15.8 | 1.5 | N | D |
| C | 1000020-1 | 68 | BD | 0 | 20.6 | 1.1 | N | D |
| C | 1000020-2 | 67 | BD | 0 | 20.6 | 1.1 | N | D |
| C | 1000020-3 | 69 | BD | 0 | 20.6 | 1.1 | N | D |
| C | 1000035-3 | 150 | BD | 0 | 42.9 | 3.1 | N | D |
| C | 1000035-4 | 152 | BD | 0 | 42.9 | 3.1 | N | D |
| C | 1000035-5 | 151 | BD | 0 | 42.9 | 3.1 | N | D |
| C | 1000040-1 | 113 | SD | 0 | 8.7 | .2 | N | C |
| C | 1000040-2 | 180 | SD | 0 | 8.7 | .2 | N | C |
| C | 1000043-2 | 124 | BD | 0 | 23.2 | .4 | N | D |
| C | 1000043-3 | 125 | BD | 0 | 23.2 | .4 | Y | A[1] |
| C | 1000045-1 | 141 | BD | .4 | 32.1 | 3.6 | N | B |
| C | 1000045-2 | 142 | BD | .4 | 32.1 | 3.6 | N | B |
| C | 1000098-1 | 133 | SD | 0 | 23.2 | .4 | N | C |

**Table 16**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by solvents and other industrial organic chemicals based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | |
| | | | | Industrial land use | All urban land uses | Brushland cover | | |
| C | 1000098-2 | 132 | SD | 0 | 23.2 | 0.4 | N | C |
| C | 1559511-1 | 90 | SD | 4.1 | 51.7 | 3.0 | Y | A |
| C | 1559511-2 | 82 | SD | 0 | 39.9 | .3 | Y | A[1] |
| C | 1559511-3 | 85 | SD | 0 | 24.6 | 2.0 | Y | A[1] |
| C | 1559511-4 | 84 | SD | 0 | 24.6 | 2.0 | Y | A[1] |
| C | 1559512-1 | 153 | SD | .4 | 33.3 | 1.8 | N | A |
| C | 1559512-10 | 159 | SD | .03 | 63.9 | 0 | N | A |
| C | 1559512-11 | 161 | SD | 0 | 24.2 | 1.9 | N | C |
| C | 1559512-2 | 155 | SD | .4 | 33.3 | 1.8 | Y | A |
| C | 1559512-3 | 154 | SD | .4 | 33.3 | 1.8 | N | A |
| C | 1559512-4 | 147 | SD | .4 | 33.3 | 1.8 | Y | A |
| C | 1559512-5 | 145 | SD | .4 | 33.3 | 1.8 | N | A |
| C | 1559512-6 | 146 | SD | .4 | 33.3 | 1.8 | Y | A |
| C | 1559512-7 | 149 | SD | .4 | 33.3 | 1.8 | N | A |
| C | 1559512-8 | 148 | SD | 0 | 16.9 | 1.2 | N | C |
| C | 1559512-9 | 158 | SD | 0 | 16.9 | 1.2 | N | C |
| C | 1559513-1 | 166 | SD | 0 | 22.5 | 2.5 | N | C |
| C | 1559513-2 | 164 | SD | 0 | 22.5 | 2.5 | N | C |
| C | 1559513-4 | 165 | BD | 0 | 22.5 | 2.5 | N | D |
| C | 1559513-5 | 163 | BD | 0 | 22.5 | 2.5 | N | D |
| C | 1559517-1 | 106 | SD | 0 | 12.1 | 3.1 | Y | A[1] |
| C | 1559517-10 | 118 | SD | 0 | 2.3 | 0 | N | B |
| C | 1559517-2 | 107 | SD | 0 | 12.1 | 3.1 | N | B |
| C | 1559517-3 | 116 | SD | 0 | 2.3 | 0 | Y | A[1] |
| C | 1559517-4 | 108 | SD | 0 | 12.1 | 3.1 | N | B |
| C | 1559517-5 | 110 | SD | 0 | 12.1 | 3.1 | N | B |
| C | 1559517-6 | 104 | SD | 0 | 50.9 | 0 | Y | A |
| C | 1559517-7 | 91 | SD | 4.1 | 51.7 | 3.0 | Y | A |
| C | 1559517-8 | 92 | SD | 4.1 | 51.7 | 3.0 | Y | A |
| C | 1559517-9 | 117 | SD | 0 | 2.3 | 0 | N | C |
| C | 1559519-1 | 28 | BD | 5.7 | 23.6 | 2.5 | N | B |
| C | 1559519-2 | 27 | BD | 5.7 | 23.6 | 2.5 | N | B |
| C | 1583825-1 | 29 | BD | 2.3 | 27.1 | 1.4 | N | B |
| C | 1592012-2 | 105 | SD | 0 | 24.6 | 0 | N | C |
| C | 1592019-1 | 38 | BD | 2.8 | 30.2 | 2.9 | N | B |
| C | 1592019-2 | 176 | BD | 2.8 | 30.2 | 2.9 | N | B |
| C | 1592020-1 | 32 | SD | 0 | 80.8 | 0 | N | A |
| C | 1592020-2 | 34 | SD | 0 | 80.8 | 0 | N | A |
| C | 1592021-2 | 56 | SD | .8 | 58.2 | .6 | N | A |
| C | 1592021-3 | 55 | SD | .8 | 58.2 | .6 | N | A |

**Table 16**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by solvents and other industrial organic chemicals based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | |
| | | | | Industrial land use | All urban land uses | Brushland cover | | |
| C | 1592021-4 | 54 | SD | 0.8 | 58.2 | 0.6 | N | A |
| C | 1592021-5 | 53 | SD | .8 | 58.2 | .6 | N | A |
| C | 1592021-6 | 50 | SD | .8 | 58.2 | .6 | N | A |
| C | 1592021-7 | 47 | SD | .8 | 58.2 | .6 | N | A |
| C | 1592021-8 | 46 | SD | .8 | 58.2 | .6 | Y | A |
| C | 1592021-9 | 45 | SD | .8 | 58.2 | .6 | Y | A |
| C | 1592023-1 | 102 | BD | 0 | 14.7 | 11.6 | N | D |
| C | 1592023-5 | 100 | BD | 0 | 14.7 | 11.6 | N | D |
| C | 1592023-7 | 98 | BD | 0 | 14.7 | 11.6 | N | D |
| C | 1592023-8 | 94 | BD | 0 | 14.7 | 11.6 | N | D |
| C | 1592023-9 | 179 | BD | 0 | 14.7 | 11.6 | N | D |
| C | 1592025-1 | 88 | SD | 4.1 | 51.7 | 3.0 | Y | A |
| C | 1592025-2 | 93 | SD | 4.1 | 51.7 | 3.0 | Y | A |
| C | 1592025-3 | 89 | SD | 4.1 | 51.7 | 3.0 | Y | A |
| C | 1615614-1 | 26 | SD | 4.6 | 48.8 | .4 | N | A |
| C | 1615614-2 | 25 | BD | 4.6 | 48.8 | .4 | N | B |
| C | 1615614-5 | 24 | SD | 0 | 49.1 | 42.9 | Y | A[1] |
| C | 1615623-1 | 157 | SD | 0 | 19.2 | 2.3 | N | C |
| C | 1615623-2 | 156 | SD | 0 | 19.2 | 2.3 | N | C |
| C | 1615624-1 | 137 | SD | .1 | 9.4 | 2.9 | N | A |
| C | 1615624-2 | 138 | SD | .1 | 9.4 | 2.9 | N | A |
| C | 1615624-3 | 136 | SD | .1 | 9.4 | 2.9 | N | A |
| C | 1615624-4 | 139 | SD | .1 | 9.4 | 2.9 | Y | A |
| C | 1615624-5 | 140 | SD | .1 | 9.4 | 2.9 | N | A |
| C | 1615624-7 | 135 | SD | .1 | 9.4 | 2.9 | N | A |
| C | 1615626-1 | 80 | SD | 0 | 77.4 | 0 | N | A |
| C | 1615626-2 | 81 | SD | 0 | 77.4 | 0 | N | A |
| C | 1647512-1 | 167 | SD | 0 | 55.7 | 0 | N | A |
| C | 1647512-2 | 168 | SD | 0 | 55.7 | 0 | N | A |
| C | 1647515-5 | 77 | SD | 0 | 61.1 | 1.2 | Y | A |
| C | 1647515-6 | 76 | SD | 0 | 61.1 | 1.2 | Y | A |
| C | 1647526-1 | 44 | BD | 0 | 18.9 | .3 | N | D |
| C | 1647529-1 | 134 | BD | 1.6 | 12.3 | 6.0 | N | B |
| C | 1647530-1 | 33 | SD | 0 | 33.6 | 0 | Y | A[1] |
| C | 1647530-3 | 40 | SD | 0 | 39.7 | 0 | N | C |
| C | 1647530-4 | 39 | SD | 0 | 39.7 | 0 | N | C |
| C | 1647530-5 | 31 | SD | 0 | 33.6 | 0 | Y | A[1] |
| C | 1858411-1 | 35 | SD | 0 | 58.5 | 0 | N | A |
| C | 1858411-2 | 37 | SD | 0 | 23.9 | .3 | N | C |
| C | 1858421-1 | 130 | SD | 0 | 66.6 | 0 | N | A |

**Table 16.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by solvents and other industrial organic chemicals based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | |
| | | | | Industrial land use | All urban land uses | Brushland cover | | |
| C | 1858421-2 | 131 | SD | 0 | 66.6 | 0 | N | A |
| C | 1858422-1 | 128 | SD | 0 | 66.6 | 0 | N | A |
| C | 1858422-2 | 129 | SD | 0 | 66.6 | 0 | N | A |
| C | 1858422-3 | 127 | SD | 0 | 66.6 | 0 | N | A |
| C | 1858423-5 | 59 | SD | .3 | 43.6 | 0 | Y | A |
| C | 1858435-1 | 70 | BD | 0 | 11.1 | .7 | N | D |
| C | 1900020-1 | 78 | SD | 0 | 73.7 | 0 | N | A |
| C | 1900023-1 | 74 | BD | 0 | 8.7 | 0 | N | D |
| C | 1900023-2 | 75 | BD | 0 | 8.7 | 0 | N | D |
| C | 1900023-3 | 71 | BD | 0 | 8.7 | 0 | N | D |
| C | 1900023-4 | 72 | BD | 0 | 8.7 | 0 | N | D |
| C | 1900023-5 | 73 | BD | 0 | 8.7 | 0 | N | D |
| C | 1900025-2 | 126 | BD | 0 | 23.2 | .4 | Y | A[1] |
| C | 1900029-1 | 160 | BD | 0 | 34.6 | 1.3 | -- | D |
| C | 1900034-1 | 30 | SD | 0 | 15.9 | 0 | N | C |
| C | 1900034-2 | 181 | SD | 0 | 15.9 | 0 | N | C |
| C | 1900036-1 | 170 | U | 0 | 38.8 | .9 | N | D |
| C | 1900036-2 | 171 | U | 0 | 38.8 | .9 | -- | D |
| C | 1900039-1 | 174 | BD | 20.1 | 34.3 | 9.3 | -- | B |
| C | 1900048-2 | 123 | BD | 0 | 23.2 | .4 | N | D |
| C | 1900049-1 | 183 | SD | 0 | 16.3 | 2.4 | -- | C |
| C | 2000004-2 | 79 | BD | 0 | 2.7 | 3.5 | N | D |
| C | 2000059-1 | 49 | BD | 0 | 7.4 | 0 | N | D |
| C | 2000059-2 | 48 | BD | 0 | 7.4 | 0 | N | D |
| C | 2000083-1 | 52 | BD | 0 | 12.8 | 0 | N | D |
| C | 2000083-2 | 51 | BD | 0 | 12.8 | 0 | N | D |
| C | 2000084-1 | 62 | BD | .5 | 13.0 | 0 | N | B |
| C | 2000165-1 | 112 | BD | 0 | 21.0 | .9 | Y | A[1] |
| C | 2051311-1 | 97 | BD | 0 | 9.1 | .3 | N | D |
| C | 2415415-1 | 64 | BD | 0 | 18.1 | 7.2 | Y | A[1] |
| C | 2519424-1 | 60 | BD | 0 | 32.6 | 0 | Y | A[1] |
| C | 2519424-3 | 177 | BD | 0 | 32.6 | 0 | N | D |
| C | 2519426-1 | 83 | BD | 0 | 18.8 | 0 | N | D |
| C | 2585312-1 | 115 | DG | 0 | 16.3 | .01 | N | C |
| C | 2585312-2 | 114 | BD | 0 | 16.3 | .01 | N | D |
| C | 2585313-1 | 103 | BD | 0 | 21.5 | .7 | N | D |
| C | 2674924-1 | 182 | SD | 0 | 14.8 | .4 | N | C |
| C | 2674925-1 | 144 | BD | 0 | 9.0 | .9 | N | D |
| C | 2674925-2 | 143 | BD | 0 | 9.0 | .9 | N | D |
| C | 2674928-1 | 162 | BD | 0 | 34.6 | 1.3 | N | D |

**Table 16.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by solvents and other industrial organic chemicals based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | |
| | | | | Industrial land use | All urban land uses | Brushland cover | | |
| C | 2753326-1 | 121 | BD | 0 | 44.4 | 2.6 | N | D |
| C | 2753326-3 | 122 | BD | 0 | 44.4 | 2.6 | N | D |
| C | 2788012-1 | 66 | BD | 0 | 10.6 | .6 | N | D |
| C | 2814410-3 | 96 | BD | 0 | 19.8 | 8.4 | N | D |
| C | 2882117-3 | 120 | SD | 0 | 17.7 | 0 | N | C |
| C | 2882117-4 | 119 | BD | 0 | 17.7 | 0 | N | D |
| C | 2942518-1 | 36 | BD | 0 | 37.9 | 0 | N | D |
| C | 2942525-1 | 111 | BD | 0 | 21.0 | .9 | N | D |
| C | 2942525-3 | 109 | BD | 0 | 21.0 | .9 | N | D |
| C | 2943224-8 | 61 | BD | 0 | 32.6 | 0 | N | D |
| C | 2973130-1 | 42 | SD | 0 | 73.1 | 0 | N | A |
| C | 2973130-2 | 43 | SD | 0 | 73.1 | 0 | N | A |
| C | 2973130-3 | 41 | SD | 0 | 73.1 | 0 | N | A |
| C | 2980001-1 | 95 | BD | 0 | 23.3 | 1.4 | -- | D |
| C | 2980003-1 | 99 | BD | 0 | 9.1 | .3 | N | D |
| C | 2980145-1 | 101 | BD | 0 | 6.4 | 0 | N | D |
| C | 2980146-1 | 58 | BD | 0 | 32.6 | 0 | N | D |
| C | 2980146-3 | 57 | BD | 0 | 32.6 | 0 | N | D |
| C | 2980196-2 | 169 | SD | 0 | 18.0 | 17.6 | N | C |
| C | 2980258-1 | 22 | BD | 2.8 | 52.1 | 0 | N | B |
| C | 2980258-2 | 23 | BD | 2.8 | 52.1 | 0 | N | B |
| C | 2980258-5 | 173 | BD | 2.8 | 52.1 | 0 | N | B |
| C | 2980264-1 | 186 | BD | 0 | 21.5 | 0 | N | D |
| C | 2980276-1 | 86 | BD | 0 | 13.6 | .4 | N | D |
| C | 2980276-2 | 87 | BD | 0 | 13.6 | .4 | N | D |
| C | 2980323-1 | 65 | BD | .4 | 37.4 | .5 | N | B |
| C | 2980340-1 | 185 | BD | 0 | 38.5 | 1.6 | Y | A[1] |
| P | 1000007-1 | 102 | BD | 0 | 8.5 | 0 | N | D |
| P | 1000007-2 | 103 | BD | 0 | 8.5 | 0 | N | D |
| P | 1000025-1 | 17 | BD | 13.3 | 55.1 | .8 | N | B |
| P | 1000039-1 | 72 | SD | 6.5 | 24.6 | 4.7 | -- | A |
| P | 1000042-1 | 5 | BD | 1.4 | 40.7 | 3.4 | Y | A[1] |
| P | 1559510-1 | 50 | BD | 0 | 23.5 | 3.7 | N | D |
| P | 1559516-1 | 92 | SD | 7.9 | 15.0 | 1.5 | Y | A |
| P | 1559516-2 | 104 | SD | 7.9 | 15.0 | 1.5 | N | A |
| P | 1583819-3 | 56 | BD | 0 | 9.0 | 9.0 | N | D |
| P | 1583819-4 | 55 | BD | 0 | 9.0 | 9.0 | N | D |
| P | 1583820-1 | 57 | BD | 0 | 6.0 | 0 | N | D |
| P | 1583823-1 | 36 | BD | 0 | 19.3 | 0 | -- | D |
| P | 1583827-1 | 18 | BD | 0 | 40.1 | 2.5 | N | D |

**Table 16**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by solvents and other industrial organic chemicals based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | |
| | | | | Industrial land use | All urban land uses | Brushland cover | | |
| P | 1583829-4 | 26 | BD | 0 | 7.0 | 0.6 | N | D |
| P | 1583829-5 | 25 | BD | 0 | 7.0 | .6 | N | D |
| P | 1583829-6 | 24 | BD | 0 | 7.0 | .6 | N | D |
| P | 1583829-7 | 27 | BD | 0 | 7.0 | .6 | N | D |
| P | 1592014-1 | 3 | BD | 1.4 | 40.7 | 3.4 | N | D |
| P | 1592015-1 | 6 | SD | 0 | 27.9 | .5 | N | C |
| P | 1592017-1 | 13 | BD | 0 | 22.3 | .6 | -- | D |
| P | 1592027-2 | 66 | BD | 0 | 37.3 | 0 | N | D |
| P | 1592027-3 | 67 | BD | 0 | 37.3 | 0 | N | D |
| P | 1592028-1 | 79 | SD | 0 | 18.5 | 0 | N | C |
| P | 1592030-1 | 75 | SD | 0 | 18.5 | 0 | -- | C |
| P | 1615611-1 | 41 | BD | 0 | 17.7 | .4 | N | D |
| P | 1615612-4 | 34 | BD | 0 | 28.1 | 0 | N | D |
| P | 1615612-5 | 35 | BD | 0 | 28.1 | 0 | N | D |
| P | 1615612-6 | 33 | BD | 0 | 28.1 | 0 | N | D |
| P | 1615613-1 | 30 | BD | .8 | 53.5 | .4 | Y | A[1] |
| P | 1615617-1 | 71 | SD | 6.5 | 24.6 | 4.7 | -- | A |
| P | 1647513-3 | 91 | SD | 15.0 | 36.9 | 0 | N | A |
| P | 1647517-1 | 10 | BD | 6.8 | 31.8 | 3.8 | N | B |
| P | 1647525-3 | 76 | BD | .5 | 20.3 | 0 | N | B |
| P | 1647525-4 | 73 | BD | .5 | 20.3 | 0 | Y | A[1] |
| P | 1647527-1 | 47 | BD | .9 | 20.1 | 0 | N | B |
| P | 1858414-1 | 68 | BD | 1.2 | 7.7 | 0 | N | B |
| P | 1858415-1 | 87 | BD | 0 | 54.2 | 1.8 | N | B |
| P | 1858417-1 | 89 | BD | 0 | 54.2 | 1.8 | N | B |
| P | 1858425-2 | 65 | BD | 0 | 26.1 | 2.3 | N | D |
| P | 1858431-1 | 83 | DG | 9.6 | 44.2 | 4.1 | Y | A |
| P | 1900003-1 | 45 | BD | 6.1 | 12.1 | .2 | N | B |
| P | 1900003-2 | 46 | BD | 6.1 | 12.1 | .2 | N | B |
| P | 1900003-3 | 43 | BD | 6.1 | 12.1 | .2 | N | B |
| P | 1900003-4 | 44 | BD | 6.1 | 12.1 | .2 | Y | A[1] |
| P | 1900004-1 | 101 | U | 5.6 | 10.0 | 4.1 | Y | A[1] |
| P | 1900004-2 | 105 | U | 5.6 | 10.0 | 4.1 | Y | A[1] |
| P | 1900024-1 | 52 | BD | 0 | 23.3 | 2.9 | N | D |
| P | 1900024-2 | 54 | BD | 0 | 23.3 | 2.9 | N | D |
| P | 1900024-3 | 53 | BD | 0 | 23.3 | 2.9 | N | D |
| P | 1900026-1 | 16 | BD | 0 | 7.7 | 0 | N | D |
| P | 1900027-3 | 90 | BD | 0 | 12.5 | 0 | N | D |
| P | 1900028-1 | 11 | BD | 8.3 | 26.1 | 1.6 | N | B |
| P | 1900035-1 | 69 | BD | 1.2 | 7.7 | 0 | N | B |

**Table 16**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by solvents and other industrial organic chemicals based on aquifer type and land use—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Area in WHPA, as percentage of total area | | | | |
| | | | | Industrial land use | All urban land uses | Brushland cover | | |
| P | 1900038-1 | 20 | BD | 0 | 27.5 | 0 | N | D |
| P | 1900040-2 | 1 | BD | 0 | 18.6 | 0 | N | D |
| P | 1900041-1 | 19 | BD | 0 | 3.1 | 0 | N | D |
| P | 1900044-1 | 29 | BD | 0 | 28.7 | .5 | Y | A[1] |
| P | 2000090-1 | 97 | BD | 1.4 | 40.7 | 3.4 | N | B |
| P | 2000110-1 | 42 | BD | 0 | 13.4 | 0 | N | D |
| P | 2000133-1 | 70 | BD | 0 | 15.7 | .9 | N | D |
| P | 2000135-1 | 49 | BD | 0 | 27.0 | .4 | N | D |
| P | 2000142-4 | 74 | SD | 0 | 7.5 | .5 | Y | A[1] |
| P | 2000145-1 | 88 | BD | 0 | 54.2 | 1.8 | Y | A[1] |
| P | 2000176-1 | 48 | BD | 0 | 40.9 | 0 | N | D |
| P | 2051719-1 | 37 | BD | 0 | 51.0 | 0 | N | B |
| P | 2051719-2 | 38 | BD | 0 | 51.0 | 0 | Y | A[1] |
| P | 2051719-3 | 39 | BD | 0 | 51.0 | 0 | N | B |
| P | 2051719-4 | 40 | BD | 0 | 51.0 | 0 | N | B |
| P | 2051729-1 | 64 | DG | 2.4 | 25.1 | 0 | N | A |
| P | 2788010-1 | 32 | BD | 0 | 17.6 | 2.7 | N | D |
| P | 2942515-1 | 9 | BD | 0 | 63.2 | 0 | N | B |
| P | 2973119-4 | 7 | BD | .7 | 24.3 | 1.6 | Y | A[1] |
| P | 2980017-1 | 94 | BD | 0 | 66.0 | 7.0 | Y | A[1] |
| P | 2980019-1 | 96 | BD | 0 | 40.6 | 40.6 | N | D |
| P | 2980030-1 | 99 | BD | 0 | 30.1 | .9 | N | D |
| P | 2980036-1 | 2 | BD | 0 | 65.8 | 0 | N | A |
| P | 2980084-2 | 31 | BD | 0 | 30.3 | 0 | N | D |
| P | 2980127-1 | 84 | BD | 0 | 20.8 | 3.5 | N | D |
| P | 2980134-1 | 21 | BD | 0 | 60.8 | 0 | N | B |
| P | 2980135-1 | 28 | BD | 0 | 66.2 | 0 | N | B |
| P | 2980138-1 | 60 | BD | 0 | 35.9 | 0 | N | D |
| P | 2980154-1 | 98 | BD | 0 | 21.4 | .1 | N | D |
| P | 2980185-2 | 77 | SD | 0 | 18.5 | 0 | N | C |
| P | 2980185-3 | 78 | SD | 0 | 18.5 | 0 | N | C |
| P | 2980192-1 | 62 | BD | 2.7 | 24.8 | 2.0 | Y | A[1] |
| P | 2980192-2 | 63 | BD | 2.7 | 24.8 | 2.0 | Y | A[1] |
| P | 2980265-1 | 59 | BD | 0 | 20.8 | 3.0 | N | D |
| P | 2980270-1 | 100 | BD | 0 | 15.7 | .8 | N | D |
| P | 2980277-1 | 14 | BD | 3.8 | 36.4 | 0 | N | B |
| P | 2980278-1 | 15 | BD | 3.8 | 36.4 | 0 | N | B |
| P | 2980301-1 | 4 | BD | 1.4 | 40.7 | 3.4 | N | B |
| P | 2980311-1 | 12 | BD | 3.8 | 38.5 | 2.3 | N | B |
| P | 2980330-1 | 106 | BD | 0 | 21.4 | .1 | N | D |
| P | 2980346-1 | 107 | U | 0 | 15.4 | 0 | -- | D |

[1]Well is designated with "A" vulnerability category based on historical water quality (solvent detections) rather than on tabulated vulnerability factors.

**Table 17**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by road-deicing chemicals based on road density and soil characteristics

[**Supply type:** C, community; P, non-community, non-transient. **Source identifier:** Combines the public-water system identifier (PWSID) and the source number assigned by the Rhode Island Department of Health. **USGS-ID:** Identifier used in figures 2 and 3. **Aquifer type:** BD, bedrock; D, dug well of undetermined aquifer type; SD, sand and gravel; U, drilled well of undetermined aquifer type. WHPA, wellhead-protection area. **Affected or unaffected:** Y, affected, N, unaffected. **Relative vulnerability:** A, most vulnerable; C, least vulnerable. Shading indicates values used in designating A and B vulnerability categories. --, not assessed]

| Supply type | Source identifier | USGS-ID | Vulnerability factor: Aquifer type | Vulnerability factor: Density of paved roads in WHPA, in miles per square mile | Vulnerability factor: Soil-leaching potential risk, area-weighted rank in WHPA | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|
| C | 1000009-1 | 63 | BD | 4.6 | 2.1 | N | C |
| C | 1000009-4 | 178 | BD | 4.6 | 2.1 | Y | A[1] |
| C | 1000020-1 | 68 | BD | 3.4 | 3.4 | N | C |
| C | 1000020-2 | 67 | BD | 3.4 | 3.4 | N | C |
| C | 1000020-3 | 69 | BD | 3.4 | 3.4 | N | C |
| C | 1000035-3 | 150 | BD | 8.7 | 4.6 | N | A |
| C | 1000035-4 | 152 | BD | 8.7 | 4.6 | N | A |
| C | 1000035-5 | 151 | BD | 8.7 | 4.6 | N | A |
| C | 1000040-1 | 113 | SD | 4.7 | 4.2 | N | C |
| C | 1000040-2 | 180 | SD | 4.7 | 4.2 | N | C |
| C | 1000043-2 | 124 | BD | 5.6 | 3.3 | N | C |
| C | 1000043-3 | 125 | BD | 5.6 | 3.3 | N | C |
| C | 1000045-1 | 141 | BD | 5.7 | 5.2 | N | C |
| C | 1000045-2 | 142 | BD | 5.7 | 5.2 | N | C |
| C | 1000098-1 | 133 | SD | 5.6 | 3.3 | Y | A[1] |
| C | 1000098-2 | 132 | SD | 5.6 | 3.3 | Y | A[1] |
| C | 1559511-1 | 90 | SD | 11.8 | 4.5 | Y | A |
| C | 1559511-2 | 82 | SD | 7.8 | 4.3 | N | C |
| C | 1559511-3 | 85 | SD | 6.2 | 4.7 | Y | A[1] |
| C | 1559511-4 | 84 | SD | 6.2 | 4.7 | N | C |
| C | 1559512-1 | 153 | SD | 7.7 | 4.2 | N | C |
| C | 1559512-10 | 159 | SD | 11.4 | 3.7 | N | B |
| C | 1559512-11 | 161 | SD | 4.9 | 3.0 | N | C |
| C | 1559512-2 | 155 | SD | 7.7 | 4.2 | N | C |
| C | 1559512-3 | 154 | SD | 7.7 | 4.2 | N | C |
| C | 1559512-4 | 147 | SD | 7.7 | 4.2 | N | C |
| C | 1559512-5 | 145 | SD | 7.7 | 4.2 | N | C |
| C | 1559512-6 | 146 | SD | 7.7 | 4.2 | N | C |
| C | 1559512-7 | 149 | SD | 7.7 | 4.2 | N | C |
| C | 1559512-8 | 148 | SD | 3.9 | 3.6 | N | C |
| C | 1559512-9 | 158 | SD | 3.9 | 3.6 | N | C |
| C | 1559513-1 | 166 | SD | 7.8 | 4.8 | N | C |
| C | 1559513-2 | 164 | SD | 7.8 | 4.8 | N | C |
| C | 1559513-4 | 165 | BD | 7.8 | 4.8 | N | C |
| C | 1559513-5 | 163 | BD | 7.8 | 4.8 | N | C |

**Table 17.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by road-deicing chemicals based on road density and soil characteristics—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Density of paved roads in WHPA, in miles per square mile | Soil-leaching potential risk, area-weighted rank in WHPA | | |
| C | 1559517-1 | 106 | SD | 4.2 | 3.5 | Y | A[1] |
| C | 1559517-10 | 118 | SD | 4.3 | 4.5 | N | C |
| C | 1559517-2 | 107 | SD | 4.2 | 3.5 | N | C |
| C | 1559517-3 | 116 | SD | 4.3 | 4.5 | N | C |
| C | 1559517-4 | 108 | SD | 4.2 | 3.5 | N | C |
| C | 1559517-5 | 110 | SD | 4.2 | 3.5 | N | C |
| C | 1559517-6 | 104 | SD | 10.5 | 3.8 | N | B |
| C | 1559517-7 | 91 | SD | 11.8 | 4.5 | Y | A |
| C | 1559517-8 | 92 | SD | 11.8 | 4.5 | N | A |
| C | 1559517-9 | 117 | SD | 4.3 | 4.5 | N | C |
| C | 1559519-1 | 28 | BD | 7.0 | 3.8 | N | C |
| C | 1559519-2 | 27 | BD | 7.0 | 3.8 | N | C |
| C | 1583825-1 | 29 | BD | 6.2 | 3.5 | N | C |
| C | 1592012-2 | 105 | SD | 6.8 | 4.1 | N | C |
| C | 1592019-1 | 38 | BD | 7.5 | 4.7 | Y | A[1] |
| C | 1592019-2 | 176 | BD | 7.5 | 4.7 | Y | A[1] |
| C | 1592020-1 | 32 | SD | 16.0 | 4.0 | N | A |
| C | 1592020-2 | 34 | SD | 16.0 | 4.0 | Y | A |
| C | 1592021-2 | 56 | SD | 13.4 | 4.6 | N | A |
| C | 1592021-3 | 55 | SD | 13.4 | 4.6 | N | A |
| C | 1592021-4 | 54 | SD | 13.4 | 4.6 | N | A |
| C | 1592021-5 | 53 | SD | 13.4 | 4.6 | N | A |
| C | 1592021-6 | 50 | SD | 13.4 | 4.6 | N | A |
| C | 1592021-7 | 47 | SD | 13.4 | 4.6 | N | A |
| C | 1592021-8 | 46 | SD | 13.4 | 4.6 | N | A |
| C | 1592021-9 | 45 | SD | 13.4 | 4.6 | N | A |
| C | 1592023-1 | 102 | BD | 6.0 | 2.9 | N | C |
| C | 1592023-5 | 100 | BD | 6.0 | 2.9 | N | C |
| C | 1592023-7 | 98 | BD | 6.0 | 2.9 | N | C |
| C | 1592023-8 | 94 | BD | 6.0 | 2.9 | N | C |
| C | 1592023-9 | 179 | BD | 6.0 | 2.9 | N | C |
| C | 1592025-1 | 88 | SD | 11.8 | 4.5 | N | A |
| C | 1592025-2 | 93 | SD | 11.8 | 4.5 | Y | A |
| C | 1592025-3 | 89 | SD | 11.8 | 4.5 | N | A |
| C | 1615614-1 | 26 | SD | 7.5 | 4.3 | Y | A[1] |
| C | 1615614-2 | 25 | BD | 7.5 | 4.3 | N | C |
| C | 1615614-5 | 24 | SD | 12.9 | 4.2 | Y | A |
| C | 1615623-1 | 157 | SD | 6.9 | 4.4 | N | C |
| C | 1615623-2 | 156 | SD | 6.9 | 4.4 | N | C |
| C | 1615624-1 | 137 | SD | 2.9 | 3.6 | N | C |

**Table 17**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by road-deicing chemicals based on road density and soil characteristics—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Density of paved roads in WHPA, in miles per square mile | Soil-leaching potential risk, area-weighted rank in WHPA | | |
| C | 1615624-2 | 138 | SD | 2.9 | 3.6 | N | C |
| C | 1615624-3 | 136 | SD | 2.9 | 3.6 | N | C |
| C | 1615624-4 | 139 | SD | 2.9 | 3.6 | N | C |
| C | 1615624-5 | 140 | SD | 2.9 | 3.6 | N | C |
| C | 1615624-7 | 135 | SD | 2.9 | 3.6 | N | C |
| C | 1615626-1 | 80 | SD | 19.0 | 6.0 | Y | A |
| C | 1615626-2 | 81 | SD | 19.0 | 6.0 | Y | A |
| C | 1647512-1 | 167 | SD | 12.9 | 4.3 | N | A |
| C | 1647512-2 | 168 | SD | 12.9 | 4.3 | N | A |
| C | 1647515-5 | 77 | SD | 12.2 | 4.4 | Y | A |
| C | 1647515-6 | 76 | SD | 12.2 | 4.4 | Y | A |
| C | 1647526-1 | 44 | BD | 5.0 | 4.0 | N | C |
| C | 1647529-1 | 134 | BD | 3.3 | 3.8 | N | C |
| C | 1647530-1 | 33 | SD | 7.7 | 3.2 | N | C |
| C | 1647530-3 | 40 | SD | 11.6 | 4.9 | Y | A |
| C | 1647530-4 | 39 | SD | 11.6 | 4.9 | Y | A |
| C | 1647530-5 | 31 | SD | 7.7 | 3.2 | N | C |
| C | 1858411-1 | 35 | SD | 4.9 | 6.0 | N | C |
| C | 1858411-2 | 37 | SD | 3.9 | 4.8 | N | C |
| C | 1858421-1 | 130 | SD | 13.2 | 3.4 | N | B |
| C | 1858421-2 | 131 | SD | 13.2 | 3.4 | N | B |
| C | 1858422-1 | 128 | SD | 13.2 | 3.4 | N | B |
| C | 1858422-2 | 129 | SD | 13.2 | 3.4 | N | B |
| C | 1858422-3 | 127 | SD | 13.2 | 3.4 | N | B |
| C | 1858423-5 | 59 | SD | 10.3 | 4.0 | Y | A |
| C | 1858435-1 | 70 | BD | 2.6 | 4.1 | N | C |
| C | 1900020-1 | 78 | SD | 14.2 | 3.7 | N | B |
| C | 1900023-1 | 74 | BD | 3.2 | 2.7 | N | C |
| C | 1900023-2 | 75 | BD | 3.2 | 2.7 | N | C |
| C | 1900023-3 | 71 | BD | 3.2 | 2.7 | N | C |
| C | 1900023-4 | 72 | BD | 3.2 | 2.7 | N | C |
| C | 1900023-5 | 73 | BD | 3.2 | 2.7 | N | C |
| C | 1900025-2 | 126 | BD | 5.6 | 3.3 | N | C |
| C | 1900029-1 | 160 | BD | 7.5 | 4.5 | -- | C |
| C | 1900034-1 | 30 | SD | 3.9 | 3.9 | N | C |
| C | 1900034-2 | 181 | SD | 3.9 | 3.9 | N | C |
| C | 1900036-1 | 170 | U | 7.2 | 4.4 | N | C |
| C | 1900036-2 | 171 | U | 7.2 | 4.4 | -- | C |
| C | 1900039-1 | 174 | BD | 4.6 | 3.7 | -- | C |
| C | 1900048-2 | 123 | BD | 5.6 | 3.3 | N | C |

**Table 17**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by road-deicing chemicals based on road density and soil characteristics—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Density of paved roads in WHPA, in miles per square mile | Soil-leaching potential risk, area-weighted rank in WHPA | | |
| C | 1900049-1 | 183 | SD | 3.8 | 5.5 | -- | C |
| C | 2000004-2 | 79 | BD | 5.2 | 4.3 | N | C |
| C | 2000059-1 | 49 | BD | 2.5 | 3.5 | N | C |
| C | 2000059-2 | 48 | BD | 2.5 | 3.5 | N | C |
| C | 2000083-1 | 52 | BD | 4.0 | 3.6 | Y | A[1] |
| C | 2000083-2 | 51 | BD | 4.0 | 3.6 | Y | A[1] |
| C | 2000084-1 | 62 | BD | 4.3 | 3.4 | N | C |
| C | 2000165-1 | 112 | BD | 3.6 | 3.2 | N | C |
| C | 2051311-1 | 97 | BD | 3.0 | 2.8 | N | C |
| C | 2415415-1 | 64 | BD | 3.2 | 2.4 | N | C |
| C | 2519424-1 | 60 | BD | 6.0 | 4.0 | N | C |
| C | 2519424-3 | 177 | BD | 6.0 | 4.0 | N | C |
| C | 2519426-1 | 83 | BD | 2.6 | 2.5 | N | C |
| C | 2585312-1 | 115 | DG | 5.5 | 3.1 | N | C |
| C | 2585312-2 | 114 | BD | 5.5 | 3.1 | N | C |
| C | 2585313-1 | 103 | BD | 6.4 | 3.4 | N | C |
| C | 2674924-1 | 182 | SD | 4.0 | 5.0 | N | C |
| C | 2674925-1 | 144 | BD | 2.8 | 3.3 | N | C |
| C | 2674925-2 | 143 | BD | 2.8 | 3.3 | N | C |
| C | 2674928-1 | 162 | BD | 7.5 | 4.5 | N | C |
| C | 2753326-1 | 121 | BD | 8.9 | 2.5 | N | B |
| C | 2753326-3 | 122 | BD | 8.9 | 2.5 | N | B |
| C | 2788012-1 | 66 | BD | 4.2 | 3.3 | -- | C |
| C | 2814410-3 | 96 | BD | 4.9 | 3.4 | N | C |
| C | 2882117-3 | 120 | SD | 3.3 | 3.8 | Y | A[1] |
| C | 2882117-4 | 119 | BD | 3.3 | 3.8 | Y | A[1] |
| C | 2942518-1 | 36 | BD | 9.3 | 3.3 | N | B |
| C | 2942525-1 | 111 | BD | 3.6 | 3.2 | N | C |
| C | 2942525-3 | 109 | BD | 3.6 | 3.2 | N | C |
| C | 2943224-8 | 61 | BD | 6.0 | 4.0 | N | C |
| C | 2973130-1 | 42 | SD | 15.5 | 4.9 | N | A |
| C | 2973130-2 | 43 | SD | 15.5 | 4.9 | N | A |
| C | 2973130-3 | 41 | SD | 15.5 | 4.9 | N | A |
| C | 2980001-1 | 95 | BD | 3.3 | 2.8 | N | C |
| C | 2980003-1 | 99 | BD | 3.0 | 2.8 | -- | C |
| C | 2980145-1 | 101 | BD | 8.3 | 3.8 | N | B |
| C | 2980146-1 | 58 | BD | 6.0 | 4.0 | N | C |
| C | 2980146-3 | 57 | BD | 6.0 | 4.0 | N | C |
| C | 2980196-2 | 169 | SD | 4.5 | 4.8 | -- | C |
| C | 2980258-1 | 22 | BD | 7.7 | 3.7 | N | C |

**Table 17**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by road-deicing chemicals based on road density and soil characteristics—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Density of paved roads in WHPA, in miles per square mile | Soil-leaching potential risk, area-weighted rank in WHPA | | |
| C | 2980258-2 | 23 | BD | 7.7 | 3.7 | N | C |
| C | 2980258-5 | 173 | BD | 7.7 | 3.7 | N | C |
| C | 2980264-1 | 186 | BD | 5.6 | 4.0 | N | C |
| C | 2980276-1 | 86 | BD | 4.1 | 3.0 | N | C |
| C | 2980276-2 | 87 | BD | 4.1 | 3.0 | N | C |
| C | 2980323-1 | 65 | BD | 7.5 | 4.4 | N | C |
| C | 2980340-1 | 185 | BD | 9.9 | 2.5 | Y | A[1] |
| P | 1000007-1 | 102 | BD | 3.2 | 3.6 | N | C |
| P | 1000007-2 | 103 | BD | 3.2 | 3.6 | N | C |
| P | 1000025-1 | 17 | BD | 11.7 | 4.0 | -- | A |
| P | 1000039-1 | 72 | SD | 4.4 | 3.8 | -- | C |
| P | 1000042-1 | 5 | BD | 6.6 | 3.7 | -- | C |
| P | 1559510-1 | 50 | BD | 5.3 | 3.7 | -- | C |
| P | 1559516-1 | 92 | SD | 4.9 | 4.7 | N | C |
| P | 1559516-2 | 104 | SD | 4.9 | 4.7 | N | C |
| P | 1583819-3 | 56 | BD | 4.3 | 2.8 | Y | A[1] |
| P | 1583819-4 | 55 | BD | 4.3 | 2.8 | Y | A[1] |
| P | 1583820-1 | 57 | BD | 3.6 | 3.6 | -- | C |
| P | 1583823-1 | 36 | BD | 4.5 | 5.6 | -- | C |
| P | 1583827-1 | 18 | BD | 5.6 | 4.2 | -- | C |
| P | 1583829-4 | 26 | BD | 3.6 | 3.4 | N | C |
| P | 1583829-5 | 25 | BD | 3.6 | 3.4 | N | C |
| P | 1583829-6 | 24 | BD | 3.6 | 3.4 | N | C |
| P | 1583829-7 | 27 | BD | 3.6 | 3.4 | N | C |
| P | 1592014-1 | 3 | BD | 6.6 | 3.7 | -- | C |
| P | 1592015-1 | 6 | SD | 3.7 | 5.9 | -- | C |
| P | 1592017-1 | 13 | BD | 4.4 | 3.8 | -- | C |
| P | 1592027-2 | 66 | BD | 5.2 | 3.8 | Y | A[1] |
| P | 1592027-3 | 67 | BD | 5.2 | 3.8 | N | C |
| P | 1592028-1 | 79 | SD | 3.5 | 3.9 | -- | C |
| P | 1592030-1 | 75 | SD | 3.5 | 3.9 | -- | C |
| P | 1615611-1 | 41 | BD | 5.4 | 3.3 | -- | C |
| P | 1615612-4 | 34 | BD | 4.4 | 2.5 | N | C |
| P | 1615612-5 | 35 | BD | 4.4 | 2.5 | N | C |
| P | 1615612-6 | 33 | BD | 4.4 | 2.5 | N | C |
| P | 1615613-1 | 30 | BD | 9.8 | 4.6 | -- | A |
| P | 1615617-1 | 71 | SD | 4.4 | 3.8 | -- | C |
| P | 1647513-3 | 91 | SD | 8.3 | 4.5 | Y | A |
| P | 1647517-1 | 10 | BD | 9.8 | 3.6 | -- | B |
| P | 1647525-3 | 76 | BD | 7.2 | 3.9 | N | C |

**Table 17.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by road-deicing chemicals based on road density and soil characteristics—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor: Aquifer type | Vulnerability factor: Density of paved roads in WHPA, in miles per square mile | Vulnerability factor: Soil-leaching potential risk, area-weighted rank in WHPA | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|
| P | 1647525-4 | 73 | BD | 7.2 | 3.9 | N | C |
| P | 1647527-1 | 47 | BD | 5.6 | 3.6 | N | C |
| P | 1858414-1 | 68 | BD | 3.3 | 3.4 | N | C |
| P | 1858415-1 | 87 | BD | 8.1 | 5.0 | -- | A |
| P | 1858417-1 | 89 | BD | 8.1 | 5.0 | -- | A |
| P | 1858425-2 | 65 | BD | 4.6 | 2.4 | -- | C |
| P | 1858431-1 | 83 | DG | 6.0 | 4.8 | -- | C |
| P | 1900003-1 | 45 | BD | 2.1 | 3.4 | N | C |
| P | 1900003-2 | 46 | BD | 2.1 | 3.4 | N | C |
| P | 1900003-3 | 43 | BD | 2.1 | 3.4 | N | C |
| P | 1900003-4 | 44 | BD | 2.1 | 3.4 | N | C |
| P | 1900004-1 | 101 | U | 24.5 | 2.7 | -- | B |
| P | 1900004-2 | 105 | U | 24.5 | 2.7 | -- | B |
| P | 1900024-1 | 52 | BD | 4.7 | 2.6 | N | C |
| P | 1900024-2 | 54 | BD | 4.7 | 2.6 | N | C |
| P | 1900024-3 | 53 | BD | 4.7 | 2.6 | N | C |
| P | 1900026-1 | 16 | BD | 1.7 | 2.8 | N | C |
| P | 1900027-3 | 90 | BD | 2.7 | 3.1 | N | C |
| P | 1900028-1 | 11 | BD | 6.3 | 3.6 | N | C |
| P | 1900035-1 | 69 | BD | 3.3 | 3.4 | N | C |
| P | 1900038-1 | 20 | BD | 5.3 | 3.9 | -- | C |
| P | 1900040-2 | 1 | BD | 3.1 | 3.5 | N | C |
| P | 1900041-1 | 19 | BD | 1.7 | 3.4 | N | C |
| P | 1900044-1 | 29 | BD | 8.5 | 2.6 | -- | B |
| P | 2000090-1 | 97 | BD | 6.6 | 3.7 | -- | C |
| P | 2000110-1 | 42 | BD | 4.3 | 4.3 | -- | C |
| P | 2000133-1 | 70 | BD | 4.9 | 3.3 | -- | C |
| P | 2000135-1 | 49 | BD | 8.8 | 4.3 | -- | A |
| P | 2000142-4 | 74 | SD | 2.9 | 4.4 | N | C |
| P | 2000145-1 | 88 | BD | 8.1 | 5.0 | -- | A |
| P | 2000176-1 | 48 | BD | 9.4 | 4.1 | -- | A |
| P | 2051719-1 | 37 | BD | .8 | 3.1 | N | C |
| P | 2051719-2 | 38 | BD | .8 | 3.1 | N | C |
| P | 2051719-3 | 39 | BD | .8 | 3.1 | N | C |
| P | 2051719-4 | 40 | BD | .8 | 3.1 | N | C |
| P | 2051729-1 | 64 | DG | 3.9 | 3.0 | -- | C |
| P | 2788010-1 | 32 | BD | 5.9 | 3.0 | -- | C |
| P | 2942515-1 | 9 | BD | 9.8 | 3.6 | -- | B |
| P | 2973119-4 | 7 | BD | 5.9 | 3.6 | N | C |
| P | 2980017-1 | 94 | BD | 12.7 | 4.2 | Y | A |

**Table 17**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by road-deicing chemicals based on road density and soil characteristics—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Affected or unaffected | Relative vulnerability |
|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Density of paved roads in WHPA, in miles per square mile | Soil-leaching potential risk, area-weighted rank in WHPA | | |
| P | 2980019-1 | 96 | BD | 11.5 | 3.0 | -- | B |
| P | 2980030-1 | 99 | BD | 4.8 | 3.8 | -- | C |
| P | 2980036-1 | 2 | BD | 12.1 | 3.9 | -- | B |
| P | 2980084-2 | 31 | BD | 4.9 | 3.8 | -- | C |
| P | 2980127-1 | 84 | BD | 5.7 | 5.1 | -- | C |
| P | 2980134-1 | 21 | BD | 7.1 | 3.6 | -- | C |
| P | 2980135-1 | 28 | BD | 13.3 | 3.5 | -- | B |
| P | 2980138-1 | 60 | BD | 7.5 | 1.5 | -- | C |
| P | 2980154-1 | 98 | BD | 5.1 | 4.8 | N | C |
| P | 2980185-2 | 77 | SD | 3.5 | 3.9 | N | C |
| P | 2980185-3 | 78 | SD | 3.5 | 3.9 | N | C |
| P | 2980192-1 | 62 | BD | 3.8 | 4.0 | N | C |
| P | 2980192-2 | 63 | BD | 3.8 | 4.0 | N | C |
| P | 2980265-1 | 59 | BD | 5.1 | 2.1 | -- | C |
| P | 2980270-1 | 100 | BD | 4.7 | 4.3 | -- | C |
| P | 2980277-1 | 14 | BD | 6.5 | 5.1 | -- | C |
| P | 2980278-1 | 15 | BD | 6.5 | 5.1 | -- | C |
| P | 2980301-1 | 4 | BD | 6.6 | 3.7 | N | C |
| P | 2980311-1 | 12 | BD | 10.2 | 3.5 | -- | B |
| P | 2980330-1 | 106 | BD | 5.1 | 4.8 | Y | A[1] |
| P | 2980346-1 | 107 | U | 6.1 | 4.0 | -- | C |

[1]Well is designated with "A" vulnerability category based on historical water quality (average sodium concentrations greater than 20 milligrams per liter) rather than on tabulated vulnerability factors.

**Table 18**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by fluoride and radionuclides based on aquifer type and bedrock geology at the well

[**Supply type:** C, community; P, non-community, non-transient. **Source identifier**: Combines the public-water system identifier (PWSID) and the source number assigned by the Rhode Island Department of Health. **USGS-ID:** Identifier used in figures 2 and 3. **Aquifer type:** BD, bedrock; D, dug well of undetermined aquifer type; SD, sand and gravel; U, drilled well of undetermined aquifer type. **Lithologic rock type:** F, felsic crystalline rocks; M, mafic crystalline rocks; MS, metasedimentary rocks; S, sedimentary rocks; C, carbonate-rick rocks. **Median fluoride concentration at well:** Concentration given in milligrams per liter. **Relative vulnerability:** A, most vulnerable; C, least vulnerable. Shading of aquifer and lithologic rock type indicates variables that were used in designating A and B vulnerability categories for fluoride; shading of aquifer type and bedrock group indicates variables that were used in designating A and B vulnerability categories for radionuclides. <, actual value less than value shown]

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Median fluoride concentration at well | Relative vulnerability | |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Lithologic rock type at well | Bedrock group | | Fluoride | Radio-nuclides |
| C | 1000009-1 | 63 | BD | F | Esmond Igneous Suite | 0.5 | A | B |
| C | 1000009-4 | 178 | BD | F | Esmond Igneous Suite | <.2 | A | B |
| C | 1000020-1 | 68 | BD | F | Scituate Igneous Suite | 4.1 | A | A |
| C | 1000020-2 | 67 | BD | F | Scituate Igneous Suite | 4.0 | A | A |
| C | 1000020-3 | 69 | BD | F | Scituate Igneous Suite | 3.6 | A | A |

**Table 18.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by fluoride and radionuclides based on aquifer type and bedrock geology at the well—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Median fluoride concen-tration at well | Relative vulnerability | |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Lithologic rock type at well | Bedrock group | | Fluoride | Radio-nuclides |
| C | 1000035-3 | 150 | BD | F | Narragansett Pier Plutonic Suite | <0.2 | A | A |
| C | 1000035-4 | 152 | BD | F | Narragansett Pier Plutonic Suite | .4 | A | A |
| C | 1000035-5 | 151 | BD | F | Narragansett Pier Plutonic Suite | .4 | A | A |
| C | 1000040-1 | 113 | SD | F | Scituate Igneous Suite | .3 | B | C |
| C | 1000040-2 | 180 | SD | F | Scituate Igneous Suite | .2 | B | C |
| C | 1000043-2 | 124 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| C | 1000043-3 | 125 | BD | F | Sterling Plutonic Group | .5 | A | A |
| C | 1000045-1 | 141 | BD | F | Sterling Plutonic Group | .3 | A | A |
| C | 1000045-2 | 142 | BD | F | Sterling Plutonic Group | .7 | A | A |
| C | 1000098-1 | 133 | SD | M | Sterling Plutonic Group | <.2 | B | C |
| C | 1000098-2 | 132 | SD | M | Sterling Plutonic Group | <.2 | B | C |
| C | 1559511-1 | 90 | SD | S | Narragansett Bay Group | <.2 | C | A[1] |
| C | 1559511-2 | 82 | SD | F | Scituate Igneous Suite | .2 | B | C |
| C | 1559511-3 | 85 | SD | F | Scituate Igneous Suite | <.2 | B | C |
| C | 1559511-4 | 84 | SD | F | Scituate Igneous Suite | .4 | B | A[1] |
| C | 1559512-1 | 153 | SD | M | Waterford Group | <.2 | B | C |
| C | 1559512-10 | 159 | SD | M | Waterford Group | <.2 | B | C |
| C | 1559512-11 | 161 | SD | F | Narragansett Pier Plutonic Suite | <.2 | B | C |
| C | 1559512-2 | 155 | SD | M | Waterford Group | <.2 | B | C |
| C | 1559512-3 | 154 | SD | M | Waterford Group | <.2 | B | C |
| C | 1559512-4 | 147 | SD | F | Sterling Plutonic Group | <.2 | B | C |
| C | 1559512-5 | 145 | SD | F | Sterling Plutonic Group | <.2 | B | C |
| C | 1559512-6 | 146 | SD | F | Sterling Plutonic Group | <.2 | B | C |
| C | 1559512-7 | 149 | SD | M | Waterford Group | <.2 | B | C |
| C | 1559512-8 | 148 | SD | F | Sterling Plutonic Group | <.2 | B | C |
| C | 1559512-9 | 158 | SD | F | Sterling Plutonic Group | <.2 | B | C |
| C | 1559513-1 | 166 | SD | F | Narragansett Pier Plutonic Suite | <.2 | B | C |
| C | 1559513-2 | 164 | SD | F | Narragansett Pier Plutonic Suite | <.2 | B | C |
| C | 1559513-4 | 165 | BD | F | Narragansett Pier Plutonic Suite | <.2 | A | A |
| C | 1559513-5 | 163 | BD | F | Narragansett Pier Plutonic Suite | .7 | A | A |
| C | 1559517-1 | 106 | SD | S | Narragansett Bay Group | .2 | C | C |
| C | 1559517-10 | 118 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1559517-2 | 107 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1559517-3 | 116 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1559517-4 | 108 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1559517-5 | 110 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1559517-6 | 104 | SD | S | Narragansett Bay Group | .2 | C | C |
| C | 1559517-7 | 91 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1559517-8 | 92 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1559517-9 | 117 | SD | S | Narragansett Bay Group | <.2 | C | C |

**Table 18.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by fluoride and radionuclides based on aquifer type and bedrock geology at the well—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Median fluoride concentration at well | Relative vulnerability | |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Lithologic rock type at well | Bedrock group | | Fluoride | Radionuclides |
| C | 1559519-1 | 28 | BD | M | Blackstone Group | <0.2 | A | A[1] |
| C | 1559519-2 | 27 | BD | M | Blackstone Group | <.2 | A | B |
| C | 1583825-1 | 29 | BD | F | Scituate Igneous Suite | 1.4 | A | A |
| C | 1592012-2 | 105 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1592019-1 | 38 | BD | M | Blackstone Group | <.2 | A | A[1] |
| C | 1592019-2 | 176 | BD | M | Blackstone Group | 1.9 | A | A[1] |
| C | 1592020-1 | 32 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1592020-2 | 34 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1592021-2 | 56 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1592021-3 | 55 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1592021-4 | 54 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1592021-5 | 53 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1592021-6 | 50 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1592021-7 | 47 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1592021-8 | 46 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1592021-9 | 45 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1592023-1 | 102 | BD | S | Narragansett Bay Group | <.2 | C | B |
| C | 1592023-5 | 100 | BD | S | Narragansett Bay Group | <.2 | C | A[1] |
| C | 1592023-7 | 98 | BD | S | Narragansett Bay Group | <.2 | C | B |
| C | 1592023-8 | 94 | BD | S | Narragansett Bay Group | <.2 | C | B |
| C | 1592023-9 | 179 | BD | S | Narragansett Bay Group | <.2 | C | B |
| C | 1592025-1 | 88 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1592025-2 | 93 | SD | S | Narragansett Bay Group | .2 | C | C |
| C | 1592025-3 | 89 | SD | S | Narragansett Bay Group | .3 | C | C |
| C | 1615614-1 | 26 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1615614-2 | 25 | BD | F | Esmond Igneous Suite | .5 | A | A[1] |
| C | 1615614-5 | 24 | SD | M | Blackstone Group | <.2 | B | C |
| C | 1615623-1 | 157 | SD | F | Narragansett Pier Plutonic Suite | <.2 | B | C |
| C | 1615623-2 | 156 | SD | F | Narragansett Pier Plutonic Suite | <.2 | B | C |
| C | 1615624-1 | 137 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1615624-2 | 138 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1615624-3 | 136 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1615624-4 | 139 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1615624-5 | 140 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1615624-7 | 135 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1615626-1 | 80 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1615626-2 | 81 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1647512-1 | 167 | SD | F | Narragansett Pier Plutonic Suite | <.2 | B | C |
| C | 1647512-2 | 168 | SD | F | Narragansett Pier Plutonic Suite | <.2 | B | C |
| C | 1647515-5 | 77 | SD | S | Narragansett Bay Group | <.2 | C | C |

**Table 18**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by fluoride and radionuclides based on aquifer type and bedrock geology at the well—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Median fluoride concentration at well | Relative vulnerability | |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Lithologic rock type at well | Bedrock group | | Fluoride | Radionuclides |
| C | 1647515-6 | 76 | SD | S | Narragansett Bay Group | <0.2 | C | C |
| C | 1647526-1 | 44 | BD | F | Esmond Igneous Suite | -- | A | B |
| C | 1647529-1 | 134 | BD | F | Esmond Igneous Suite | <.2 | A | B |
| C | 1647530-1 | 33 | SD | MS | Blackstone Group | <.2 | C | A[1] |
| C | 1647530-3 | 40 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1647530-4 | 39 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1647530-5 | 31 | SD | MS | Blackstone Group | <.2 | C | A[1] |
| C | 1858411-1 | 35 | SD | M | Blackstone Group | <.2 | B | C |
| C | 1858411-2 | 37 | SD | M | Blackstone Group | <.2 | B | C |
| C | 1858421-1 | 130 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1858421-2 | 131 | SD | F | Esmond Igneous Suite | .2 | B | C |
| C | 1858422-1 | 128 | SD | F | Esmond Igneous Suite | .9 | B | C |
| C | 1858422-2 | 129 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| C | 1858422-3 | 127 | SD | F | Esmond Igneous Suite | .5 | B | C |
| C | 1858423-5 | 59 | SD | S | Narragansett Bay Group | <.2 | C | C |
| C | 1858435-1 | 70 | BD | F | Esmond Igneous Suite | <.2 | A | B |
| C | 1900020-1 | 78 | SD | F | Scituate Igneous Suite | <.2 | B | C |
| C | 1900023-1 | 74 | BD | F | Scituate Igneous Suite | 1.6 | A | A |
| C | 1900023-2 | 75 | BD | F | Scituate Igneous Suite | 1.3 | A | A |
| C | 1900023-3 | 71 | BD | F | Scituate Igneous Suite | 1.0 | A | A |
| C | 1900023-4 | 72 | BD | F | Scituate Igneous Suite | 1.2 | A | A |
| C | 1900023-5 | 73 | BD | F | Scituate Igneous Suite | 1.5 | A | A |
| C | 1900025-2 | 126 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| C | 1900029-1 | 160 | BD | F | Narragansett Pier Plutonic Suite | -- | A | A |
| C | 1900034-1 | 30 | SD | F | Scituate Igneous Suite | <.2 | B | C |
| C | 1900034-2 | 181 | SD | F | Scituate Igneous Suite | <.2 | B | C |
| C | 1900036-1 | 170 | U | F | Esmond Igneous Suite | .9 | B | C |
| C | 1900036-2 | 171 | U | F | Esmond Igneous Suite | -- | B | C |
| C | 1900039-1 | 174 | BD | S | Narragansett Bay Group | -- | C | B |
| C | 1900048-2 | 123 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| C | 1900049-1 | 183 | SD | F | Esmond Igneous Suite | -- | B | C |
| C | 2000004-2 | 79 | BD | F | Esmond Igneous Suite | .4 | A | B |
| C | 2000059-1 | 49 | BD | F | Harmony Group | .6 | A | B |
| C | 2000059-2 | 48 | BD | F | Harmony Group | .7 | A | B |
| C | 2000083-1 | 52 | BD | S | metaclastic | <.2 | C | A[1] |
| C | 2000083-2 | 51 | BD | S | metaclastic | <.2 | C | A[1] |
| C | 2000084-1 | 62 | BD | M | gabbro/diorite | <.2 | A | A[1] |
| C | 2000165-1 | 112 | BD | F | Scituate Igneous Suite | .6 | A | A |
| C | 2051311-1 | 97 | BD | S | Narragansett Bay Group | <.2 | C | B |
| C | 2415415-1 | 64 | BD | F | Esmond Igneous Suite | <.2 | A | B |

**Table 18.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by fluoride and radionuclides based on aquifer type and bedrock geology at the well—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Median fluoride concentration at well | Relative vulnerability | |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Lithologic rock type at well | Bedrock group | | Fluoride | Radionuclides |
| C | 2519424-1 | 60 | BD | F | Esmond Igneous Suite | 1.0 | A | B |
| C | 2519424-3 | 177 | BD | F | Esmond Igneous Suite | 1.8 | A | B |
| C | 2519426-1 | 83 | BD | F | Scituate Igneous Suite | <.2 | A | A |
| C | 2585312-1 | 115 | DG | F | Esmond Igneous Suite | <.2 | B | C |
| C | 2585312-2 | 114 | BD | F | Esmond Igneous Suite | <.2 | A | A[1] |
| C | 2585313-1 | 103 | BD | F | Scituate Igneous Suite | -- | A | A |
| C | 2674924-1 | 182 | SD | F | Narragansett Pier Plutonic Suite | <.2 | B | C |
| C | 2674925-1 | 144 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| C | 2674925-2 | 143 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| C | 2674928-1 | 162 | BD | F | Narragansett Pier Plutonic Suite | -- | A | A |
| C | 2753326-1 | 121 | BD | S | Narragansett Bay Group | <.2 | B | A[1] |
| C | 2753326-3 | 122 | BD | S | Narragansett Bay Group | <.2 | B | A[1] |
| C | 2788012-1 | 66 | BD | F | Esmond Igneous Suite | <.2 | A | B |
| C | 2814410-3 | 96 | BD | F | Scituate Igneous Suite | .4 | A | A |
| C | 2882117-3 | 120 | SD | F | Esmond Igneous Suite | <.2 | B | A[1] |
| C | 2882117-4 | 119 | BD | F | Esmond Igneous Suite | 2.0 | A | B |
| C | 2942518-1 | 36 | BD | F | Esmond Igneous Suite | .3 | A | A[1] |
| C | 2942525-1 | 111 | BD | F | Scituate Igneous Suite | 1.5 | A | A |
| C | 2942525-3 | 109 | BD | F | Scituate Igneous Suite | 1.4 | A | A |
| C | 2943224-8 | 61 | BD | F | Esmond Igneous Suite | 2.1 | A | A[1] |
| C | 2973130-1 | 42 | SD | F | Harmony Group | <.2 | B | C |
| C | 2973130-2 | 43 | SD | F | Harmony Group | <.2 | B | C |
| C | 2973130-3 | 41 | SD | F | Harmony Group | <.2 | B | C |
| C | 2980001-1 | 95 | BD | F | Granites of southeastern R.I. | .4 | A | A |
| C | 2980003-1 | 99 | BD | S | Narragansett Bay Group | <.2 | C | B |
| C | 2980145-1 | 101 | BD | F | Scituate Igneous Suite | <.2 | A | A |
| C | 2980146-1 | 58 | BD | M | Blackstone Group | 1.4 | A | A[1] |
| C | 2980146-3 | 57 | BD | M | Blackstone Group | 1.4 | A | A[1] |
| C | 2980196-2 | 169 | SD | -- | -- | <.2 | C | C |
| C | 2980258-1 | 22 | BD | M | Blackstone Group | .3 | A | A[1] |
| C | 2980258-2 | 23 | BD | M | Blackstone Group | .2 | A | A[1] |
| C | 2980258-5 | 173 | BD | M | Blackstone Group | .3 | A | A[1] |
| C | 2980264-1 | 186 | BD | F | Esmond Igneous Suite | .3 | A | B |
| C | 2980276-1 | 86 | BD | F | Scituate Igneous Suite | .3 | A | A |
| C | 2980276-2 | 87 | BD | F | Scituate Igneous Suite | .3 | A | A |
| C | 2980323-1 | 65 | BD | F | Scituate Igneous Suite | -- | A | A |
| C | 2980340-1 | 185 | BD | F | Granites of southeastern R.I. | <.2 | A | A |
| P | 1000007-1 | 102 | BD | F | Harmony Group | .2 | A | B |
| P | 1000007-2 | 103 | BD | F | Harmony Group | <.2 | A | B |
| P | 1000025-1 | 17 | BD | C | Blackstone Group | <.2 | C | B |

**Table 18**. Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by fluoride and radionuclides based on aquifer type and bedrock geology at the well—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Median fluoride concentration at well | Relative vulnerability | |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Lithologic rock type at well | Bedrock group | | Fluoride | Radionuclides |
| P | 1000039-1 | 72 | SD | F | Esmond Igneous Suite | -- | B | C |
| P | 1000042-1 | 5 | BD | M | Blackstone Group | -- | A | B |
| P | 1559510-1 | 50 | BD | F | Scituate Igneous Suite | -- | A | A |
| P | 1559516-1 | 92 | SD | M | Waterford Group | <0.2 | B | C |
| P | 1559516-2 | 104 | SD | M | Waterford Group | -- | B | C |
| P | 1583819-3 | 56 | BD | F | Scituate Igneous Suite | <.2 | A | A |
| P | 1583819-4 | 55 | BD | F | Scituate Igneous Suite | <.2 | A | A |
| P | 1583820-1 | 57 | BD | F | Scituate Igneous Suite | -- | A | A |
| P | 1583823-1 | 36 | BD | F | Esmond Igneous Suite | -- | A | B |
| P | 1583827-1 | 18 | BD | F | Esmond Igneous Suite | -- | A | B |
| P | 1583829-4 | 26 | BD | F | Esmond Igneous Suite | <.2 | A | B |
| P | 1583829-5 | 25 | BD | F | Esmond Igneous Suite | <.2 | A | A[1] |
| P | 1583829-6 | 24 | BD | F | Esmond Igneous Suite | <.2 | A | A[1] |
| P | 1583829-7 | 27 | BD | F | Esmond Igneous Suite | <.2 | A | A[1] |
| P | 1592014-1 | 3 | BD | M | Blackstone Group | -- | A | B |
| P | 1592015-1 | 6 | SD | F | Esmond Igneous Suite | <.2 | B | C |
| P | 1592017-1 | 13 | BD | F | Harmony Group | -- | A | B |
| P | 1592027-2 | 66 | BD | F | Sterling Plutonic Group | .9 | A | A |
| P | 1592027-3 | 67 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| P | 1592028-1 | 79 | SD | F | Sterling Plutonic Group | -- | B | C |
| P | 1592030-1 | 75 | SD | F | Sterling Plutonic Group | -- | B | C |
| P | 1615611-1 | 41 | BD | F | Scituate Igneous Suite | -- | A | A |
| P | 1615612-4 | 34 | BD | F | Scituate Igneous Suite | .9 | A | A |
| P | 1615612-5 | 35 | BD | F | Scituate Igneous Suite | 1.4 | A | A |
| P | 1615612-6 | 33 | BD | F | Scituate Igneous Suite | .6 | A | A |
| P | 1615613-1 | 30 | BD | F | Scituate Igneous Suite | -- | A | A |
| P | 1615617-1 | 71 | SD | F | Esmond Igneous Suite | -- | B | C |
| P | 1647513-3 | 91 | SD | F | Sterling Plutonic Group | <.2 | B | C |
| P | 1647517-1 | 10 | BD | F | Esmond Igneous Suite | 1.2 | A | B |
| P | 1647525-3 | 76 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| P | 1647525-4 | 73 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| P | 1647527-1 | 47 | BD | F | Scituate Igneous Suite | .5 | A | A |
| P | 1858414-1 | 68 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| P | 1858415-1 | 87 | BD | MS | Plainfield Formation | .3 | C | B |
| P | 1858417-1 | 89 | BD | MS | Plainfield Formation | -- | C | B |
| P | 1858425-2 | 65 | BD | F | Granites of southeastern R.I. | <.2 | A | A |
| P | 1858431-1 | 83 | DG | F | Sterling Plutonic Group | -- | B | C |
| P | 1900003-1 | 45 | BD | F | Scituate Igneous Suite | <.2 | A | A |
| P | 1900003-2 | 46 | BD | F | Scituate Igneous Suite | <.2 | A | A |
| P | 1900003-3 | 43 | BD | F | Scituate Igneous Suite | <.2 | A | A |

**Table 18.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by fluoride and radionuclides based on aquifer type and bedrock geology at the well—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Median fluoride concen-tration at well | Relative vulnerability | |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Lithologic rock type at well | Bedrock group | | Fluoride | Radio-nuclides |
| P | 1900003-4 | 44 | BD | F | Scituate Igneous Suite | <0.2 | A | A |
| P | 1900004-1 | 101 | U | F | Harmony Group | -- | B | C |
| P | 1900004-2 | 105 | U | F | Harmony Group | -- | B | C |
| P | 1900024-1 | 52 | BD | F | Scituate Igneous Suite | 1.1 | A | A |
| P | 1900024-2 | 54 | BD | F | Scituate Igneous Suite | 2.3 | A | A |
| P | 1900024-3 | 53 | BD | F | Scituate Igneous Suite | .9 | A | A |
| P | 1900026-1 | 16 | BD | F | Esmond Igneous Suite | 1.3 | A | B |
| P | 1900027-3 | 90 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| P | 1900028-1 | 11 | BD | M | Blackstone Group | .2 | A | B |
| P | 1900035-1 | 69 | BD | F | Sterling Plutonic Group | .2 | A | A |
| P | 1900038-1 | 20 | BD | F | Harmony Group | 1.4 | A | B |
| P | 1900040-2 | 1 | BD | F | Esmond Igneous Suite | .7 | A | A[1] |
| P | 1900041-1 | 19 | BD | F | Esmond Igneous Suite | .7 | A | B |
| P | 1900044-1 | 29 | BD | F | Harmony Group | .2 | A | B |
| P | 2000090-1 | 97 | BD | M | Blackstone Group | -- | A | B |
| P | 2000110-1 | 42 | BD | F | Scituate Igneous Suite | -- | A | A |
| P | 2000133-1 | 70 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| P | 2000135-1 | 49 | BD | F | Scituate Igneous Suite | <.2 | A | A |
| P | 2000142-4 | 74 | SD | F | Sterling Plutonic Group | <.2 | B | C |
| P | 2000145-1 | 88 | BD | MS | Plainfield Formation | <.2 | C | B |
| P | 2000176-1 | 48 | BD | F | Scituate Igneous Suite | -- | A | A |
| P | 2051719-1 | 37 | BD | F | Scituate Igneous Suite | .4 | A | A |
| P | 2051719-2 | 38 | BD | F | Scituate Igneous Suite | .4 | A | A |
| P | 2051719-3 | 39 | BD | F | Scituate Igneous Suite | .9 | A | A |
| P | 2051719-4 | 40 | BD | F | Scituate Igneous Suite | .5 | A | A |
| P | 2051729-1 | 64 | DG | F | Esmond Igneous Suite | <.2 | B | C |
| P | 2788010-1 | 32 | BD | F | Esmond Igneous Suite | .4 | A | B |
| P | 2942515-1 | 9 | BD | M | Blackstone Group | .3 | A | B |
| P | 2973119-4 | 7 | BD | F | Esmond Igneous Suite | .4 | A | B |
| P | 2980017-1 | 94 | BD | F | Narragansett Pier Plutonic Suite | .5 | A | A |
| P | 2980019-1 | 96 | BD | F | Narragansett Pier Plutonic Suite | <.2 | A | A |
| P | 2980030-1 | 99 | BD | F | Scituate Igneous Suite | .3 | A | A |
| P | 2980036-1 | 2 | BD | F | Esmond Igneous Suite | -- | A | B |
| P | 2980084-2 | 31 | BD | F | Scituate Igneous Suite | -- | A | A |
| P | 2980127-1 | 84 | BD | F | Sterling Plutonic Group | <.2 | A | A |
| P | 2980134-1 | 21 | BD | F | Harmony Group | .6 | A | B |
| P | 2980135-1 | 28 | BD | F | Esmond Igneous Suite | -- | A | B |
| P | 2980138-1 | 60 | BD | F | Granites of southeastern Rhode Island | .3 | A | A |
| P | 2980154-1 | 98 | BD | F | Harmony Group | .4 | A | B |
| P | 2980185-2 | 77 | SD | F | Sterling Plutonic Group | 1.9 | B | C |

**Table 18.** Relative vulnerability of community and non-community, non-transient supply wells in Rhode Island to contamination by fluoride and radionuclides based on aquifer type and bedrock geology at the well—*Continued*

| Supply type | Source identifier | USGS-ID | Vulnerability factor | | | Median fluoride concentration at well | Relative vulnerability | |
|---|---|---|---|---|---|---|---|---|
| | | | Aquifer type | Lithologic rock type at well | Bedrock group | | Fluoride | Radionuclides |
| P | 2980185-3 | 78 | SD | F | Sterling Plutonic Group | 1.9 | B | C |
| P | 2980192-1 | 62 | BD | F | Esmond Igneous Suite | 1.4 | A | A[1] |
| P | 2980192-2 | 63 | BD | F | Esmond Igneous Suite | 1.6 | A | A[1] |
| P | 2980265-1 | 59 | BD | S | Narragansett Bay Group | -- | A | B |
| P | 2980270-1 | 100 | BD | F | Sterling Plutonic Group | -- | A | A |
| P | 2980277-1 | 14 | BD | F | Harmony Group | -- | A | B |
| P | 2980278-1 | 15 | BD | F | Harmony Group | -- | A | B |
| P | 2980301-1 | 4 | BD | M | Blackstone Group | <.2 | A | A[1] |
| P | 2980311-1 | 12 | BD | M | Blackstone Group | -- | A | B |
| P | 2980330-1 | 106 | BD | F | Harmony Group | .4 | A | B |
| P | 2980346-1 | 107 | U | F | Esmond Igneous Suite | -- | B | C |

[1]Well is designated with "A" vulnerability category based on historical water quality (measured gross alpha or beta radioactivity greater than 5 picocuries per liter) rather than on tabulated vulnerability factors

# APPENDIXES 1—6

**Appendix 1**. Wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island

[**WHPA:** Wellhead-protection area]

| WHPA | Area, in square miles | WHPA | Area, in square miles | WHPA | Area, in square miles |
|---|---|---|---|---|---|
| C1 | 0.357 | C46 | 0.494 | P17 | 0.343 |
| C2 | 1.116 | C47 | 3.493 | P18 | .343 |
| C3 | .011 | C48 | .205 | P19 | 1.596 |
| C4 | .449 | C49 | 1.221 | P20 | .343 |
| C5 | .464 | C50 | 3.201 | P21 | .343 |
| C6 | .786 | C51 | .468 | P22 | .343 |
| C7 | .058 | C52 | .232 | P23 | .343 |
| C8 | .029 | C53 | .481 | P24 | .343 |
| C9 | .527 | C54 | .482 | P25 | .384 |
| C10 | .360 | C55 | 1.047 | P26 | .343 |
| C11 | .247 | C56 | 1.025 | P27 | .343 |
| C12 | .023 | C57 | .595 | P28 | .396 |
| C13 | .390 | C58 | 2.979 | P29 | .343 |
| C14 | .063 | C59 | 1.200 | P30 | .421 |
| C15 | .064 | C60 | .847 | P31 | .343 |
| C16 | 1.140 | C61 | 1.736 | P32 | .343 |
| C17 | 1.028 | C62 | 1.485 | P33 | .425 |
| C18 | .935 | C63 | 1.386 | P34 | .343 |
| C19 | .835 | C64 | 1.396 | P35 | .343 |
| C20 | .764 | C65 | 1.077 | P36 | .343 |
| C21 | .908 | C66 | .386 | P37 | .343 |
| C22 | .720 | C67 | 3.019 | P38 | .391 |
| C23 | .441 | C68 | .771 | P39 | .400 |
| C24 | .357 | C69 | 1.150 | P40 | .343 |
| C25 | .656 | C70 | .211 | P41 | .343 |
| C26 | .758 | C71 | .671 | P42 | .343 |
| C27 | .526 | C72 | .449 | P43 | .349 |
| C28 | .758 | C73 | .449 | P44 | .343 |
| C29 | .516 | C74 | .449 | P45 | .343 |
| C30 | .754 | P1 | .343 | P46 | .347 |
| C31 | .705 | P2 | .343 | P47 | .446 |
| C32 | .022 | P3 | .343 | P48 | .343 |
| C33 | .086 | P4 | .813 | P49 | .439 |
| C34 | .644 | P5 | .343 | P50 | .343 |
| C35 | .461 | P6 | .343 | P51 | .733 |
| C36 | .471 | P7 | .343 | P52 | .362 |
| C37 | .695 | P8 | .343 | P53 | .343 |
| C38 | 1.490 | P9 | .343 | P54 | .343 |
| C39 | 1.391 | P10 | .343 | P55 | .343 |
| C40 | .352 | P11 | .343 | P56 | .594 |
| C41 | .449 | P12 | 1.772 | P57 | .343 |
| C42 | .376 | P13 | .437 | P58 | .343 |
| C43 | .814 | P14 | .343 | P59 | .349 |
| C44 | .394 | P15 | .343 | P60 | .343 |
| C45 | .413 | P16 | .343 | P61 | .343 |
| | | | | P62 | .343 |

**Appendix 2.** Land use and land cover in wellhead-protection areas for community and non-community, non-transient supply

[**WHPA:** Wellhead-protection area. **Land use and land cover:** Given as areal percentage of the total WHPA. --, not present]

| WHPA | Land use and land cover | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Residential urban | Commercial urban | Industrial urban | Transportation urban | Mixed urban | Urban with parks and golf courses | Urban open space and cemeteries | Institutional urban |
| C1 | 45.31 | 1.10 | 2.84 | 0.75 | -- | -- | 2.12 | -- |
| C2 | 34.09 | 3.82 | 4.58 | 1.71 | -- | 1.32 | 1.20 | 2.13 |
| C3 | 40.36 | -- | -- | -- | -- | -- | -- | 8.75 |
| C4 | 38.08 | .69 | -- | -- | -- | -- | -- | -- |
| C5 | 14.18 | -- | 5.66 | 2.83 | -- | -- | -- | .99 |
| C6 | 17.15 | 2.43 | 2.26 | 3.82 | -- | -- | 1.13 | .32 |
| C7 | 33.64 | -- | -- | -- | -- | -- | -- | -- |
| C8 | 15.89 | -- | -- | -- | -- | -- | -- | -- |
| C9 | 17.50 | 15.47 | -- | 2.05 | -- | 2.89 | -- | -- |
| C10 | 21.96 | 4.13 | 2.81 | 1.21 | -- | -- | -- | .15 |
| C11 | 46.31 | 23.22 | -- | -- | -- | -- | 5.81 | 5.45 |
| C12 | 58.55 | -- | -- | -- | -- | -- | -- | -- |
| C13 | 22.10 | -- | -- | -- | -- | -- | -- | 1.77 |
| C14 | 39.23 | -- | -- | .49 | -- | -- | -- | -- |
| C15 | 73.05 | -- | -- | -- | -- | -- | -- | -- |
| C16 | 49.34 | .39 | .81 | 3.29 | -- | .60 | 2.62 | 1.16 |
| C17 | 18.29 | .16 | -- | .43 | -- | -- | -- | -- |
| C18 | 6.24 | -- | -- | -- | -- | .18 | .10 | .85 |
| C19 | 9.41 | .10 | -- | -- | 1.38 | -- | -- | 1.87 |
| C20 | 32.44 | 2.56 | .31 | 1.30 | -- | 4.10 | -- | 2.93 |
| C21 | 28.45 | 1.87 | -- | 1.42 | -- | -- | .87 | -- |
| C22 | 6.66 | 5.20 | .53 | -- | -- | -- | .54 | .10 |
| C23 | 13.29 | 1.64 | -- | -- | -- | -- | -- | .86 |
| C24 | 16.21 | 1.93 | -- | -- | -- | -- | -- | -- |
| C25 | 20.05 | 10.43 | .44 | -- | -- | .60 | 1.67 | 4.20 |
| C26 | 9.49 | .30 | -- | -- | -- | -- | -- | .80 |
| C27 | 16.15 | -- | -- | -- | -- | 1.25 | -- | 3.20 |
| C28 | 10.24 | .73 | -- | -- | -- | -- | .10 | -- |
| C29 | 8.18 | -- | -- | .55 | -- | -- | -- | -- |
| C30 | 43.78 | 9.76 | -- | -- | -- | 3.12 | 1.91 | 2.55 |
| C31 | .60 | 1.87 | -- | .20 | -- | -- | -- | -- |
| C32 | 66.51 | 7.19 | -- | -- | -- | -- | -- | -- |
| C33 | 72.96 | -- | -- | -- | -- | 4.49 | -- | -- |
| C34 | 32.88 | 4.20 | -- | 1.47 | -- | -- | 1.31 | -- |
| C35 | 17.70 | -- | -- | 1.12 | -- | -- | -- | -- |
| C36 | 18.54 | 5.25 | -- | .85 | -- | -- | -- | -- |
| C37 | 10.24 | -- | -- | 3.36 | -- | -- | -- | -- |
| C38 | 27.17 | 9.39 | 4.14 | 5.63 | -- | 5.18 | -- | .21 |
| C39 | 13.88 | -- | -- | -- | -- | .40 | -- | .39 |
| C40 | 19.94 | 1.17 | -- | 1.85 | -- | -- | -- | .35 |

wells in Rhode Island

| WHPA | Land use and land cover | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pasture agricultural | Cropland agricultural | Orchard and nursery agricultural | Idle agricultural | Forest | Brushland | Water | Wetland | Barren |
| C1 | 1.16 | -- | -- | -- | 34.34 | -- | 3.34 | 9.05 | -- |
| C2 | .21 | -- | 4.00 | 0.57 | 31.52 | 0.35 | 7.40 | 7.06 | 0.05 |
| C3 | -- | -- | -- | -- | .32 | 42.88 | -- | 7.68 | -- |
| C4 | -- | -- | .05 | 1.10 | 35.48 | .87 | 14.24 | 6.59 | 2.90 |
| C5 | 4.95 | 5.63 | -- | -- | 55.32 | 2.47 | 4.45 | 1.90 | 1.63 |
| C6 | 2.25 | 3.08 | -- | -- | 59.36 | 1.39 | 2.09 | 3.99 | .74 |
| C7 | -- | -- | -- | .05 | 44.30 | -- | 14.69 | 7.20 | .12 |
| C8 | -- | -- | -- | -- | 84.11 | -- | -- | -- | -- |
| C9 | 2.05 | 7.51 | -- | -- | 32.13 | -- | -- | 19.07 | 1.33 |
| C10 | 2.23 | 1.61 | -- | -- | 39.10 | 2.92 | 9.84 | 10.19 | 3.86 |
| C11 | -- | -- | -- | -- | 14.28 | -- | .01 | 4.08 | .83 |
| C12 | -- | -- | -- | -- | 33.68 | -- | -- | 7.77 | -- |
| C13 | -- | .85 | -- | -- | 62.41 | .31 | -- | 5.92 | 6.65 |
| C14 | 9.56 | -- | -- | -- | 19.28 | -- | -- | 6.79 | 24.66 |
| C15 | -- | -- | -- | -- | 26.16 | -- | -- | .79 | -- |
| C16 | 2.71 | .24 | -- | .31 | 17.53 | .63 | 3.09 | 14.05 | 3.24 |
| C17 | 1.60 | -- | -- | -- | 62.61 | .31 | 9.34 | 5.96 | 1.31 |
| C18 | .50 | 2.23 | 2.11 | -- | 77.76 | -- | .49 | 8.86 | .69 |
| C19 | 8.31 | 4.87 | .03 | 7.09 | 38.21 | -- | 20.46 | 8.27 | -- |
| C20 | 13.46 | 7.67 | 1.93 | 3.31 | 21.73 | -- | 2.64 | 2.71 | 2.93 |
| C21 | 3.54 | -- | -- | -- | 55.63 | -- | 1.67 | 5.72 | .84 |
| C22 | 4.75 | 2.36 | 13.71 | 2.73 | 38.88 | -- | 16.87 | 7.67 | -- |
| C23 | 1.42 | -- | -- | -- | 74.46 | 1.49 | -- | 6.84 | -- |
| C24 | 7.15 | -- | 1.33 | -- | 62.94 | 7.22 | .25 | 2.97 | -- |
| C25 | -- | .35 | -- | .49 | 40.79 | .47 | 13.23 | 6.99 | .29 |
| C26 | 1.52 | 2.25 | -- | -- | 78.52 | .57 | .03 | 6.52 | -- |
| C27 | 2.97 | 3.32 | -- | -- | 51.54 | 1.11 | .18 | 20.29 | -- |
| C28 | 1.40 | 1.10 | -- | -- | 57.28 | .66 | .45 | 27.19 | .87 |
| C29 | 1.95 | 16.98 | -- | -- | 61.66 | -- | 1.80 | 8.89 | -- |
| C30 | 1.14 | -- | 1.15 | -- | 15.71 | 1.17 | 3.88 | 15.51 | .32 |
| C31 | 3.95 | .20 | -- | -- | 75.23 | 3.48 | 4.69 | 9.78 | -- |
| C32 | -- | 26.30 | -- | -- | -- | -- | -- | -- | -- |
| C33 | 2.95 | -- | -- | -- | 5.94 | -- | -- | 3.02 | 10.64 |
| C34 | 2.57 | -- | -- | 3.83 | 36.91 | .32 | 2.55 | 8.12 | 5.86 |
| C35 | .96 | -- | -- | -- | 66.02 | -- | .25 | 12.54 | 1.41 |
| C36 | -- | -- | -- | -- | 48.77 | 1.99 | .07 | 23.80 | .75 |
| C37 | 4.05 | -- | -- | -- | 68.35 | .36 | .25 | 13.39 | -- |
| C38 | -- | .42 | -- | .02 | 18.59 | 3.02 | .74 | 17.89 | 7.61 |
| C39 | 1.47 | -- | 1.85 | -- | 56.90 | 11.56 | -- | 12.74 | .81 |
| C40 | 1.56 | 2.91 | -- | -- | 46.62 | 1.40 | -- | 19.71 | 4.50 |

**Appendix 2**. Land use and land cover in wellhead-protection areas for community and non-community, non-transient supply

| WHPA | Land use and land cover | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Residential urban | Commercial urban | Industrial urban | Transportation urban | Mixed urban | Urban with parks and golf courses | Urban open space and cemeteries | Institutional urban |
| C41 | 10.58 | 1.51 | 20.14 | 2.12 | -- | -- | -- | -- |
| C42 | 17.55 | 1.82 | -- | .41 | -- | -- | -- | -- |
| C43 | 6.55 | 1.33 | -- | 1.21 | -- | -- | -- | -- |
| C44 | 6.45 | -- | -- | -- | -- | -- | -- | -- |
| C45 | 5.21 | .02 | -- | 13.54 | -- | 1.07 | 1.20 | 0.46 |
| C46 | 38.96 | 5.75 | -- | 5.44 | -- | -- | -- | .71 |
| C47 | 9.88 | .53 | -- | 1.58 | -- | .08 | -- | .06 |
| C48 | 11.12 | -- | -- | -- | -- | -- | .37 | 13.10 |
| C49 | 20.25 | -- | -- | -- | -- | .71 | -- | -- |
| C50 | 4.43 | .17 | -- | 3.45 | -- | -- | -- | .70 |
| C51 | 11.74 | -- | -- | 4.57 | -- | -- | -- | -- |
| C52 | 2.34 | -- | -- | -- | -- | -- | -- | -- |
| C53 | 14.73 | -- | -- | 1.57 | -- | -- | -- | 1.38 |
| C54 | 39.84 | -- | -- | -- | -- | 3.15 | -- | 1.37 |
| C55 | 6.23 | .87 | -- | 8.25 | -- | 7.84 | -- | -- |
| C56 | 14.44 | .93 | -- | .43 | -- | 12.08 | 1.97 | 36.76 |
| C57 | 9.58 | .21 | 1.57 | -- | -- | -- | -- | .97 |
| C58 | 9.05 | .21 | .10 | .07 | -- | -- | -- | -- |
| C59 | 21.98 | 2.49 | .40 | 5.58 | -- | -- | 1.32 | .29 |
| C60 | 8.97 | -- | -- | -- | -- | -- | -- | -- |
| C61 | 20.42 | 1.04 | .40 | 5.94 | -- | 3.97 | .53 | .73 |
| C62 | 15.77 | -- | -- | 3.02 | -- | -- | -- | .41 |
| C63 | 38.66 | 1.51 | -- | 2.77 | -- | -- | -- | -- |
| C64 | 12.10 | 1.35 | -- | 1.34 | -- | -- | -- | -- |
| C65 | 16.66 | -- | -- | -- | -- | -- | -- | .20 |
| C66 | 49.19 | 9.19 | .03 | 1.93 | 2.09 | -- | -- | -- |
| C67 | 12.54 | 5.18 | -- | 4.15 | -- | .96 | 1.33 | .02 |
| C68 | 12.33 | 2.37 | -- | 5.39 | -- | 14.01 | .49 | -- |
| C69 | 14.44 | 1.59 | -- | 6.42 | -- | -- | -- | -- |
| C70 | 52.06 | -- | -- | .96 | -- | 2.69 | -- | -- |
| C71 | 11.90 | -- | -- | 4.81 | -- | -- | 1.30 | -- |
| C72 | 10.33 | -- | -- | -- | -- | -- | .59 | 10.58 |
| C73 | 37.17 | -- | -- | 1.36 | -- | -- | -- | -- |
| C74 | 8.80 | -- | -- | -- | -- | 6.35 | -- | 1.16 |
| P1 | 4.40 | -- | 5.62 | -- | -- | -- | -- | -- |
| P2 | 7.10 | -- | -- | 11.54 | -- | -- | -- | -- |
| P3 | 55.09 | 9.66 | -- | -- | -- | .24 | -- | .81 |
| P4 | 23.71 | 2.63 | 1.37 | 13.01 | -- | -- | -- | -- |
| P5 | 9.69 | -- | -- | 5.66 | -- | -- | -- | -- |
| P6 | 11.86 | -- | -- | -- | -- | 13.95 | -- | 2.04 |

| WHPA | Land use and land cover | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pasture agricultural | Cropland agricultural | Orchard and nursery agricultural | Idle agricultural | Forest | Brushland | Water | Wetland | Barren |
| C41 | 14.67 | 5.44 | 5.95 | -- | 5.61 | 9.32 | 1.08 | 22.29 | 1.31 |
| C42 | -- | -- | -- | -- | 52.87 | 8.38 | -- | 4.55 | 14.42 |
| C43 | 4.23 | -- | -- | -- | 58.73 | .34 | .11 | 27.42 | .09 |
| C44 | 1.38 | -- | -- | -- | 86.91 | -- | .37 | 4.90 | -- |
| C45 | .01 | 3.62 | -- | -- | 52.26 | .74 | -- | 21.86 | -- |
| C46 | 1.83 | 1.70 | -- | 0.29 | 23.06 | -- | -- | 20.59 | 1.68 |
| C47 | 1.42 | 16.36 | 6.01 | 1.55 | 33.08 | 3.13 | 1.17 | 12.09 | 13.06 |
| C48 | 1.70 | 5.86 | -- | -- | 55.53 | -- | -- | 12.10 | -- |
| C49 | .24 | 1.14 | -- | -- | 65.25 | .90 | .10 | 9.09 | 2.33 |
| C50 | 1.47 | 5.80 | -- | .49 | 72.44 | .22 | 1.59 | 8.39 | .86 |
| C51 | 2.94 | -- | -- | -- | 68.63 | .01 | -- | 7.78 | 4.34 |
| C52 | .02 | -- | -- | -- | 47.84 | -- | 35.52 | 14.28 | -- |
| C53 | -- | 1.69 | .22 | -- | 59.08 | -- | 8.96 | 12.37 | -- |
| C54 | 2.29 | 34.50 | -- | 5.16 | -- | 2.60 | .18 | 9.32 | 1.60 |
| C55 | 3.63 | 4.30 | -- | 2.17 | 54.62 | .35 | .03 | 9.17 | 2.55 |
| C56 | 4.01 | 10.81 | -- | .27 | 11.60 | -- | .44 | 6.27 | -- |
| C57 | 13.39 | 1.55 | 1.76 | -- | 47.67 | 6.01 | 2.67 | 14.61 | -- |
| C58 | 5.90 | 8.82 | 4.15 | 1.57 | 41.03 | 2.92 | .92 | 24.73 | .50 |
| C59 | 3.36 | 2.27 | -- | -- | 45.84 | 3.61 | 3.06 | 6.07 | 3.74 |
| C60 | -- | 1.90 | -- | -- | 63.06 | .93 | .02 | 25.02 | .10 |
| C61 | 1.08 | 9.92 | .25 | .32 | 41.29 | 1.77 | .28 | 4.84 | 6.93 |
| C62 | 1.54 | 6.39 | .34 | -- | 59.28 | 2.27 | 4.82 | 6.16 | -- |
| C63 | .29 | -- | -- | .02 | 51.59 | 3.11 | .16 | 1.03 | .86 |
| C64 | -- | -- | -- | -- | 74.44 | .42 | 2.62 | 6.37 | 1.37 |
| C65 | 2.41 | 7.21 | -- | -- | 46.71 | 1.20 | .42 | 22.15 | 3.05 |
| C66 | -- | -- | -- | -- | 36.14 | -- | -- | -- | -- |
| C67 | 2.08 | 3.92 | -- | -- | 10.07 | 1.87 | 1.00 | 55.90 | 1.00 |
| C68 | -- | 3.41 | -- | -- | 53.81 | 1.26 | -- | 6.62 | .32 |
| C69 | -- | 1.64 | -- | -- | 53.10 | 2.49 | .43 | 18.76 | 1.14 |
| C70 | -- | -- | -- | -- | 7.39 | -- | .16 | 36.74 | -- |
| C71 | 9.72 | -- | -- | 1.12 | 49.20 | 17.56 | -- | 1.73 | 2.67 |
| C72 | .03 | 5.18 | -- | -- | 54.86 | -- | .07 | 15.65 | 2.71 |
| C73 | 6.09 | 7.57 | -- | -- | 26.47 | 1.56 | -- | 17.98 | 1.79 |
| C74 | -- | -- | -- | -- | 35.93 | 2.36 | 28.27 | 3.88 | 13.25 |
| P1 | -- | -- | -- | -- | 83.87 | 4.06 | -- | 2.06 | -- |
| P2 | 3.93 | -- | .50 | 2.06 | 63.85 | -- | .39 | 10.64 | -- |
| P3 | .05 | -- | 4.43 | .54 | 20.69 | -- | 2.04 | 6.45 | -- |
| P4 | -- | -- | -- | 1.49 | 39.44 | 3.38 | 2.04 | 11.61 | 1.33 |
| P5 | 21.46 | 2.81 | -- | .80 | 27.26 | -- | -- | 32.31 | -- |
| P6 | -- | -- | -- | 5.83 | 32.69 | .49 | 21.76 | -- | 11.37 |

**Appendix 2**. Land use and land cover in wellhead-protection areas for community and non-community, non-transient supply

| WHPA | Land use and land cover | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Residential urban | Commercial urban | Industrial urban | Transportation urban | Mixed urban | Urban with parks and golf courses | Urban open space and cemeteries | Institutional urban |
| P7 | 8.29 | 4.33 | 0.70 | 2.28 | -- | -- | -- | 8.71 |
| P8 | 29.72 | 24.89 | -- | 3.15 | -- | 2.08 | -- | 3.36 |
| P9 | 13.11 | 6.13 | 6.83 | 1.82 | -- | -- | 2.48 | 1.47 |
| P10 | 12.82 | -- | 8.27 | 5.00 | -- | -- | -- | -- |
| P11 | 25.71 | 5.56 | 3.84 | -- | -- | -- | 2.58 | .84 |
| P12 | 16.27 | .79 | -- | 1.76 | -- | 2.12 | -- | 1.38 |
| P13 | 29.76 | .06 | 3.76 | -- | -- | 2.34 | -- | .46 |
| P14 | 9.04 | -- | 13.30 | 15.94 | -- | 9.83 | -- | 6.98 |
| P15 | 17.99 | 14.71 | -- | -- | -- | -- | 4.21 | 2.64 |
| P16 | 3.07 | -- | -- | -- | -- | -- | -- | -- |
| P17 | 18.74 | 8.75 | -- | -- | -- | -- | -- | -- |
| P18 | 43.57 | 4.53 | -- | -- | -- | 10.71 | .70 | 1.34 |
| P19 | 3.76 | -- | -- | .16 | -- | 1.34 | .03 | 1.76 |
| P20 | 3.76 | -- | -- | -- | -- | -- | -- | 4.70 |
| P21 | 56.70 | 8.73 | -- | -- | -- | .68 | -- | .06 |
| P22 | 22.15 | 6.58 | -- | -- | -- | -- | -- | -- |
| P23 | 16.96 | 13.18 | -- | -- | -- | -- | -- | -- |
| P24 | 28.08 | 13.00 | .85 | -- | -- | 1.15 | 2.46 | 8.02 |
| P25 | 4.17 | .99 | -- | -- | -- | 4.59 | -- | 11.69 |
| P26 | .45 | 6.39 | -- | 23.28 | -- | -- | .14 | -- |
| P27 | 16.73 | -- | -- | -- | -- | -- | -- | .89 |
| P28 | 22.36 | .09 | -- | -- | -- | 1.43 | -- | 4.25 |
| P29 | 10.38 | 6.01 | -- | -- | -- | -- | -- | 2.91 |
| P30 | .33 | -- | -- | -- | -- | 50.67 | -- | -- |
| P31 | 16.27 | -- | -- | -- | -- | -- | -- | 1.39 |
| P32 | 8.93 | -- | -- | 2.09 | -- | 2.42 | -- | -- |
| P33 | 3.50 | -- | 6.09 | 2.56 | -- | -- | -- | -- |
| P34 | 16.47 | .55 | .93 | .02 | -- | -- | -- | 2.09 |
| P35 | 11.56 | 20.91 | -- | -- | -- | -- | -- | 8.41 |
| P36 | 8.63 | 1.53 | -- | 16.87 | -- | -- | -- | -- |
| P37 | 5.10 | 3.03 | -- | -- | -- | .85 | 12.68 | 1.88 |
| P38 | .97 | -- | -- | -- | -- | -- | 22.35 | -- |
| P39 | .67 | -- | -- | .94 | -- | 2.01 | 1.60 | 3.81 |
| P40 | 1.45 | -- | -- | -- | -- | 3.23 | -- | 1.36 |
| P41 | 12.77 | 2.49 | -- | -- | -- | -- | 2.38 | 3.15 |
| P42 | 30.90 | 4.07 | -- | -- | -- | -- | .46 | .52 |
| P43 | 15.07 | 1.90 | 2.73 | 5.06 | -- | -- | -- | -- |
| P44 | 9.39 | -- | 2.43 | -- | -- | 13.27 | -- | -- |
| P45 | 11.38 | 5.84 | -- | .51 | -- | 3.20 | 2.49 | 2.68 |
| P46 | 6.99 | 2.95 | -- | -- | -- | 21.98 | -- | 5.42 |

| WHPA | Land use and land cover | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pasture agricultural | Cropland agricultural | Orchard and nursery agricultural | Idle agricultural | Forest | Brushland | Water | Wetland | Barren |
| P7 | 7.57 | 17.15 | 0.34 | -- | 47.19 | 1.62 | 0.16 | 1.10 | 0.58 |
| P8 | -- | -- | -- | -- | 27.22 | -- | 1.82 | 7.70 | -- |
| P9 | .29 | 12.01 | -- | -- | 41.72 | 3.80 | 3.54 | 5.42 | 1.40 |
| P10 | 6.78 | 1.55 | -- | -- | 54.83 | 1.64 | 5.52 | 1.70 | 1.90 |
| P11 | .08 | 9.20 | -- | -- | 41.78 | 2.30 | 3.53 | 4.57 | -- |
| P12 | 12.56 | .91 | 1.22 | -- | 45.97 | .64 | 2.14 | 12.24 | 1.99 |
| P13 | .70 | 2.38 | -- | -- | 43.18 | -- | 4.09 | 13.28 | -- |
| P14 | 7.99 | -- | -- | -- | 22.00 | .83 | 1.59 | 11.08 | 1.43 |
| P15 | 2.22 | 6.54 | .76 | 0.74 | 37.13 | 2.50 | 2.51 | 7.55 | -- |
| P16 | -- | -- | -- | -- | 83.55 | -- | -- | 13.38 | -- |
| P17 | 4.00 | -- | -- | -- | 48.97 | -- | 1.65 | 9.12 | 8.77 |
| P18 | -- | 5.83 | -- | -- | 16.77 | -- | 3.15 | 13.40 | -- |
| P19 | 4.35 | 2.44 | -- | .38 | 70.68 | .59 | .42 | 14.11 | -- |
| P20 | 2.13 | .33 | -- | 1.40 | 75.44 | -- | -- | 10.80 | 1.44 |
| P21 | -- | -- | -- | -- | 29.94 | -- | -- | 3.89 | -- |
| P22 | .47 | -- | 12.75 | 1.17 | 46.31 | .51 | -- | 10.05 | -- |
| P23 | -- | 4.27 | -- | 3.70 | 29.22 | .90 | 28.09 | 3.51 | .19 |
| P24 | -- | -- | -- | .94 | 31.22 | .43 | 6.82 | 7.04 | -- |
| P25 | 3.71 | -- | -- | -- | 57.97 | .14 | 3.20 | 12.73 | .82 |
| P26 | -- | -- | -- | -- | 59.33 | -- | -- | 10.40 | -- |
| P27 | .16 | -- | -- | -- | 68.45 | 2.67 | 1.10 | 9.39 | .61 |
| P28 | 3.79 | 1.59 | -- | -- | 49.17 | -- | -- | 17.32 | -- |
| P29 | -- | 4.03 | -- | -- | 58.26 | -- | .56 | 15.80 | 2.05 |
| P30 | -- | .21 | .05 | 1.90 | 34.61 | -- | 1.69 | 10.55 | -- |
| P31 | .72 | 6.80 | -- | -- | 67.80 | .37 | 1.71 | 4.94 | -- |
| P32 | 4.73 | -- | -- | -- | 48.30 | -- | 8.16 | 24.40 | .97 |
| P33 | -- | -- | -- | -- | 83.81 | .21 | -- | 3.84 | -- |
| P34 | 4.79 | 6.05 | 1.22 | -- | 49.05 | -- | 3.21 | 15.63 | -- |
| P35 | -- | 2.50 | -- | -- | 33.70 | -- | -- | 10.17 | 12.76 |
| P36 | 1.33 | -- | -- | .78 | 54.39 | .40 | 5.22 | 10.86 | -- |
| P37 | 3.39 | 8.71 | -- | -- | 58.37 | 3.67 | -- | 2.33 | -- |
| P38 | -- | -- | -- | -- | 66.12 | 2.89 | -- | 7.67 | -- |
| P39 | -- | 6.71 | -- | -- | 59.70 | 8.95 | -- | 15.60 | -- |
| P40 | -- | -- | -- | -- | 80.14 | -- | -- | 13.83 | -- |
| P41 | 10.45 | 9.97 | -- | .67 | 31.52 | 3.04 | -- | 22.99 | .58 |
| P42 | 9.13 | 5.48 | -- | -- | 40.58 | -- | -- | 7.48 | 1.40 |
| P43 | -- | -- | -- | -- | 40.08 | 1.96 | -- | 33.21 | -- |
| P44 | -- | 26.25 | -- | -- | 34.74 | -- | .49 | 12.24 | 1.18 |
| P45 | 6.71 | 23.24 | -- | -- | 6.02 | 2.26 | 1.30 | 34.37 | -- |
| P46 | 1.42 | 15.28 | -- | -- | 37.76 | -- | .32 | 7.87 | -- |

**Appendix 2**. Land use and land cover in wellhead-protection areas for community and non-community, non-transient supply

| WHPA | Land use and land cover | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Residential urban | Commercial urban | Industrial urban | Transportation urban | Mixed urban | Urban with parks and golf courses | Urban open space and cemeteries | Institutional urban |
| P47 | 6.56 | -- | 1.19 | -- | -- | -- | -- | -- |
| P48 | 4.09 | 1.72 | -- | 9.94 | -- | -- | -- | -- |
| P49 | 8.61 | 3.66 | 6.49 | 5.80 | -- | -- | -- | -- |
| P50 | 15.75 | -- | -- | -- | -- | -- | -- | -- |
| P51 | 9.01 | -- | -- | 2.49 | -- | 2.89 | -- | 4.16 |
| P52 | 15.34 | -- | .50 | -- | -- | .87 | -- | 3.63 |
| P53 | 5.16 | -- | -- | 2.33 | -- | -- | -- | -- |
| P54 | 33.87 | -- | 9.62 | -- | -- | -- | -- | .76 |
| P55 | 17.96 | .93 | -- | 1.03 | -- | -- | -- | .92 |
| P56 | 38.40 | 4.64 | -- | -- | -- | 5.93 | 2.28 | 2.95 |
| P57 | 7.39 | -- | -- | .77 | -- | 2.41 | -- | 1.96 |
| P58 | 19.72 | 1.44 | 15.02 | -- | -- | .65 | -- | .07 |
| P59 | 6.65 | -- | 7.92 | -- | -- | -- | .48 | -- |
| P60 | 46.75 | 12.48 | -- | 6.82 | -- | -- | -- | -- |
| P61 | 17.72 | -- | -- | -- | -- | 22.84 | -- | -- |
| P62 | 6.82 | .93 | -- | -- | -- | -- | -- | -- |

| WHPA | Land use and land cover | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pasture agricultural | Cropland agricultural | Orchard and nursery agricultural | Idle agricultural | Forest | Brushland | Water | Wetland | Barren |
| P47 | 5.28 | 0.47 | -- | 1.24 | 69.23 | -- | 6.73 | 9.31 | -- |
| P48 | 7.84 | 4.38 | -- | 3.05 | 52.83 | 0.94 | -- | 11.63 | 3.59 |
| P49 | 1.77 | 14.26 | 2.89 | 10.10 | 24.65 | 4.66 | -- | 17.10 | -- |
| P50 | .73 | -- | -- | -- | 73.20 | .84 | .24 | 9.24 | -- |
| P51 | -- | 37.41 | -- | -- | 30.10 | -- | .57 | 10.46 | 2.93 |
| P52 | 3.65 | .37 | -- | 2.20 | 67.25 | -- | 1.15 | 5.04 | -- |
| P53 | -- | 4.66 | 2.92 | 3.29 | 68.12 | .50 | -- | 11.17 | 1.86 |
| P54 | -- | 1.96 | -- | 2.93 | 29.99 | 4.13 | 9.29 | 7.45 | -- |
| P55 | 1.18 | 8.01 | -- | -- | 36.24 | 3.45 | 5.21 | 19.10 | 5.99 |
| P56 | 5.99 | 4.40 | -- | -- | 12.15 | 1.82 | 4.15 | 16.04 | 1.25 |
| P57 | -- | -- | -- | -- | 72.88 | -- | -- | 13.67 | .92 |
| P58 | -- | 8.57 | .40 | .43 | 27.74 | -- | 4.24 | 20.50 | 1.23 |
| P59 | 3.67 | -- | -- | -- | 38.91 | 1.50 | 3.04 | 37.24 | .60 |
| P60 | -- | 1.89 | -- | 8.42 | 4.98 | 6.98 | 4.40 | 2.02 | 5.27 |
| P61 | -- | -- | -- | -- | .36 | 40.59 | 1.93 | .43 | 16.13 |
| P62 | 7.68 | 4.00 | .48 | -- | 60.18 | -- | .85 | 19.06 | -- |

**Appendix 3**. Surficial geology and ground-water reservoirs in wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island

[**WHPA:** Wellhead-protection area. **Surficial geology and ground-water reservoirs**: Given as areal percentage of the total WHPA. --, not present]

| WHPA | Surficial geology | | | | | Ground-water reservoirs |
|---|---|---|---|---|---|---|
| | Stratified drift | Till | Mixed till and stratified drift | Exposed bedrock | Water | |
| C1 | 20.65 | 76.09 | -- | -- | 3.26 | 6.42 |
| C2 | 57.74 | 34.36 | -- | -- | 7.90 | 7.60 |
| C3 | 59.60 | 40.40 | -- | -- | -- | 28.00 |
| C4 | 73.43 | 13.38 | -- | -- | 13.19 | -- |
| C5 | 33.27 | 63.89 | -- | -- | 2.84 | .54 |
| C6 | 25.84 | 72.66 | -- | -- | 1.50 | 10.37 |
| C7 | 15.32 | 84.66 | -- | -- | .02 | 11.00 |
| C8 | 52.10 | 47.90 | -- | -- | -- | -- |
| C9 | 18.22 | 81.78 | -- | -- | -- | -- |
| C10 | 62.79 | 29.77 | -- | -- | 7.45 | 26.72 |
| C11 | 67.28 | 32.60 | -- | -- | .12 | 2.47 |
| C12 | 81.29 | 18.71 | -- | -- | -- | 8.00 |
| C13 | 71.29 | 28.67 | -- | -- | .05 | -- |
| C14 | 44.34 | 55.66 | -- | -- | -- | 4.44 |
| C15 | 65.49 | 34.51 | -- | -- | -- | -- |
| C16 | 46.93 | 44.43 | -- | -- | 8.63 | 18.56 |
| C17 | 43.30 | 49.15 | -- | -- | 7.55 | -- |
| C18 | 32.86 | 66.52 | -- | -- | .62 | -- |
| C19 | 18.10 | 60.90 | -- | -- | 21.00 | -- |
| C20 | 40.70 | 56.74 | -- | -- | 2.56 | 5.46 |
| C21 | 39.36 | 59.53 | -- | -- | 1.11 | 33.13 |
| C22 | 16.05 | 67.51 | -- | -- | 16.44 | -- |
| C23 | -- | 100.00 | -- | -- | -- | -- |
| C24 | -- | 100.00 | -- | -- | -- | -- |
| C25 | 52.38 | 35.85 | -- | -- | 11.77 | -- |
| C26 | 21.53 | 78.47 | -- | -- | -- | -- |
| C27 | 29.69 | 70.31 | -- | -- | -- | -- |
| C28 | 85.62 | 14.38 | -- | -- | -- | -- |
| C29 | -- | 98.62 | -- | -- | 1.38 | -- |
| C30 | 89.02 | 7.15 | -- | -- | 3.83 | 35.51 |
| C31 | 35.89 | 59.62 | -- | -- | 4.49 | -- |
| C32 | 100.00 | -- | -- | -- | -- | -- |
| C33 | 100.00 | -- | -- | -- | -- | -- |
| C34 | 97.37 | -- | -- | -- | 2.63 | 11.32 |
| C35 | 5.81 | 94.04 | -- | -- | .15 | -- |
| C36 | 68.34 | 31.66 | -- | -- | -- | 20.42 |
| C37 | 2.14 | 97.77 | -- | -- | .09 | -- |
| C38 | 94.64 | 4.32 | -- | -- | 1.04 | 64.75 |
| C39 | -- | 100.00 | -- | -- | -- | -- |
| C40 | -- | 99.88 | -- | -- | .12 | -- |

**Appendix 3**. Surficial geology and ground-water reservoirs in wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| WHPA | Surficial geology | | | | | Ground-water reservoirs |
|---|---|---|---|---|---|---|
| | Stratified drift | Till | Mixed till and stratified drift | Exposed bedrock | Water | |
| C41 | 2.12 | 96.39 | -- | -- | 1.48 | -- |
| C42 | 16.21 | 83.79 | -- | -- | -- | -- |
| C43 | -- | 99.83 | -- | -- | .17 | -- |
| C44 | 30.65 | 68.99 | -- | -- | .36 | -- |
| C45 | -- | 100.00 | -- | -- | -- | -- |
| C46 | 97.81 | -- | 2.15 | -- | .04 | 58.79 |
| C47 | 69.24 | 10.73 | 18.35 | -- | 1.68 | 8.72 |
| C48 | 45.08 | 54.92 | -- | -- | -- | 13.29 |
| C49 | 3.57 | 96.43 | -- | -- | -- | -- |
| C50 | 45.48 | 53.13 | -- | -- | 1.39 | 12.04 |
| C51 | 17.90 | 82.04 | -- | -- | .06 | -- |
| C52 | 32.05 | 31.06 | -- | -- | 36.89 | 54.63 |
| C53 | 47.24 | 43.58 | -- | -- | 9.17 | -- |
| C54 | -- | 99.62 | -- | -- | .38 | -- |
| C55 | 28.96 | 70.87 | -- | -- | .17 | -- |
| C56 | 62.49 | 37.37 | -- | -- | .14 | 43.38 |
| C57 | 44.13 | 52.96 | -- | -- | 2.91 | 2.17 |
| C58 | 62.39 | 23.97 | 13.51 | -- | .13 | 24.16 |
| C59 | 65.21 | 32.06 | -- | -- | 2.73 | 29.35 |
| C60 | 78.88 | 21.12 | -- | -- | -- | -- |
| C61 | 60.09 | 38.85 | -- | -- | 1.06 | 16.23 |
| C62 | 24.79 | 10.10 | 60.69 | -- | 4.41 | -- |
| C63 | 20.90 | 22.89 | 56.21 | -- | .00 | -- |
| C64 | 13.43 | -- | 84.01 | -- | 2.56 | -- |
| C65 | 53.45 | 46.51 | -- | -- | .03 | 25.69 |
| C66 | 40.63 | 57.16 | -- | -- | 2.21 | 9.86 |
| C67 | 65.49 | 26.82 | 6.76 | -- | .92 | -- |
| C68 | 30.17 | -- | 69.78 | -- | .05 | -- |
| C69 | 21.16 | 24.64 | 53.71 | -- | .49 | -- |
| C70 | 90.09 | -- | -- | -- | 9.91 | -- |
| C71 | -- | -- | 99.72 | -- | .28 | -- |
| C72 | 63.83 | 36.12 | -- | -- | .05 | 14.79 |
| C73 | -- | 99.98 | -- | -- | .02 | -- |
| C74 | 71.71 | 1.54 | -- | -- | 26.75 | 20.50 |
| P1 | -- | 100.00 | -- | -- | -- | -- |
| P2 | 39.71 | 59.84 | -- | -- | .46 | -- |
| P3 | 35.22 | 64.39 | -- | -- | .38 | -- |
| P4 | 38.28 | 58.99 | -- | -- | 2.72 | 5.86 |
| P5 | 7.79 | 91.94 | -- | -- | .26 | -- |
| P6 | 77.16 | 2.02 | -- | -- | 20.82 | 50.44 |

**Appendix 3**. Surficial geology and ground-water reservoirs in wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| WHPA | Surficial geology | | | | | Ground-water reservoirs |
|---|---|---|---|---|---|---|
| | Stratified drift | Till | Mixed till and stratified drift | Exposed bedrock | Water | |
| P7 | 65.32 | 34.42 | -- | -- | 0.27 | 0.25 |
| P8 | 29.47 | 69.44 | -- | -- | 1.09 | -- |
| P9 | 63.62 | 33.54 | -- | -- | 2.84 | -- |
| P10 | 34.46 | 61.80 | -- | -- | 3.74 | 4.12 |
| P11 | 33.69 | 63.82 | -- | -- | 2.49 | 16.71 |
| P12 | 59.59 | 38.83 | -- | -- | 1.59 | -- |
| P13 | 90.98 | 2.44 | -- | -- | 6.58 | 49.63 |
| P14 | 13.94 | 86.06 | -- | -- | -- | -- |
| P15 | 91.89 | 3.64 | -- | -- | 4.47 | 58.36 |
| P16 | 8.82 | 91.18 | -- | -- | -- | -- |
| P17 | 51.41 | 46.24 | -- | -- | 2.36 | 15.46 |
| P18 | 7.58 | 89.75 | -- | -- | 2.67 | -- |
| P19 | 4.00 | 95.56 | -- | 0.11 | .34 | -- |
| P20 | -- | 100.00 | -- | -- | -- | -- |
| P21 | 19.98 | 79.90 | -- | -- | .12 | -- |
| P22 | -- | 99.45 | -- | -- | .55 | -- |
| P23 | 39.19 | 33.23 | -- | -- | 27.59 | -- |
| P24 | 63.82 | 32.08 | -- | -- | 4.10 | -- |
| P25 | 82.44 | 14.43 | -- | -- | 3.13 | -- |
| P26 | 7.06 | 92.94 | -- | -- | -- | -- |
| P27 | 57.32 | 41.61 | -- | -- | 1.07 | -- |
| P28 | 29.26 | 70.74 | -- | -- | -- | -- |
| P29 | 73.30 | 26.70 | -- | -- | -- | -- |
| P30 | -- | 98.78 | -- | -- | 1.22 | -- |
| P31 | 18.47 | 78.89 | -- | -- | 2.64 | -- |
| P32 | 70.54 | 23.93 | -- | -- | 5.53 | -- |
| P33 | -- | 100.00 | -- | -- | -- | -- |
| P34 | .36 | 96.98 | -- | -- | 2.66 | -- |
| P35 | 62.94 | 36.54 | -- | -- | .52 | -- |
| P36 | 77.89 | 18.05 | -- | -- | 4.06 | -- |
| P37 | -- | 100.00 | -- | -- | -- | -- |
| P38 | -- | 100.00 | -- | -- | -- | -- |
| P39 | -- | 100.00 | -- | -- | -- | -- |
| P40 | 20.73 | 79.27 | -- | -- | -- | -- |
| P41 | 13.28 | 57.02 | 5.85 | -- | 23.84 | -- |
| P42 | -- | 99.80 | -- | -- | .20 | -- |
| P43 | 72.69 | 27.18 | -- | -- | .13 | -- |
| P44 | 52.57 | 46.63 | -- | -- | .80 | 24.59 |
| P45 | -- | 96.59 | -- | -- | 3.41 | -- |
| P46 | 84.21 | 15.62 | -- | -- | .17 | -- |

**Appendix 3**. Surficial geology and ground-water reservoirs in wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| WHPA | Surficial geology | | | | | Ground-water reservoirs |
|---|---|---|---|---|---|---|
| | Stratified drift | Till | Mixed till and stratified drift | Exposed bedrock | Water | |
| P47 | 17.97 | 75.28 | -- | -- | 6.75 | -- |
| P48 | 3.01 | 96.92 | -- | -- | .07 | -- |
| P49 | 97.58 | 2.42 | -- | -- | -- | 59.20 |
| P50 | 99.56 | -- | -- | -- | .44 | 89.10 |
| P51 | 97.86 | 2.09 | -- | -- | .05 | 72.21 |
| P52 | 69.80 | 28.90 | -- | -- | 1.29 | -- |
| P53 | 20.11 | 79.89 | -- | -- | -- | -- |
| P54 | 91.36 | -- | -- | -- | 8.64 | 3.66 |
| P55 | 81.71 | 13.33 | -- | -- | 4.97 | 52.22 |
| P56 | 96.30 | 0.48 | -- | -- | 3.22 | 34.70 |
| P57 | 65.26 | 34.74 | -- | -- | -- | -- |
| P58 | 96.57 | -- | -- | -- | 3.43 | 76.81 |
| P59 | 79.52 | 17.93 | -- | -- | 2.54 | 28.49 |
| P60 | 94.44 | 1.64 | -- | -- | 3.92 | -- |
| P61 | 98.91 | -- | -- | -- | 1.09 | -- |
| P62 | 16.39 | 82.44 | -- | -- | 1.17 | -- |

**Appendix 4**. Soil characteristics in wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island

[**WHPA:** Wellhead-protection area. **Soil hydrologic group:** Given as areal percentage of the total WHPA. **Soil leaching potential risk:** Soil leachability classification system from Pepper (1998). --, not present]

| WHPA | Soil hydrologic group | | | | | Soil leaching potential risk, area-weighted rank |
|---|---|---|---|---|---|---|
| | A | B | C | D | Urban soils, water, or soils of unknown group | |
| C1 | 15.42 | 70.35 | 10.92 | -- | 3.31 | 3.7 |
| C2 | 33.23 | 34.14 | 18.46 | 1.25 | 12.93 | 4.3 |
| C3 | 60.41 | 12.18 | 10.20 | -- | 17.20 | 4.2 |
| C4 | 35.36 | 33.96 | 13.07 | .29 | 17.31 | 4.4 |
| C5 | 18.90 | 44.71 | 31.42 | -- | 4.97 | 3.8 |
| C6 | 4.42 | 37.91 | 52.01 | 2.72 | 2.94 | 3.5 |
| C7 | -- | 63.30 | 36.69 | -- | .02 | 3.2 |
| C8 | 17.93 | 63.26 | -- | -- | 18.82 | 3.9 |
| C9 | 11.45 | 23.16 | 55.11 | -- | 10.28 | 3.3 |
| C10 | 41.18 | 34.68 | 14.59 | -- | 9.55 | 4.7 |
| C11 | 17.24 | 68.70 | 3.63 | .38 | 10.05 | 4.0 |
| C12 | 89.86 | -- | 10.14 | -- | -- | 6.0 |
| C13 | 36.42 | 34.17 | 23.57 | -- | 5.83 | 4.8 |
| C14 | 49.21 | 50.56 | -- | -- | .23 | 4.9 |
| C15 | 41.05 | 50.55 | 8.40 | -- | -- | 4.9 |

**Appendix 4.** Soil characteristics in wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| WHPA | Soil hydrologic group | | | | | Soil leaching potential risk, area-weighted rank |
|---|---|---|---|---|---|---|
| | A | B | C | D | Urban soils, water, or soils of unknown group | |
| C16 | 43.06 | 29.10 | 7.13 | 3.14 | 17.57 | 4.6 |
| C17 | 16.17 | 60.87 | 14.89 | .26 | 7.81 | 4.0 |
| C18 | 14.34 | 36.77 | 48.12 | -- | .77 | 3.5 |
| C19 | 15.79 | 37.17 | 24.65 | .29 | 22.10 | 3.6 |
| C20 | 36.81 | 51.19 | 8.22 | .30 | 3.48 | 4.0 |
| C21 | 21.64 | 16.46 | 56.75 | 2.30 | 2.85 | 4.0 |
| C22 | .47 | 67.01 | 14.67 | .33 | 17.52 | 3.4 |
| C23 | -- | -- | 100.00 | -- | -- | 2.1 |
| C24 | -- | .40 | 98.60 | 1.00 | -- | 2.4 |
| C25 | 31.79 | 48.84 | 3.37 | 2.90 | 13.11 | 4.4 |
| C26 | 6.12 | 38.60 | 55.08 | .18 | .02 | 3.3 |
| C27 | 12.40 | 10.03 | 65.87 | 6.28 | 5.43 | 3.4 |
| C28 | 18.97 | 44.03 | 13.31 | 22.01 | 1.67 | 4.1 |
| C29 | -- | 18.72 | 77.91 | -- | 3.37 | 2.7 |
| C30 | 36.58 | 40.14 | 9.37 | 2.67 | 11.24 | 4.4 |
| C31 | 14.04 | 65.50 | 9.97 | 6.00 | 4.49 | 4.3 |
| C32 | 70.79 | 29.21 | -- | -- | -- | 3.7 |
| C33 | 80.96 | -- | .36 | .75 | 17.94 | 6.0 |
| C34 | 69.78 | 14.72 | 6.32 | 3.49 | 5.69 | 4.3 |
| C35 | -- | 22.11 | 75.07 | 2.31 | .50 | 2.5 |
| C36 | 20.18 | 67.51 | 1.30 | 10.21 | .81 | 4.7 |
| C37 | .42 | 87.88 | 10.01 | .50 | 1.19 | 3.0 |
| C38 | 54.77 | 7.31 | 3.32 | 10.26 | 24.35 | 4.5 |
| C39 | 8.35 | 7.29 | 71.99 | 9.30 | 3.08 | 2.9 |
| C40 | -- | 4.34 | 89.02 | 4.82 | 1.82 | 2.8 |
| C41 | 19.45 | 1.02 | 45.75 | 8.96 | 24.83 | 3.7 |
| C42 | 5.30 | 43.52 | 37.01 | -- | 14.17 | 3.4 |
| C43 | -- | 48.63 | 22.10 | 20.75 | 8.51 | 2.8 |
| C44 | 19.14 | 73.46 | .95 | 4.67 | 1.77 | 3.8 |
| C45 | -- | 3.15 | 85.90 | 2.18 | 8.77 | 3.4 |
| C46 | 55.23 | 10.30 | 6.13 | 21.64 | 6.69 | 3.8 |
| C47 | 25.24 | 49.04 | 6.13 | 10.92 | 8.67 | 3.5 |
| C48 | 15.28 | 45.64 | 36.23 | 2.84 | .01 | 4.1 |
| C49 | 1.26 | 34.75 | 63.11 | -- | .87 | 3.2 |
| C50 | 27.85 | 51.64 | 13.96 | 2.42 | 4.12 | 4.2 |
| C51 | -- | 92.97 | -- | 3.69 | 3.35 | 3.1 |
| C52 | 36.61 | 16.56 | -- | 10.65 | 36.19 | 4.5 |
| C53 | 8.72 | 68.97 | .81 | 12.30 | 9.19 | 3.8 |
| C54 | -- | -- | 97.42 | -- | 2.58 | 2.5 |
| C55 | 3.54 | 75.43 | 11.27 | .61 | 9.15 | 3.3 |

**Appendix 4**. Soil characteristics in wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| WHPA | Soil hydrologic group | | | | | Soil leaching potential risk, area-weighted rank |
|---|---|---|---|---|---|---|
| | A | B | C | D | Urban soils, water, or soils of unknown group | |
| C56 | 9.17 | 67.37 | 6.80 | 6.33 | 10.33 | 3.4 |
| C57 | 23.91 | 58.03 | .62 | 10.00 | 7.43 | 3.8 |
| C58 | 29.09 | 40.36 | 3.83 | 26.19 | .54 | 3.6 |
| C59 | 48.09 | 29.99 | 2.27 | 10.65 | 8.71 | 5.2 |
| C60 | 25.03 | 48.78 | 6.43 | 19.77 | -- | 3.3 |
| C61 | 22.45 | 52.82 | 11.10 | 1.22 | 12.40 | 4.2 |
| C62 | 67.68 | 19.53 | -- | 4.87 | 7.91 | 4.4 |
| C63 | 72.96 | 21.36 | .32 | -- | 5.36 | 4.6 |
| C64 | 86.38 | 1.67 | .03 | 6.82 | 5.10 | 5.0 |
| C65 | 17.55 | 37.78 | 26.25 | 15.16 | 3.26 | 3.6 |
| C66 | 25.92 | 36.25 | 11.79 | 1.76 | 24.28 | 3.7 |
| C67 | 8.41 | 21.39 | 4.79 | 55.02 | 10.39 | 3.0 |
| C68 | 64.44 | 27.40 | .29 | 6.44 | 1.43 | 4.5 |
| C69 | 48.46 | 28.92 | 11.56 | 9.70 | 1.35 | 4.8 |
| C70 | -- | 49.74 | 10.60 | 25.87 | 13.79 | 4.3 |
| C71 | 77.56 | 8.89 | 11.26 | -- | 2.29 | 4.8 |
| C72 | 20.88 | 47.39 | 22.07 | 5.40 | 4.26 | 4.0 |
| C73 | -- | 1.13 | 88.25 | 10.60 | .02 | 2.5 |
| C74 | 43.09 | 7.31 | 6.22 | -- | 43.38 | 5.5 |
| P1 | -- | 50.33 | 49.67 | -- | -- | 2.7 |
| P2 | 2.96 | 86.79 | 9.15 | 1.10 | -- | 3.5 |
| P3 | 26.48 | 41.74 | 26.94 | -- | 4.84 | 3.9 |
| P4 | 10.67 | 69.93 | 7.77 | .79 | 10.84 | 3.7 |
| P5 | -- | 41.08 | 50.51 | 7.63 | .79 | 4.0 |
| P6 | 63.00 | -- | -- | -- | 37.00 | 5.9 |
| P7 | 45.02 | 13.72 | 38.46 | -- | 2.80 | 3.6 |
| P8 | 21.22 | 50.15 | 10.12 | 1.70 | 16.81 | 3.6 |
| P9 | 48.91 | 20.68 | 26.62 | -- | 3.79 | 3.6 |
| P10 | 23.17 | 10.19 | 60.60 | -- | 6.03 | 3.6 |
| P11 | 3.40 | 20.61 | 71.31 | -- | 4.68 | 3.5 |
| P12 | 23.06 | 53.72 | 9.00 | 5.56 | 8.66 | 3.8 |
| P13 | 56.46 | 11.43 | 22.13 | -- | 9.98 | 5.1 |
| P14 | -- | 57.52 | 4.35 | 8.28 | 29.85 | 4.0 |
| P15 | 14.58 | 21.82 | 56.85 | -- | 6.76 | 4.2 |
| P16 | .41 | 93.64 | 5.64 | .32 | -- | 3.4 |
| P17 | 24.99 | 30.67 | 36.88 | -- | 7.46 | 3.9 |
| P18 | 6.43 | 75.42 | 15.49 | -- | 2.67 | 3.6 |
| P19 | 2.29 | 19.95 | 72.43 | .48 | 4.85 | 3.4 |
| P20 | -- | 78.24 | 21.76 | -- | -- | 3.6 |
| P21 | 25.63 | 67.93 | 4.10 | -- | 2.34 | 3.5 |

**Appendix 4**. Soil characteristics in wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| WHPA | Soil hydrologic group | | | | | Soil leaching potential risk, area-weighted rank |
|---|---|---|---|---|---|---|
| | A | B | C | D | Urban soils, water, or soils of unknown group | |
| P22 | -- | 3.52 | 84.55 | 3.93 | 8.00 | 2.6 |
| P23 | 14.16 | 49.23 | 5.69 | .99 | 29.92 | 3.8 |
| P24 | 41.56 | 46.85 | 2.76 | 3.97 | 4.86 | 4.6 |
| P25 | 40.23 | 35.58 | 1.33 | 12.60 | 10.26 | 4.8 |
| P26 | -- | 61.66 | 15.94 | .29 | 22.10 | 3.8 |
| P27 | 14.37 | .72 | 80.47 | -- | 4.44 | 3.0 |
| P28 | .36 | 4.09 | 90.73 | -- | 4.83 | 2.5 |
| P29 | 49.56 | 16.69 | 26.50 | 2.83 | 4.41 | 5.6 |
| P30 | -- | 18.79 | 78.27 | -- | 2.94 | 3.1 |
| P31 | 4.41 | 46.64 | 45.37 | .94 | 2.64 | 3.3 |
| P32 | 27.01 | 40.32 | 16.23 | 1.74 | 14.70 | 4.3 |
| P33 | -- | 89.27 | 4.62 | -- | 6.11 | 3.4 |
| P34 | -- | 39.16 | 47.86 | 7.34 | 5.64 | 3.6 |
| P35 | 12.18 | 39.98 | 19.10 | .00 | 28.74 | 4.1 |
| P36 | 21.91 | 49.77 | 1.49 | 7.91 | 18.92 | 4.3 |
| P37 | 1.26 | 11.84 | 86.90 | -- | -- | 3.7 |
| P38 | -- | 5.40 | 94.60 | -- | -- | 2.6 |
| P39 | -- | -- | 98.93 | -- | 1.07 | 2.8 |
| P40 | 16.80 | 59.10 | .01 | 24.09 | -- | 3.6 |
| P41 | -- | -- | 64.05 | 12.11 | 23.84 | 2.1 |
| P42 | -- | -- | 97.26 | 2.54 | .20 | 1.5 |
| P43 | 2.18 | 46.41 | 27.12 | 22.74 | 1.55 | 4.0 |
| P44 | 1.42 | 81.68 | 14.50 | -- | 2.41 | 3.0 |
| P45 | -- | -- | 52.91 | 43.59 | 3.50 | 2.4 |
| P46 | 30.21 | 55.74 | 10.86 | 3.02 | .17 | 3.8 |
| P47 | -- | 74.00 | 19.22 | -- | 6.78 | 3.4 |
| P48 | -- | 83.38 | 9.23 | .71 | 6.68 | 3.3 |
| P49 | 7.51 | 73.60 | 8.69 | 10.20 | -- | 3.8 |
| P50 | 51.81 | 36.32 | .83 | 10.60 | .44 | 4.3 |
| P51 | 23.86 | 72.31 | .47 | .67 | 2.68 | 3.9 |
| P52 | 29.05 | 62.71 | 1.35 | .64 | 6.25 | 3.9 |
| P53 | 6.86 | 63.99 | 26.30 | 2.86 | -- | 4.4 |
| P54 | 57.10 | 20.36 | 1.24 | 6.08 | 15.22 | 4.8 |
| P55 | 42.67 | 23.48 | 2.68 | 19.90 | 11.27 | 5.1 |
| P56 | 50.39 | 14.97 | 11.38 | 16.11 | 7.16 | 5.0 |
| P57 | 37.27 | 46.92 | .59 | 14.67 | .56 | 3.1 |
| P58 | 13.80 | 35.46 | 23.20 | 4.80 | 22.75 | 4.5 |
| P59 | 35.19 | 19.47 | 2.42 | 40.37 | 2.55 | 4.7 |
| P60 | 71.40 | 4.00 | -- | 3.54 | 21.06 | 4.2 |
| P61 | 5.49 | 39.46 | -- | -- | 55.05 | 3.0 |
| P62 | -- | 43.86 | 54.97 | -- | 1.17 | 2.8 |

**Appendix 5**. Density of roads in wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island

[**WHPA:** Wellhead-protection area. Density of roads given in milles per square mile]

| WHPA | Density of all paved roads | Density of interstate and state highways | WHPA | Density of all paved roads | Density of interstate and state highways |
|---|---|---|---|---|---|
| C1 | 7.702 | 1.612 | C46 | 10.461 | 3.351 |
| C2 | 7.494 | 2.709 | C47 | 4.246 | .778 |
| C3 | 12.913 | 4.486 | C48 | 6.843 | 1.634 |
| C4 | 7.227 | 3.335 | C49 | 3.604 | -- |
| C5 | 6.959 | 2.465 | C50 | 4.715 | 2.079 |
| C6 | 6.229 | 2.309 | C51 | 5.482 | 1.542 |
| C7 | 7.656 | -- | C52 | 4.317 | 2.301 |
| C8 | 3.920 | -- | C53 | 3.281 | 1.603 |
| C9 | 9.328 | 3.758 | C54 | 8.877 | -- |
| C10 | 7.525 | 3.778 | C55 | 5.638 | 2.914 |
| C11 | 15.983 | 4.235 | C56 | 13.180 | 2.159 |
| C12 | 4.861 | -- | C57 | 3.272 | 1.103 |
| C13 | 3.910 | 2.286 | C58 | 2.924 | .415 |
| C14 | 11.597 | -- | C59 | 5.707 | 1.906 |
| C15 | 15.518 | -- | C60 | 2.819 | .338 |
| C16 | 13.381 | .800 | C61 | 7.658 | .710 |
| C17 | 5.028 | .746 | C62 | 6.872 | 1.951 |
| C18 | 2.543 | -- | C63 | 8.735 | 2.137 |
| C19 | 3.950 | -- | C64 | 4.023 | 1.587 |
| C20 | 10.253 | 2.842 | C65 | 3.897 | 2.051 |
| C21 | 6.004 | 1.281 | C66 | 11.425 | -- |
| C22 | 4.291 | 1.520 | C67 | 4.853 | 1.796 |
| C23 | 4.638 | 1.045 | C68 | 7.550 | 2.181 |
| C24 | 3.172 | 2.350 | C69 | 7.827 | 2.586 |
| C25 | 7.535 | 4.084 | C70 | 12.852 | -- |
| C26 | 4.176 | .611 | C71 | 4.455 | 1.184 |
| C27 | 3.413 | 2.186 | C72 | 5.632 | .689 |
| C28 | 2.639 | 1.251 | C73 | 9.868 | 9.868 |
| C29 | 3.191 | -- | C74 | 3.827 | 1.138 |
| C30 | 12.240 | 2.114 | P1 | 24.482 | 1.903 |
| C31 | 5.163 | 1.191 | P2 | 3.130 | .694 |
| C32 | 14.201 | 4.295 | P3 | 12.093 | 4.542 |
| C33 | 18.998 | -- | P4 | 6.600 | 3.626 |
| C34 | 7.751 | -- | P5 | 6.095 | 3.647 |
| C35 | 2.589 | -- | P6 | 3.673 | -- |
| C36 | 6.218 | 1.649 | P7 | 5.893 | 2.441 |
| C37 | 4.081 | -- | P8 | 9.829 | 4.368 |
| C38 | 11.805 | 3.352 | P9 | 9.775 | 5.517 |
| C39 | 6.044 | -- | P10 | 6.259 | 3.554 |
| C40 | 3.348 | -- | P11 | 10.151 | 3.398 |
| C41 | 4.577 | -- | P12 | 4.356 | 1.799 |
| C42 | 4.871 | 1.646 | P13 | 6.526 | 1.323 |
| C43 | 2.978 | 1.253 | P14 | 11.735 | 7.220 |
| C44 | 8.295 | -- | P15 | 5.649 | 3.452 |
| C45 | 6.357 | 3.563 | | | |

**Appendix 5**. Density of roads in wellhead-protection areas for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| WHPA | Density of all paved roads | Density of interstate and state highways |
|---|---|---|
| P16 | 1.688 | 1.688 |
| P17 | 5.297 | 1.778 |
| P18 | 7.114 | 2.828 |
| P19 | 3.616 | .519 |
| P20 | 3.209 | 1.616 |
| P21 | 13.263 | 2.875 |
| P22 | 8.479 | 3.717 |
| P23 | 4.806 | 2.977 |
| P24 | 9.786 | 5.360 |
| P25 | 5.088 | 3.046 |
| P26 | 4.852 | 3.012 |
| P27 | 5.925 | 1.408 |
| P28 | 4.412 | 1.988 |
| P29 | 4.510 | 3.795 |
| P30 | .833 | -- |
| P31 | 5.358 | -- |
| P32 | 4.324 | -- |
| P33 | 2.051 | -- |
| P34 | 5.555 | 3.340 |
| P35 | 9.428 | 4.797 |
| P36 | 8.819 | 6.659 |
| P37 | 5.293 | 1.951 |
| P38 | 4.723 | 1.713 |
| P39 | 4.300 | 2.463 |
| P40 | 3.586 | 2.000 |
| P41 | 5.083 | 1.630 |
| P42 | 7.460 | 2.408 |
| P43 | 3.754 | 1.877 |
| P44 | 3.946 | 1.364 |
| P45 | 4.586 | 3.506 |
| P46 | 5.243 | 3.052 |
| P47 | 3.279 | -- |
| P48 | 4.945 | 3.380 |
| P49 | 4.432 | .990 |
| P50 | 4.689 | 1.138 |
| P51 | 3.514 | 1.729 |
| P52 | 7.239 | 3.792 |
| P53 | 2.932 | -- |
| P54 | 6.017 | 2.177 |
| P55 | 5.687 | 1.934 |
| P56 | 8.070 | 3.231 |
| P57 | 2.749 | 1.957 |
| P58 | 8.313 | 2.342 |
| P59 | 4.852 | -- |
| P60 | 12.691 | 5.512 |
| P61 | 11.545 | -- |
| P62 | 1.750 | 1.221 |

**Appendix 6**. Bedrock geology at well locations and distance of wells to the closest surface-water body for community and non-community, non-transient supply wells in Rhode Island

[**Supply type:** C, community; P, non-community, non-transient. **Source identifier:** Combines the public-water system identifier (PWSID) and the source number assigned by the Rhode Island Department of Health. **USGS-ID:** Identifier used in figures 2 and 3. **Lithologic rock type:** F, felsic igneous and metamorphic rocks; M, mafic and intermediate igneous rocks, including mixed mafic and felsic lithologies; MS, metamorphosed clastic sedimentary rocks; S, un- or weakly metamorphosed clastics sedimentary rocks; C, carbonate-rich rocks; --, not available or not applicable. Bedrock geologic group and unit names from Hermes and others (1996)]

| Supply type | Source identifier | USGS-ID | Bedrock geology at well: Litho-logic rock type | Bedrock geology at well: Bedrock suite or group | Bedrock geology at well: Bedrock map unit | Distance to the closest surface-water body, in feet |
|---|---|---|---|---|---|---|
| C | 1000009-1 | 63 | F | Esmond Igneous Suite | augen granite gneiss | 1,180 |
| C | 1000009-4 | 178 | F | Esmond Igneous Suite | augen granite gneiss | 1,070 |
| C | 1000020-1 | 68 | F | Scituate Igneous Suite | granite | 1,630 |
| C | 1000020-2 | 67 | F | Scituate Igneous Suite | granite | 1,480 |
| C | 1000020-3 | 69 | F | Scituate Igneous Suite | granite | 1,700 |
| C | 1000035-3 | 150 | F | Narragansett Pier Plutonic Suite | granite | 3,210 |
| C | 1000035-4 | 152 | F | Narragansett Pier Plutonic Suite | granite | 3,040 |
| C | 1000035-5 | 151 | F | Narragansett Pier Plutonic Suite | granite | 3,110 |
| C | 1000040-1 | 113 | F | Scituate Igneous Suite | granite | 330 |
| C | 1000040-2 | 180 | F | Scituate Igneous Suite | granite | 550 |
| C | 1000043-2 | 124 | F | Sterling Plutonic Group | alaskite gneiss | 690 |
| C | 1000043-3 | 125 | F | Sterling Plutonic Group | alaskite gneiss | 590 |
| C | 1000045-1 | 141 | F | Sterling Plutonic Group | granite gneiss | 110 |
| C | 1000045-2 | 142 | F | Sterling Plutonic Group | granite gneiss | 190 |
| C | 1000098-1 | 133 | M | Sterling Plutonic Group | mafic/intermediate gneiss | 140 |
| C | 1000098-2 | 132 | M | Sterling Plutonic Group | mafic/intermediate gneiss | 160 |
| C | 1559511-1 | 90 | S | Narragansett Bay Group | Rhode Island formation | 300 |
| C | 1559511-2 | 82 | F | Scituate Igneous Suite | granite | 110 |
| C | 1559511-3 | 85 | F | Scituate Igneous Suite | granite | 320 |
| C | 1559511-4 | 84 | F | Scituate Igneous Suite | granite | 200 |
| C | 1559512-1 | 153 | M | Waterford Group | Mamacoke Formation | 50 |
| C | 1559512-10 | 159 | M | Waterford Group | Mamacoke Formation | 250 |
| C | 1559512-11 | 161 | F | Narragansett Pier Plutonic Suite | granite | 2,570 |
| C | 1559512-2 | 155 | M | Waterford Group | Mamacoke Formation | 40 |
| C | 1559512-3 | 154 | M | Waterford Group | Mamacoke Formation | 60 |
| C | 1559512-4 | 147 | F | Sterling Plutonic Group | granite gneiss | 180 |
| C | 1559512-5 | 145 | F | Sterling Plutonic Group | granite gneiss | 190 |
| C | 1559512-6 | 146 | F | Sterling Plutonic Group | granite gneiss | 130 |
| C | 1559512-7 | 149 | M | Waterford Group | Mamacoke Formation | 130 |
| C | 1559512-8 | 148 | F | Sterling Plutonic Group | granite gneiss | 990 |
| C | 1559512-9 | 158 | F | Sterling Plutonic Group | alaskite gneiss | 500 |
| C | 1559513-1 | 166 | F | Narragansett Pier Plutonic Suite | porphyritic granite | 1,310 |
| C | 1559513-2 | 164 | F | Narragansett Pier Plutonic Suite | porphyritic granite | 1,230 |
| C | 1559513-4 | 165 | F | Narragansett Pier Plutonic Suite | porphyritic granite | 1,270 |
| C | 1559513-5 | 163 | F | Narragansett Pier Plutonic Suite | porphyritic granite | 180 |

**Appendix 6.** Bedrock geology at well locations and distance of wells to the closest surface-water body for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Supply type | Source identifier | USGS-ID | Bedrock geology at well: Litho-logic rock type | Bedrock geology at well: Bedrock suite or group | Bedrock geology at well: Bedrock map unit | Distance to the closest surface-water body, in feet |
|---|---|---|---|---|---|---|
| C | 1559517-1 | 106 | S | Narragansett Bay Group | Rhode Island Formation | 210 |
| C | 1559517-10 | 118 | S | Narragansett Bay Group | Rhode Island Formation | 170 |
| C | 1559517-2 | 107 | S | Narragansett Bay Group | Rhode Island Formation | 160 |
| C | 1559517-3 | 116 | S | Narragansett Bay Group | Rhode Island Formation | 160 |
| C | 1559517-4 | 108 | S | Narragansett Bay Group | Rhode Island Formation | 130 |
| C | 1559517-5 | 110 | S | Narragansett Bay Group | Rhode Island Formation | 260 |
| C | 1559517-6 | 104 | S | Narragansett Bay Group | Rhode Island Formation | 620 |
| C | 1559517-7 | 91 | S | Narragansett Bay Group | Rhode Island Formation | 330 |
| C | 1559517-8 | 92 | S | Narragansett Bay Group | Rhode Island Formation | 40 |
| C | 1559517-9 | 117 | S | Narragansett Bay Group | Rhode Island Formation | 190 |
| C | 1559519-1 | 28 | M | Blackstone Group | undifferentiated rock | 30 |
| C | 1559519-2 | 27 | M | Blackstone Group | undifferentiated rock | 40 |
| C | 1583825-1 | 29 | F | Scituate Igneous Suite | granite | 660 |
| C | 1592012-2 | 105 | F | Esmond Igneous Suite | augen granite gneiss | 510 |
| C | 1592019-1 | 38 | M | Blackstone Group | undifferentiated rock | 520 |
| C | 1592019-2 | 176 | M | Blackstone Group | undifferentiated rock | 550 |
| C | 1592020-1 | 32 | F | Esmond Igneous Suite | augen granite gneiss | 700 |
| C | 1592020-2 | 34 | F | Esmond Igneous Suite | augen granite gneiss | 720 |
| C | 1592021-2 | 56 | S | Narragansett Bay Group | Rhode Island Formation | 230 |
| C | 1592021-3 | 55 | S | Narragansett Bay Group | Rhode Island Formation | 130 |
| C | 1592021-4 | 54 | S | Narragansett Bay Group | Rhode Island Formation | 400 |
| C | 1592021-5 | 53 | S | Narragansett Bay Group | Rhode Island Formation | 50 |
| C | 1592021-6 | 50 | S | Narragansett Bay Group | -- | 30 |
| C | 1592021-7 | 47 | S | Narragansett Bay Group | Rhode Island Formation | 160 |
| C | 1592021-8 | 46 | S | Narragansett Bay Group | Rhode Island Formation | 140 |
| C | 1592021-9 | 45 | S | Narragansett Bay Group | Rhode Island Formation | 40 |
| C | 1592023-1 | 102 | S | Narragansett Bay Group | Rhode Island Formation | 3,160 |
| C | 1592023-5 | 100 | S | Narragansett Bay Group | Rhode Island Formation | 2,990 |
| C | 1592023-7 | 98 | S | Narragansett Bay Group | Rhode Island Formation | 2,810 |
| C | 1592023-8 | 94 | S | Narragansett Bay Group | Rhode Island Formation | 20 |
| C | 1592023-9 | 179 | S | Narragansett Bay Group | Rhode Island Formation | 20 |
| C | 1592025-1 | 88 | S | Narragansett Bay Group | Rhode Island Formation | 380 |
| C | 1592025-2 | 93 | S | Narragansett Bay Group | Rhode Island Formation | 120 |
| C | 1592025-3 | 89 | S | Narragansett Bay Group | Rhode Island Formation | 140 |
| C | 1615614-1 | 26 | F | Esmond Igneous Suite | granite | 70 |
| C | 1615614-2 | 25 | F | Esmond Igneous Suite | granite | 430 |
| C | 1615614-5 | 24 | M | Blackstone Group | undifferentiated rock | 300 |
| C | 1615623-1 | 157 | F | Narragansett Pier Plutonic Suite | granite | 180 |
| C | 1615623-2 | 156 | F | Narragansett Pier Plutonic Suite | granite | 120 |
| C | 1615624-1 | 137 | F | Esmond Igneous Suite | augen granite gneiss | 180 |

**Appendix 6.** Bedrock geology at well locations and distance of wells to the closest surface-water body for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Supply type | Source identifier | USGS-ID | Bedrock geology at well: Litho-logic rock type | Bedrock geology at well: Bedrock suite or group | Bedrock geology at well: Bedrock map unit | Distance to the closest surface-water body, in feet |
|---|---|---|---|---|---|---|
| C | 1615624-2 | 138 | F | Esmond Igneous Suite | augen granite gneiss | 60 |
| C | 1615624-3 | 136 | F | Esmond Igneous Suite | augen granite gneiss | 490 |
| C | 1615624-4 | 139 | F | Esmond Igneous Suite | augen granite gneiss | 310 |
| C | 1615624-5 | 140 | F | Esmond Igneous Suite | augen granite gneiss | 600 |
| C | 1615624-7 | 135 | F | Esmond Igneous Suite | augen granite gneiss | 1,010 |
| C | 1615626-1 | 80 | S | Narragansett Bay Group | Rhode Island Formation | 1,450 |
| C | 1615626-2 | 81 | S | Narragansett Bay Group | Rhode Island Formation | 1,550 |
| C | 1647512-1 | 167 | F | Narragansett Pier Plutonic Suite | porphyritic granite | 350 |
| C | 1647512-2 | 168 | F | Narragansett Pier Plutonic Suite | porphyritic granite | 470 |
| C | 1647515-5 | 77 | S | Narragansett Bay Group | Rhode Island Formation | 670 |
| C | 1647515-6 | 76 | S | Narragansett Bay Group | Rhode Island Formation | 580 |
| C | 1647526-1 | 44 | F | Esmond Igneous Suite | augen granite gneiss | 540 |
| C | 1647529-1 | 134 | F | Esmond Igneous Suite | augen granite gneiss | 480 |
| C | 1647530-1 | 33 | MS | Blackstone Group | quartzite | 80 |
| C | 1647530-3 | 40 | S | Narragansett Bay Group | Rhode Island Formation | 240 |
| C | 1647530-4 | 39 | S | Narragansett Bay Group | Rhode Island Formation | 270 |
| C | 1647530-5 | 31 | MS | Blackstone Group | quartzite | 90 |
| C | 1858411-1 | 35 | M | Blackstone Group | undifferentiated rock | 110 |
| C | 1858411-2 | 37 | M | Blackstone Group | undifferentiated rock | 110 |
| C | 1858421-1 | 130 | F | Esmond Igneous Suite | augen granite gneiss | 310 |
| C | 1858421-2 | 131 | F | Esmond Igneous Suite | augen granite gneiss | 270 |
| C | 1858422-1 | 128 | F | Esmond Igneous Suite | augen granite gneiss | 120 |
| C | 1858422-2 | 129 | F | Esmond Igneous Suite | augen granite gneiss | 290 |
| C | 1858422-3 | 127 | F | Esmond Igneous Suite | augen granite gneiss | 190 |
| C | 1858423-5 | 59 | S | Narragansett Bay Group | Rhode Island Formation | 190 |
| C | 1858435-1 | 70 | F | Esmond Igneous Suite | augen granite gneiss | 620 |
| C | 1900020-1 | 78 | F | Scituate Igneous Suite | granite | 1,310 |
| C | 1900023-1 | 74 | F | Scituate Igneous Suite | alkali-feldspar granite | 590 |
| C | 1900023-2 | 75 | F | Scituate Igneous Suite | alkali-feldspar granite | 470 |
| C | 1900023-3 | 71 | F | Scituate Igneous Suite | alkali-feldspar granite | 1,030 |
| C | 1900023-4 | 72 | F | Scituate Igneous Suite | alkali-feldspar granite | 940 |
| C | 1900023-5 | 73 | F | Scituate Igneous Suite | alkali-feldspar granite | 770 |
| C | 1900025-2 | 126 | F | Sterling Plutonic Group | alaskite gneiss | 810 |
| C | 1900029-1 | 160 | F | Narragansett Pier Plutonic Suite | granite | 520 |
| C | 1900034-1 | 30 | F | Scituate Igneous Suite | granite | 120 |
| C | 1900034-2 | 181 | F | Scituate Igneous Suite | granite | 120 |
| C | 1900036-1 | 170 | F | Esmond Igneous Suite | granite | 710 |
| C | 1900036-2 | 171 | F | Esmond Igneous Suite | granite | 710 |
| C | 1900039-1 | 174 | S | Narragansett Bay Group | Rhode Island Formation | 580 |
| C | 1900048-2 | 123 | F | Sterling Plutonic Group | alaskite gneiss | 510 |

**Appendix 6.** Bedrock geology at well locations and distance of wells to the closest surface-water body for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Supply type | Source identifier | USGS-ID | Bedrock geology at well | | | Distance to the closest surface-water body, in feet |
|---|---|---|---|---|---|---|
| | | | Litho-logic rock type | Bedrock suite or group | Bedrock map unit | |
| C | 1900049-1 | 183 | F | Esmond Igneous Suite | granite | 160 |
| C | 2000004-2 | 79 | F | Esmond Igneous Suite | augen granite gneiss | 470 |
| C | 2000059-1 | 49 | F | Harmony Group | Absalona Formation | 280 |
| C | 2000059-2 | 48 | F | Harmony Group | Absalona Formation | 180 |
| C | 2000083-1 | 52 | S | metaclastic | metaclastic rock, undivided | 320 |
| C | 2000083-2 | 51 | S | metaclastic | metaclastic rock, undivided | 370 |
| C | 2000084-1 | 62 | M | gabbro/diorite | gabbro/diorite | 530 |
| C | 2000165-1 | 112 | F | Scituate Igneous Suite | granite | 1,890 |
| C | 2051311-1 | 97 | S | Narragansett Bay Group | Rhode Island Formation | 570 |
| C | 2415415-1 | 64 | F | Esmond Igneous Suite | granite gneiss | 2,060 |
| C | 2519424-1 | 60 | F | Esmond Igneous Suite | granite gneiss | 180 |
| C | 2519424-3 | 177 | F | Esmond Igneous Suite | granite gneiss | 180 |
| C | 2519426-1 | 83 | F | Scituate Igneous Suite | granite | 1,130 |
| C | 2585312-1 | 115 | F | Esmond Igneous Suite | augen granite gneiss | 1,650 |
| C | 2585312-2 | 114 | F | Esmond Igneous Suite | augen granite gneiss | 1,210 |
| C | 2585313-1 | 103 | F | Scituate Igneous Suite | granite | 1,860 |
| C | 2674924-1 | 182 | F | Narragansett Pier Plutonic Suite | granite | 1,170 |
| C | 2674925-1 | 144 | F | Sterling Plutonic Group | alaskite gneiss | 660 |
| C | 2674925-2 | 143 | F | Sterling Plutonic Group | alaskite gneiss | 670 |
| C | 2674928-1 | 162 | F | Narragansett Pier Plutonic Suite | granite | 2,010 |
| C | 2753326-1 | 121 | S | Narragansett Bay Group | Rhode Island Formation | 1,100 |
| C | 2753326-3 | 122 | S | Narragansett Bay Group | Rhode Island Formation | 880 |
| C | 2788012-1 | 66 | F | Esmond Igneous Suite | augen granite gneiss | 1,780 |
| C | 2814410-3 | 96 | F | Scituate Igneous Suite | granite | 2,980 |
| C | 2882117-3 | 120 | F | Esmond Igneous Suite | augen granite gneiss | 360 |
| C | 2882117-4 | 119 | F | Esmond Igneous Suite | augen granite gneiss | 140 |
| C | 2942518-1 | 36 | F | Esmond Igneous Suite | granite | 780 |
| C | 2942525-1 | 111 | F | Scituate Igneous Suite | granite | 2,790 |
| C | 2942525-3 | 109 | F | Scituate Igneous Suite | granite | 2,300 |
| C | 2943224-8 | 61 | F | Esmond Igneous Suite | granite gneiss | 1,070 |
| C | 2973130-1 | 42 | F | Harmony Group | Absalona Formation | 70 |
| C | 2973130-2 | 43 | F | Harmony Group | Absalona Formation | 110 |
| C | 2973130-3 | 41 | F | Harmony Group | Absalona Formation | 90 |
| C | 2980001-1 | 95 | F | Granites of southeastern R.I. | granite | 710 |
| C | 2980003-1 | 99 | S | Narragansett Bay Group | Purgatory Conglomerate | 210 |
| C | 2980145-1 | 101 | F | Scituate Igneous Suite | granite | 1,340 |
| C | 2980146-1 | 58 | M | Blackstone Group | undifferentiated rock | 340 |
| C | 2980146-3 | 57 | M | Blackstone Group | undifferentiated rock | 220 |
| C | 2980196-2 | 169 | -- | no bedrock unit exposed | -- | 720 |
| C | 2980258-1 | 22 | M | Blackstone Group | undifferentiated rock | 1,030 |

**Appendix 6.** Bedrock geology at well locations and distance of wells to the closest surface-water body for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Supply type | Source identifier | USGS-ID | Bedrock geology at well: Litho-logic rock type | Bedrock geology at well: Bedrock suite or group | Bedrock geology at well: Bedrock map unit | Distance to the closest surface-water body, in feet |
|---|---|---|---|---|---|---|
| C | 2980258-2 | 23 | M | Blackstone Group | undifferentiated rock | 1,000 |
| C | 2980258-5 | 173 | M | Blackstone Group | undifferentiated rock | 1,060 |
| C | 2980264-1 | 186 | F | Esmond Igneous Suite | augen granite gneiss | 1,430 |
| C | 2980276-1 | 86 | F | Scituate Igneous Suite | granite | 930 |
| C | 2980276-2 | 87 | F | Scituate Igneous Suite | granite | 940 |
| C | 2980323-1 | 65 | F | Scituate Igneous Suite | granite | 1,420 |
| C | 2980340-1 | 185 | F | Granites of southeastern R.I. | granite | 480 |
| P | 1000007-1 | 102 | F | Harmony Group | Absalona Formation | 680 |
| P | 1000007-2 | 103 | F | Harmony Group | Absalona Formation | 780 |
| P | 1000025-1 | 17 | C | Blackstone Group | epidote and biotite schist | 2,280 |
| P | 1000039-1 | 72 | F | Esmond Igneous Suite | augen granite gneiss | 180 |
| P | 1000042-1 | 5 | M | Blackstone Group | undifferentiated rock | 270 |
| P | 1559510-1 | 50 | F | Scituate Igneous Suite | granite | 2,300 |
| P | 1559516-1 | 92 | M | Waterford Group | Mamacoke Formation | 20 |
| P | 1559516-2 | 104 | M | Waterford Group | Mamacoke Formation | 20 |
| P | 1583819-3 | 56 | F | Scituate Igneous Suite | granite | 3,640 |
| P | 1583819-4 | 55 | F | Scituate Igneous Suite | granite | 3,620 |
| P | 1583820-1 | 57 | F | Scituate Igneous Suite | granite | 2,070 |
| P | 1583823-1 | 36 | F | Esmond Igneous Suite | augen granite gneiss | 370 |
| P | 1583827-1 | 18 | F | Esmond Igneous Suite | augen granite gneiss | 600 |
| P | 1583829-4 | 26 | F | Esmond Igneous Suite | augen granite gneiss | 1,250 |
| P | 1583829-5 | 25 | F | Esmond Igneous Suite | augen granite gneiss | 1,240 |
| P | 1583829-6 | 24 | F | Esmond Igneous Suite | augen granite gneiss | 1,270 |
| P | 1583829-7 | 27 | F | Esmond Igneous Suite | augen granite gneiss | 1,070 |
| P | 1592014-1 | 3 | M | Blackstone Group | undifferentiated rock | 560 |
| P | 1592015-1 | 6 | F | Esmond Igneous Suite | granite | 160 |
| P | 1592017-1 | 13 | F | Harmony Group | Absalona Formation | 180 |
| P | 1592027-2 | 66 | F | Sterling Plutonic Group | granite gneiss | 440 |
| P | 1592027-3 | 67 | F | Sterling Plutonic Group | granite gneiss | 480 |
| P | 1592028-1 | 79 | F | Sterling Plutonic Group | alaskite gneiss | 760 |
| P | 1592030-1 | 75 | F | Sterling Plutonic Group | alaskite gneiss | 1,000 |
| P | 1615611-1 | 41 | F | Scituate Igneous Suite | granite | 1,110 |
| P | 1615612-4 | 34 | F | Scituate Igneous Suite | granite | 1,250 |
| P | 1615612-5 | 35 | F | Scituate Igneous Suite | granite | 990 |
| P | 1615612-6 | 33 | F | Scituate Igneous Suite | granite | 1,230 |
| P | 1615613-1 | 30 | F | Scituate Igneous Suite | granite | 1,220 |
| P | 1615617-1 | 71 | F | Esmond Igneous Suite | augen granite gneiss | 360 |
| P | 1647513-3 | 91 | F | Sterling Plutonic Group | alaskite gneiss | 130 |
| P | 1647517-1 | 10 | F | Esmond Igneous Suite | granite | 200 |
| P | 1647525-3 | 76 | F | Sterling Plutonic Group | alaskite gneiss | 1,350 |

**Appendix 6.** Bedrock geology at well locations and distance of wells to the closest surface-water body for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Supply type | Source identifier | USGS-ID | Bedrock geology at well: Litho-logic rock type | Bedrock geology at well: Bedrock suite or group | Bedrock geology at well: Bedrock map unit | Distance to the closest surface-water body, in feet |
|---|---|---|---|---|---|---|
| P | 1647525-4 | 73 | F | Sterling Plutonic Group | alaskite gneiss | 1,290 |
| P | 1647527-1 | 47 | F | Scituate Igneous Suite | granite | 1,390 |
| P | 1858414-1 | 68 | F | Sterling Plutonic Group | alaskite gneiss | 700 |
| P | 1858415-1 | 87 | MS | Plainfield Formation | Plainfield Formation | 20 |
| P | 1858417-1 | 89 | MS | Plainfield Formation | Plainfield Formation | 470 |
| P | 1858425-2 | 65 | F | Granites of southeastern R.I. | porphyritic granite | 920 |
| P | 1858431-1 | 83 | F | Sterling Plutonic Group | alaskite gneiss | 240 |
| P | 1900003-1 | 45 | F | Scituate Igneous Suite | granite | 2,740 |
| P | 1900003-2 | 46 | F | Scituate Igneous Suite | granite | 2,730 |
| P | 1900003-3 | 43 | F | Scituate Igneous Suite | granite | 2,930 |
| P | 1900003-4 | 44 | F | Scituate Igneous Suite | granite | 2,840 |
| P | 1900004-1 | 101 | F | Harmony Group | Woonasquatucket Formation | 2,600 |
| P | 1900004-2 | 105 | F | Harmony Group | Woonasquatucket Formation | 2,600 |
| P | 1900024-1 | 52 | F | Scituate Igneous Suite | granite | 2,410 |
| P | 1900024-2 | 54 | F | Scituate Igneous Suite | granite | 2,600 |
| P | 1900024-3 | 53 | F | Scituate Igneous Suite | granite | 2,510 |
| P | 1900026-1 | 16 | F | Esmond Igneous Suite | granite | 1,000 |
| P | 1900027-3 | 90 | F | Sterling Plutonic Group | alaskite gneiss | 2,170 |
| P | 1900028-1 | 11 | M | Blackstone Group | undifferentiated rock | 1,080 |
| P | 1900035-1 | 69 | F | Sterling Plutonic Group | alaskite gneiss | 410 |
| P | 1900038-1 | 20 | F | Harmony Group | Absalona Formation | 600 |
| P | 1900040-2 | 1 | F | Esmond Igneous Suite | augen granite gneiss | 1,210 |
| P | 1900041-1 | 19 | F | Esmond Igneous Suite | augen granite gneiss | 500 |
| P | 1900044-1 | 29 | F | Harmony Group | Absalona Formation | 280 |
| P | 2000090-1 | 97 | M | Blackstone Group | undifferentiated rock | 480 |
| P | 2000110-1 | 42 | F | Scituate Igneous Suite | granite | 210 |
| P | 2000133-1 | 70 | F | Sterling Plutonic Group | alaskite gneiss | 280 |
| P | 2000135-1 | 49 | F | Scituate Igneous Suite | granite | 960 |
| P | 2000142-4 | 74 | F | Sterling Plutonic Group | alaskite gneiss | 80 |
| P | 2000145-1 | 88 | MS | Plainfield Formation | Plainfield Formation | 480 |
| P | 2000176-1 | 48 | F | Scituate Igneous Suite | granite | 180 |
| P | 2051719-1 | 37 | F | Scituate Igneous Suite | alkali-feldspar granite | 660 |
| P | 2051719-2 | 38 | F | Scituate Igneous Suite | alkali-feldspar granite | 710 |
| P | 2051719-3 | 39 | F | Scituate Igneous Suite | alkali-feldspar granite | 440 |
| P | 2051719-4 | 40 | F | Scituate Igneous Suite | alkali-feldspar granite | 160 |
| P | 2051729-1 | 64 | F | Esmond Igneous Suite | augen granite gneiss | 180 |
| P | 2788010-1 | 32 | F | Esmond Igneous Suite | augen granite gneiss | 210 |
| P | 2942515-1 | 9 | M | Blackstone Group | undifferentiated rock | 470 |
| P | 2973119-4 | 7 | F | Esmond Igneous Suite | granite | 500 |
| P | 2980017-1 | 94 | F | Narragansett Pier Plutonic Suite | granite | 940 |

**Appendix 6.** Bedrock geology at well locations and distance of wells to the closest surface-water body for community and non-community, non-transient supply wells in Rhode Island—*Continued*

| Supply type | Source identifier | USGS-ID | Bedrock geology at well: Litho-logic rock type | Bedrock geology at well: Bedrock suite or group | Bedrock geology at well: Bedrock map unit | Distance to the closest surface-water body, in feet |
|---|---|---|---|---|---|---|
| P | 2980019-1 | 96 | F | Narragansett Pier Plutonic Suite | granite | 680 |
| P | 2980030-1 | 99 | F | Scituate Igneous Suite | granite | 440 |
| P | 2980036-1 | 2 | F | Esmond Igneous Suite | granite | 1,150 |
| P | 2980084-2 | 31 | F | Scituate Igneous Suite | alkali-feldspar granite | 380 |
| P | 2980127-1 | 84 | F | Sterling Plutonic Group | granite gneiss | 440 |
| P | 2980134-1 | 21 | F | Harmony Group | Woonasquatucket Formation | 280 |
| P | 2980135-1 | 28 | F | Esmond Igneous Suite | granite | 490 |
| P | 2980138-1 | 60 | F | Granites of southeastern R.I. | granite | 400 |
| P | 2980154-1 | 98 | F | Harmony Group | Absalona Formation | 570 |
| P | 2980185-2 | 77 | F | Sterling Plutonic Group | alaskite gneiss | 1,480 |
| P | 2980185-3 | 78 | F | Sterling Plutonic Group | alaskite gneiss | 1,420 |
| P | 2980192-1 | 62 | F | Esmond Igneous Suite | augen granite gneiss | 530 |
| P | 2980192-2 | 63 | F | Esmond Igneous Suite | augen granite gneiss | 560 |
| P | 2980265-1 | 59 | S | Narragansett Bay Group | Rhode Island Formation | 210 |
| P | 2980270-1 | 100 | F | Sterling Plutonic Group | alaskite gneiss | 1,550 |
| P | 2980277-1 | 14 | F | Harmony Group | Absalona Formation | 60 |
| P | 2980278-1 | 15 | F | Harmony Group | Absalona Formation | 90 |
| P | 2980301-1 | 4 | M | Blackstone Group | undifferentiated rock | 850 |
| P | 2980311-1 | 12 | M | Blackstone Group | undifferentiated rock | 380 |
| P | 2980330-1 | 106 | F | Harmony Group | Absalona Formation | 260 |
| P | 2980346-1 | 107 | F | Esmond Igneous Suite | granite gneiss | 120 |

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Subdistrict Chief,
Rhode Island District
U.S. Geological Survey
Water Resources Division
275 Promenade St., Suite 150
Providence, Rhode Island 02908