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UNUSUALLY SENSITIVE AREAS FOR DRINKING WATER RESOURCES

REPORT FOR RHODE ISLAND

Prepared by:
Joanne N. Halls, Jeffrey A. Dahlin, Miles O. Hayes, and Jacqueline Michel
Research Planning, Inc.
1121 Park Street
Columbia, South Carolina 29201

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INTRODUCTION

The Research and Special Programs Administration (RSPA) of the Department of Transportation is required to identify areas unusually sensitive to environmental damage in the event of a hazardous liquid pipeline accident, in accordance with pipeline safety laws (49 U.S.C. Section 60109). Accordingly, workshops were held with regulatory agencies, pipeline operators, and the public during which a process was developed to identify "unusually sensitive areas" (USAs) for drinking water resources. This process, which has been adopted by RSPA, consists of first identifying environmentally sensitive drinking water resources and other primary concerns, and then applying the following five filtering criteria to determine which of the drinking water source locations (i.e., surface water intakes, ground water wells) should be USAs:

Filter Criteria #1

If the public water system is a Transient Noncommunity Water System (TNCWS), the water intakes shall not be designated as USAs.

Filter Criteria #2

For Community Water Systems (CWS) and Nontransient Noncommunity Water Systems (NTNCWS) that obtain their water supply primarily from surface water sources, and do not have an adequate alternative source of water, the water intakes shall be designated as USAs.

Filter Criteria #3

For CWS and NTNCWS that obtain their water supply primarily from ground water sources, where the source aquifer is identified as a Class I or Class IIa, as defined in Pettyjohn et al. (1991), and do not have an adequate alternative source of water, these wells shall be designated as USAs. The wellhead protection areas for such systems shall be designated as USAs.

Filter Criteria #4

For CWS and NTNCWS that obtain their water primarily from ground water sources, where the source aquifer is identified as a Class IIb, IIc, III, IIIv, or U, as defined in Pettyjohn et al. (1991), the public water systems that rely on these aquifers shall not be designated as USAs.

Filter Criteria #5

For CWS and NTNCWS that obtain their water supply primarily from ground water sources, where the source aquifer is identified as a Class I or Class IIa (as defined in Pettyjohn et al., 1991), and the aquifer is designated as a sole source aquifer, an area twice the wellhead protection area shall be designated as a USA.

All CWS and NTNCWS that obtain their water from surface water sources are automatically designated as USAs because information on which to evaluate whether they have an adequate alternative water supply is not available. Unfortunately, data for surface water sources are not available for the state of Rhode Island. Therefore, the rest of this discussion describes the process that has been developed and implemented to classify ground water wells that supply the CWS and NTNCWS in Rhode Island. The necessary data for carrying out this analysis are available in digital format, and the data quality is good. The status of data collection and evaluation for all states can be reviewed in the USA Data Catalog, which is available from RSPA.

A key to implementing the process for identifying USAs for ground water wells is distinguishing those wells that obtain their water from Class I or Class IIa aquifers (filter criteria 3 and 5), from those that do not (filter criteria 4). Another major factor is the thickness of overlying, impermeable materials. For example, if Class I and IIa aquifers are overlain by more than 50 feet of impermeable material such as glacial till or shale, then wells in that area would be Class III and, therefore, not USAs. In this situation, the overlying impermeable layer would prevent a pipeline release at the land surface from reaching the aquifer.

THE PETTYJOHN CLASSIFICATION SCHEME

The aquifer classification scheme developed in a report "Regional Assessment of the Aquifer Vulnerability and Sensitivity in the Conterminous United States" for the U.S. Environmental Protection Agency (USEPA/600/2-91/043) by Pettyjohn et al. (1991) is used to determine those parts of aquifers at risk to contamination from pipeline releases of a hazardous liquid. The Pettyjohn classification, based on an assessment of the potential contamination of ground water throughout the United States by the subsurface emplacement of fluids through injection wells, is outlined below:

Class I (surficial or shallow permeable units; highly vulnerable to contamination)

Class Ia: Unconsolidated Aquifers. Consist of surficial, unconsolidated, and permeable alluvial, terrace, outwash, beach, dune and other similar deposits.

Class Ib: Soluble and Fractured Bedrock Aquifers. Consist of limestone, dolomite, and, locally, evaporitic units that contain documented karst features or solution channels, regardless of size. Also includes sedimentary strata and metamorphic and igneous rocks that are significantly faulted, fractured, or jointed.

Class Ic: Semiconsolidated Aquifers. Consist of semiconsolidated systems that contain poorly to moderately indurated sand and gravel that are interbedded with clay and silt.

Class Id: Covered Aquifers. Consists of any Class I aquifer that is overlain by less than 50 feet of low permeability, unconsolidated material, such as glacial till, lacustrian, and loess deposits.

Class II (consolidated bedrock aquifers; moderately vulnerable to contamination)

Class IIa: Higher Yield Bedrock Aquifers. Consist of fairly coarse sandstone or conglomerate that contain lesser amounts of interbedded fine-grained clastics and occasionally carbonate units. In general, well yields must exceed 50 gallons per minute (gpm) to be included in this class.

Class IIb: Lower Yield Bedrock Aquifers. Consist of the same clastic rock types present in the higher yield systems. May also consist of crystalline rocks that are fractured to some degree. Well yields are commonly less than 50 gpm.

Class IIc: Covered Bedrock Aquifers. Consist of Class IIa and IIb aquifers that are overlain by less than 50 feet of unconsolidated material of low permeability.

Class III (covered consolidated or unconsolidated aquifers)

This class includes those aquifers that are overlain by more than 50 feet of low permeability material. The Class IIIv is used where wells derive water from a Class I or IIa aquifer underneath a confining shale layer and the shale layer thickness is unknown.

Class U (undifferentiated aquifers)

This classification is used where several lithologic and hydrologic conditions are present within a mapable area. This class is intended to convey a wider range of vulnerability than is usually contained in any other single class.

Subclass v (variably covered aquifers)

The modifier "v" is used to describe areas where an undetermined or highly variable thickness of low permeability sediments overlies the major water-bearing zone. In practice, we have used this modifier where the geologic description of the aquifer indicates that there is a confining unit above the water-producing zone.

IDENTIFYING USAs FOR DRINKING WATER RESOURCES IN RHODE ISLAND

Data Sources

All of the data for drinking water resources in Rhode Island is maintained by the Rhode Island Geographic Information System (RIGIS). RIGIS provided Arc/INFO coverages for all of the well water supplies, surficial glacial geology, bedrock geology, wellhead protection areas, and sole source aquifers. There is currently no complete and reliable database for surface water intakes. The digital data did not contain information regarding the source aquifer for the wells. This information, which was obtained from the Rhode Island Department of Environmental Management (RIDEM), Office of Water Resources, as a printed data table, was used to update the digital files. The wells database has a field that identifies the CWS, NTNCWS, and Transient Noncommunity Water System (TNCWS) wells, which provides the necessary information to apply filter criteria l. Currently there is no means of determining if there is an adequate alternative source of water for the wells and this will require contacting the owner/operator of each system, which is not feasible at this time. Therefore, in applying filter criteria 2 and 3, we have assumed that all wells do not have an adequate alternative source of water.

The Geology and Pettyjohn Classification of Aquifers in Rhode Island

As shown in Table 1, there are three primary aquifers in Rhode Island (summarized from the 1992 U.S. Geological Survey publication “Groundwater Atlas of the United States, Segment 12” and Pettyjohn et al., 1991).

TABLE 1. Rhode Island's aquifers and their classification according to the Pettyjohn classification scheme.

Aquifer Name	Aquifer Description	Pettyjohn Classification
Pleistocene stratified outwash and ice-contact deposits	Unconsolidated, moderately sorted lenses of gravel, sand and silt deposited by glacial meltwater streams (covers 42% of land surface in Rhode Island)	Class Ia because it is surficial, unconsolidated, and consists of permeable deposits of sand and gravel
Semi-consolidated sandstone	Mesozoic age, semiconsolidated sandstones on the higher elevations of Block Island	Class Ic because it is a semiconsolidated sandstone that is poorly to moderately indurated
Bedrock	Near Narragansett Bay bedrock is well indurated to metamorphosed Pennsylvanian sedimentary rocks. Elsewhere, bedrock is of igneous and metamorphic origin. Recoverable water occurs in fractures. Covered with glacial till in most places	Either class Uv or IIb because of the low permeability of the rock (hence, low yields) and the near universal presence of an overburden of impermeable glacial till

Processing Steps

Every public water system well in Rhode Island was evaluated according to the Pettyjohn scheme. The results are presented by aquifer in order from the youngest to the oldest (Fig. 1). When a well has multiple water sources, the shallowest source is used to determine the Pettyjohn class because it is the source most likely to be impacted by pollutants moving downward from the surface.

There are 631 public water system groundwater wells in the Rhode Island database of which 364 are TNCWS wells and were removed based on filter criteria #1. Of the 267 remaining groundwater wells, 171 are CWS wells and 96 are NTNCWS wells.

The well data were in two separate files, community wells and noncommunity wells. These two files were joined together to produce a single well coverage. Attributes identifying data quality and the Pettyjohn classification were added to the well coverage. The following distances (from the data provider's metadata reports) were used in determining the spatial accuracy of each data layer:

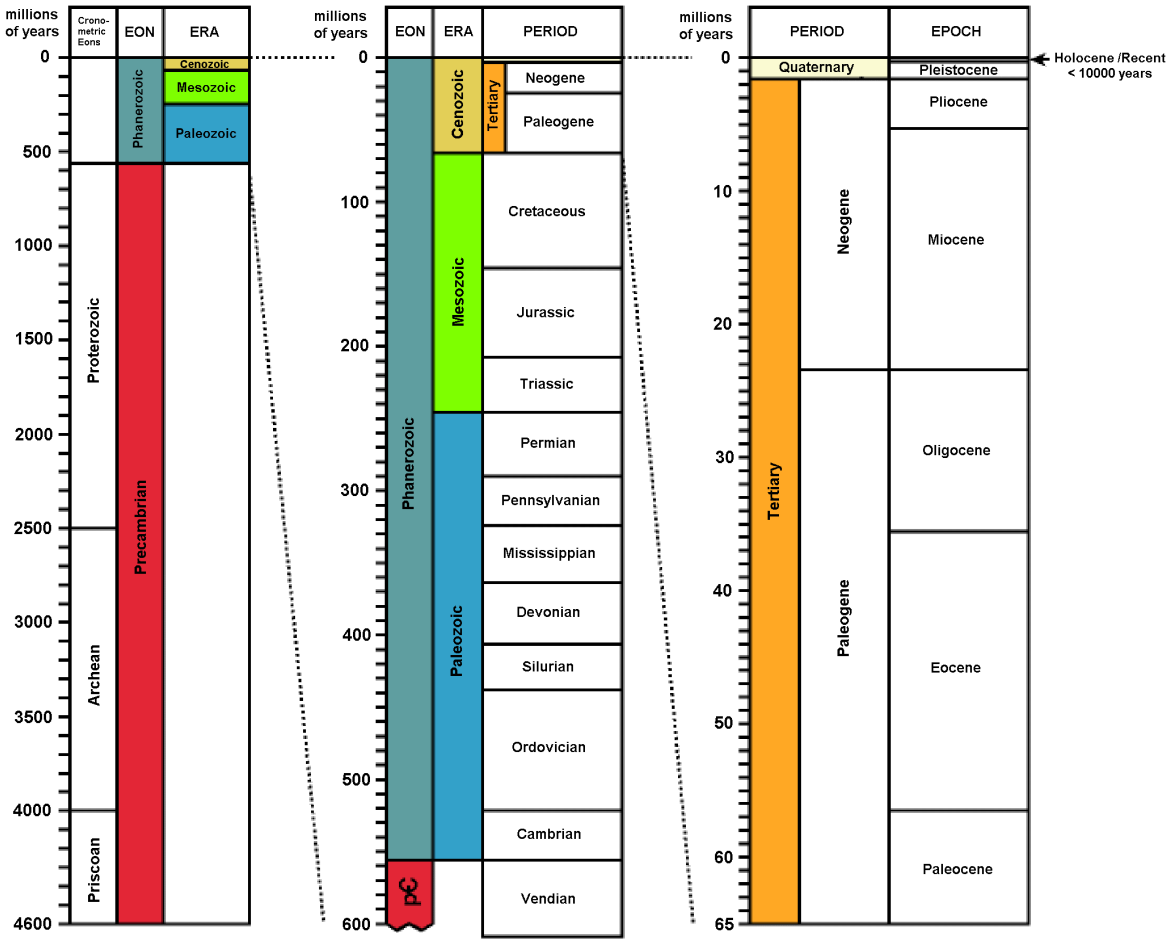

Figure 1. Geologic time scale.

groundwater wells: +/- 50 feet

surficial glacial geology: +/- 40 feet

bedrock geology: +/- 4000 meters

The sequential Geographic Information System (GIS) processing began with the intersection of the groundwater wells with the polygons delineating the boundaries of Pleistocene stratified outwash and ice-contact deposits (labeled outwash on Fig. 2). This material covers approximately 42 percent of the land surface of the state (Pettyjohn et al., 1991). The wells that fall outside or beyond the boundaries of the Pleistocence stratified outwash and ice-contact deposits were analyzed to determine if the wells fall within the allowable accuracy ranges. The wells were then assigned the following quality values:

Quality Rank	Description of the Data Quality
1	source information is available and the well is located within the boundary of the associated data layer (glacial outwash)
2	source information is available and the well is located within the spatial tolerance of the associated data layer
3	source information is available and the well is located beyond the spatial tolerance of the associated data layer
4	source information is not available, but other attributes were used to classify the well

Pleistocene Stratified Outwash and Ice-Contact Deposits Aquifer

A total of 95 wells (89 are community wells and 6 are nontransient noncommunity wells) derive water from the stratified outwash and ice-contact deposits aquifer. All of these wells are Class Ia because this aquifer is located at the land surface and is composed of highly permeable, coarse-grained sand and gravel. These productive sediments typically fill deeply incised bedrock valleys throughout the state. During melting of the Pleistocene ice sheets, abundant meltwater flowed down a steep gradient provided by the ice and transported rock fragments released from the melting ice beyond the ice front. Sand and gravel were deposited at the contact of the ice front and by sediment-laden streams flowing away from the glaciers (U.S. Geological Survey, 1995). It is common for wells that tap these coarse sediments to yield flows measured in hundreds of gpm.

Only two wells that derive water from the stratified outwash are located outside the mapped boundaries of the outwash and these were manually checked. One well is located within 90 feet of the outwash which is within the accuracy range (Quality = 2), and the second well is located beyond the accuracy range (Quality = 3). All of the other wells that obtain water from the glacial outwash were assigned a quality value of 1 because they occur within the mapped boundaries of the outwash (Fig. 2).

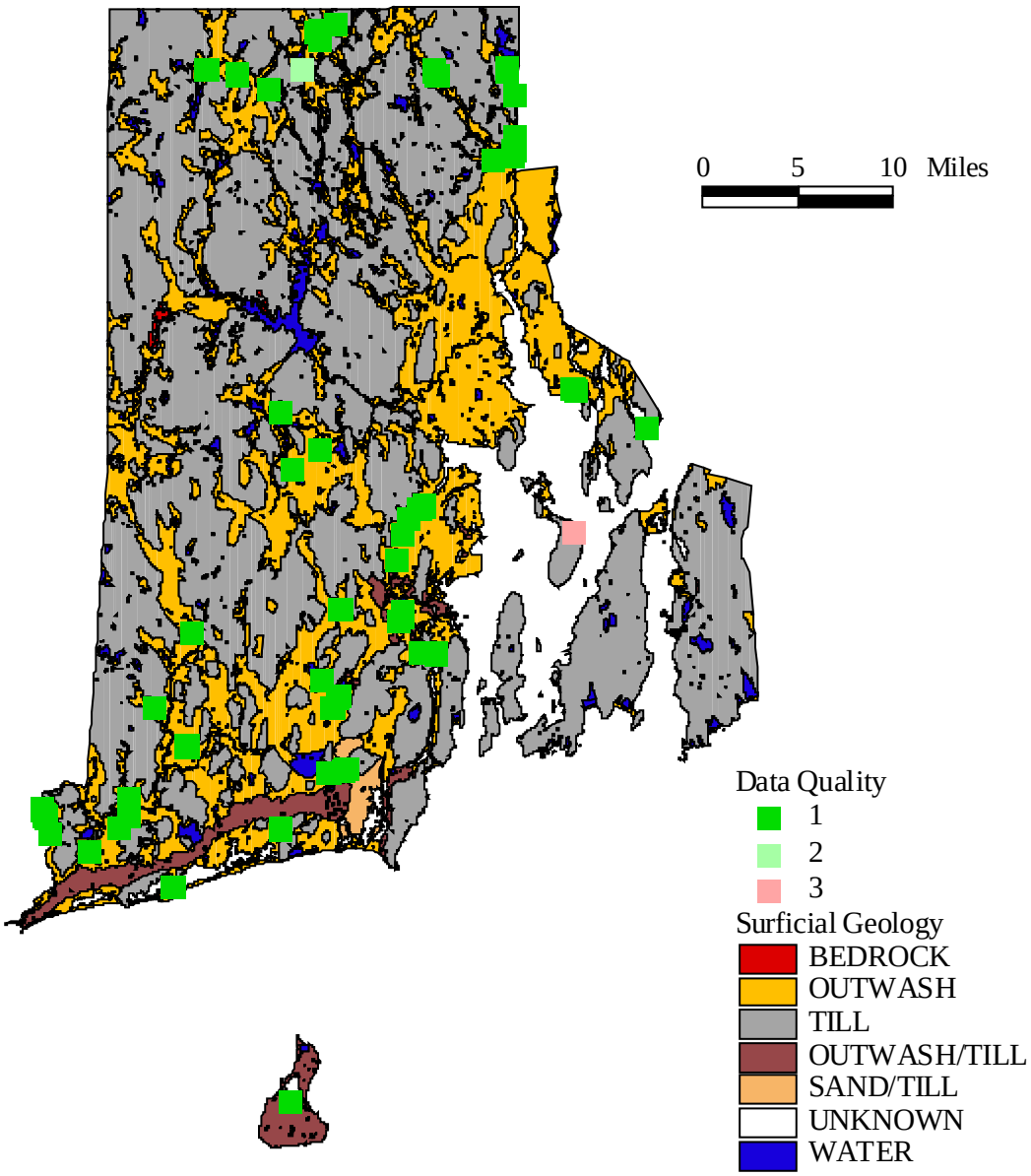

Figure 2. Groundwater wells, classified by data quality, that obtain water from the Pleistocene stratified outwash and ice-contact deposits aquifer (labeled outwash). All of these wells are Pettyjohn Class Ia USAs.

Semiconsolidated Sandstone Aquifer

Although Pettyjohn et al. (1991) show that the semiconsolidated sandstone aquifer of Upper Mesozoic age is exposed on the higher elevations of Block Island, the surficial geology map from RIGIS shows that the surface is covered by glacial outwash and till (Fig. 3). Two of the three community wells on Block Island had data indicating they obtained water from bedrock wells. Ernie Panceira (RIDEM, personnel communication) stated that these wells obtain water from glacial till, not bedrock, but the depth was not known. These two wells have been assigned a Class U and a quality value of 4.

Bedrock Aquifers

The remaining 170 groundwater wells obtain water from bedrock aquifers throughout the state. These aquifers range from indurated/metamorphosed Pennsylvanian sedimentary rocks in the Narragansett Bay area to igneous/metamorphic rocks elsewhere, largely granite and granite gneiss (Pettyjohn et al., 1991). The bedrock is overlain by variable thicknesses of impermeable glacial till, thus they would typically be Class Uv (variably covered undifferentiated aquifers). In some places, however, Class IIb (lower yield bedrock aquifers) would probably be more appropriate. In any event, these wells are not considered to be USAs because of the thick impermeable glacial till above them and their minimal water yield (Fig. 4).

Rhode Island Drinking Water USAs

The final USAs for Rhode Island were derived by selecting all of the Pettyjohn Class Ia wells (95) and intersecting them with the wellhead protection areas (WHPAs) delineated by RIDEM. Forty-nine wells derive water from a sole source aquifer, thus the WHPAs for those wells are doubled in area to create the final USAs (Fig. 5). A total of 38 WHPAs encompass all of the Class Ia wells.

In the GIS database, the USAs have "region" topology, which means that wells that have overlapping USA polygons are still identified by each well and all of the associated attributes of each well. Of the 267 public water system groundwater wells in Rhode Island, 95 were classified as Ia. Therefore, 36 percent of the public groundwater wells in Rhode Island were identified as USAs (Fig. 6).

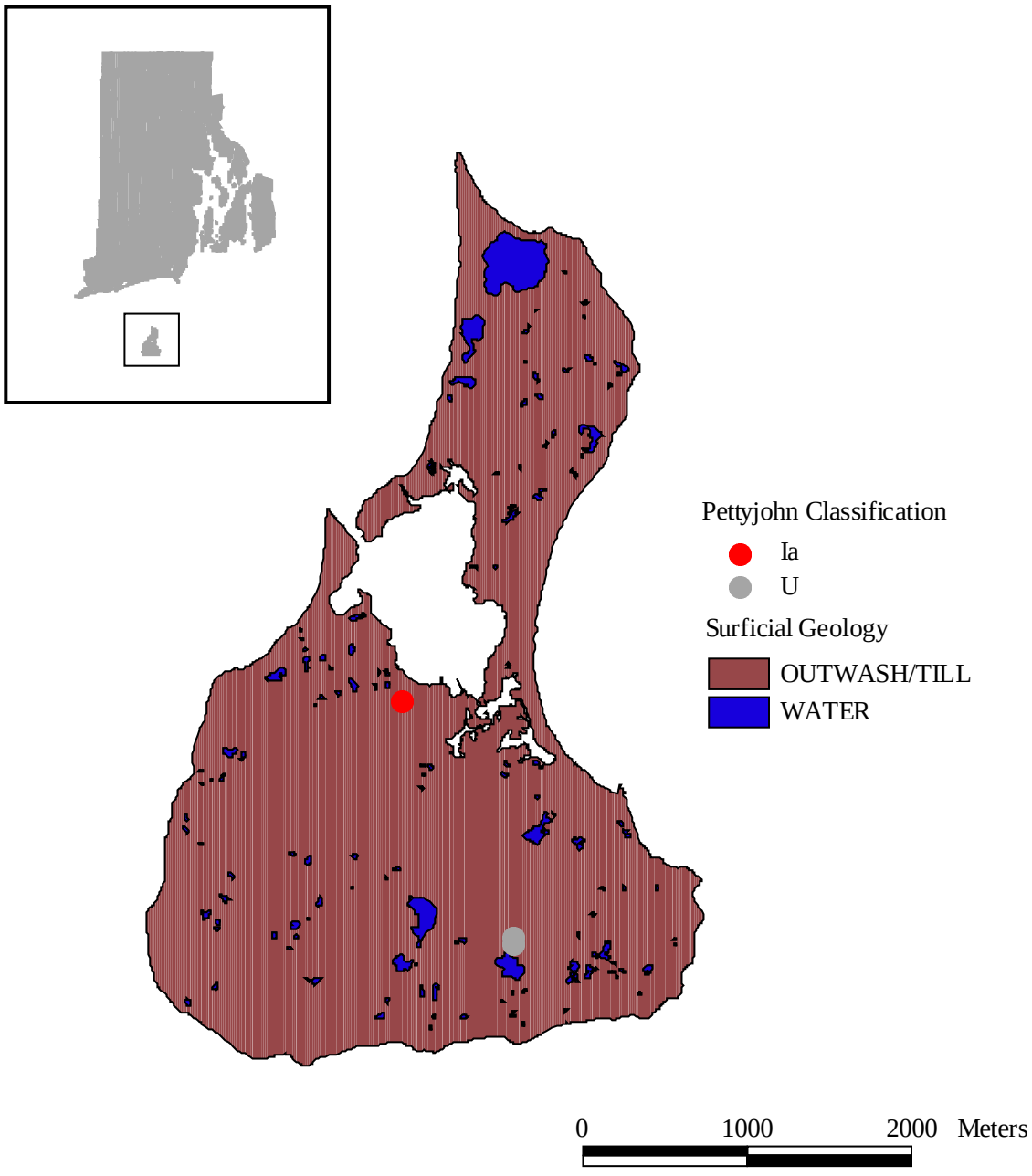

Figure 3. The surficial geology of Block Island, Rhode Island.

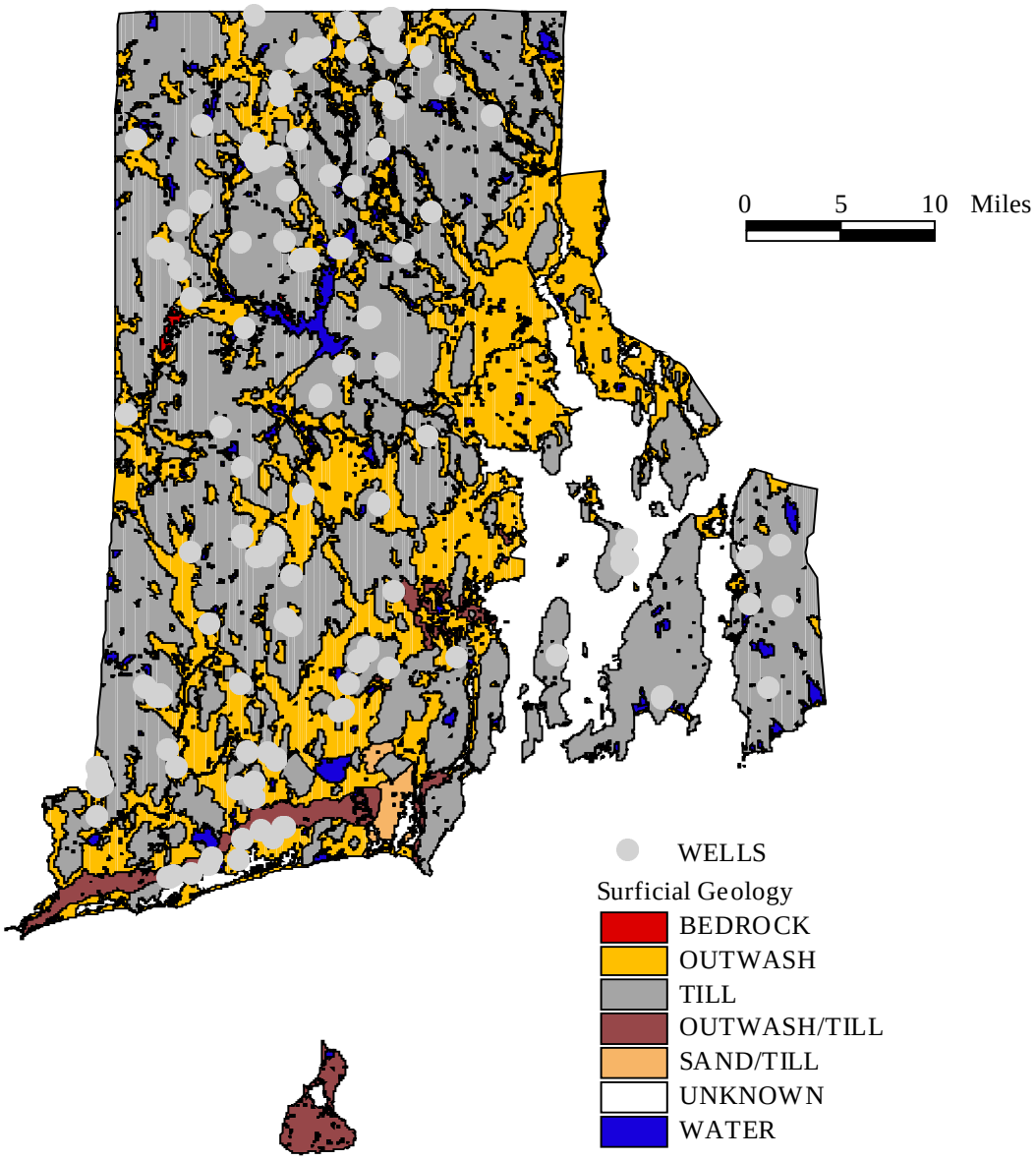

Figure 4. Groundwater wells that source bedrock aquifers.

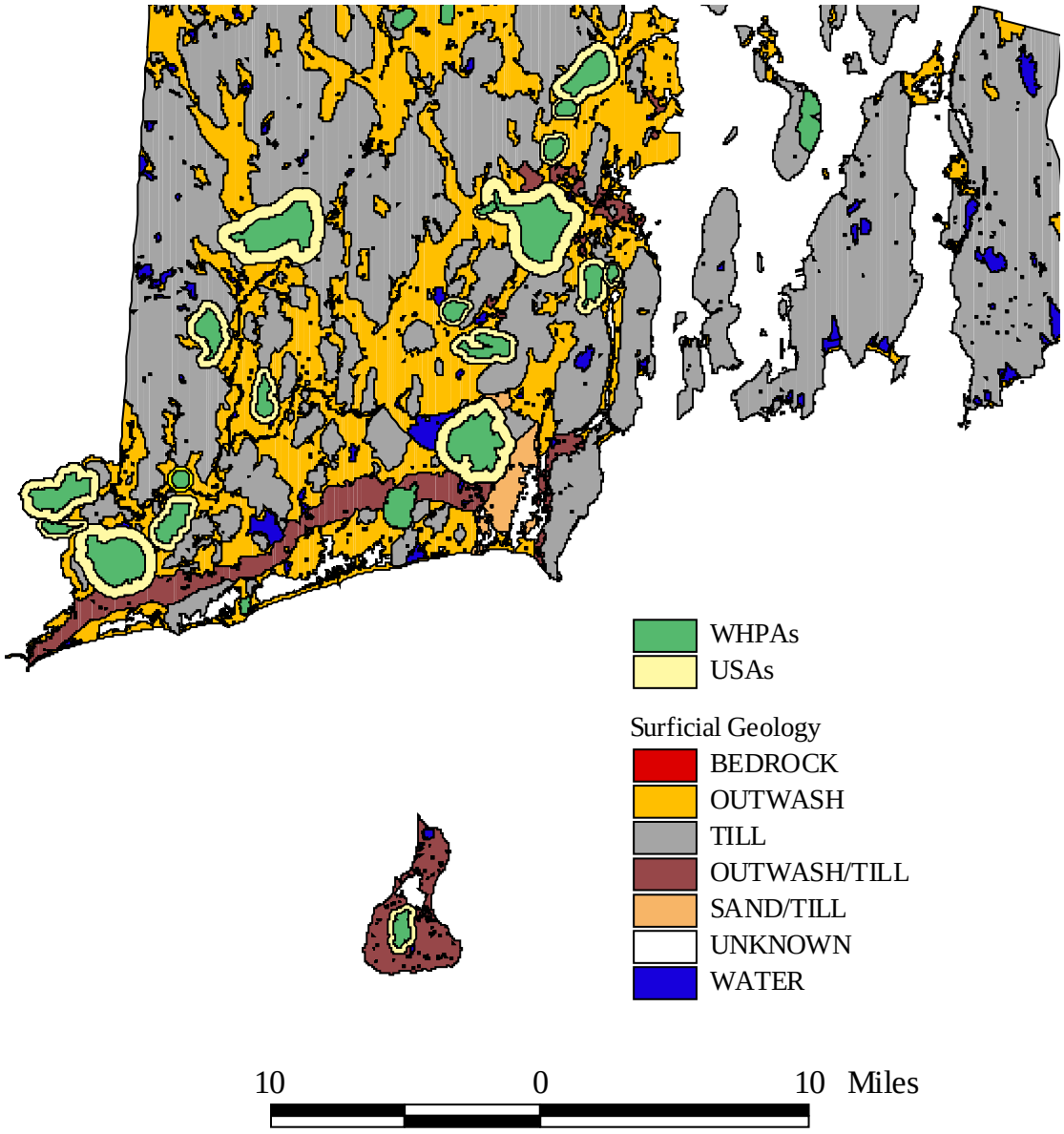

Figure 5. A closer look at the southern portion of Rhode Island showing the original wellhead protection areas (WHPAs) and resulting unusually sensitive areas (USAs) which are twice the WHPA size when the source is a sole source aquifer.

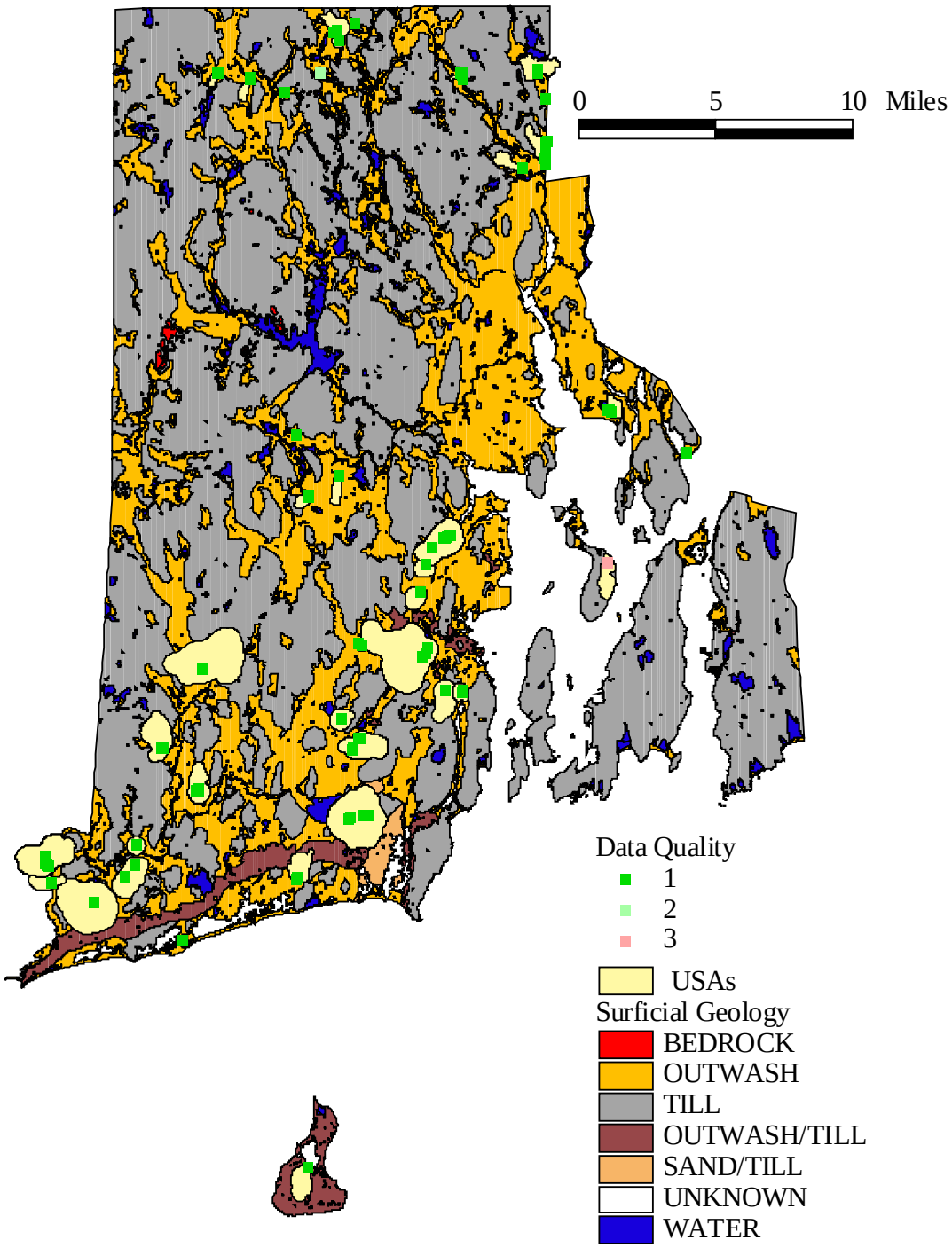

Figure 6. Rhode Island unusually sensitive areas.

Data quality is always a concern when performing spatial analysis among various data layers. Of the 95 USAs, 93 are Quality = 1 (97.8 percent), one was identified within the spatial tolerance and was Quality = 2 (1.1 percent), and one could not be accurately identified because it was beyond the spatial tolerance and was quality = 3 (1.1 percent). The two Class U wells on Block Island were quality = 4 since the source information was known to be incorrect. The most important variable in assessing the Pettyjohn vulnerability classification is the source of the water. All of the groundwater wells in the RIGIS database have source information.

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