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Groundwater Quality from Private Domestic Water-Supply Wells in the Vicinity of Petroleum Production in Southwestern Indiana

Open-File Report 2016–1081

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

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By Martin R. Risch and Cheryl A. Silcox

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Volume	
liter (L)	0.2642	gallon (gal)
	Flow rate	
liter per minute (L/min)	0.2642	gallon per minute (gal/min)

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

$$°F=(1.8×°C)+32$$

Supplemental Information

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

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

Activities for radioactive constituents in water are given in picocurie per liter (pCi/L).

Abbreviations

ATSDR	Agency for Toxic Substance and Disease Registry
DI	deionized
IDEM	Indiana Department of Environmental Management
NWQL	National Water Quality Laboratory
QC	quality control
TIC	tentatively identified compound
USGS	U.S. Geological Survey

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Abstract

The U.S. Geological Survey provided technical support to the Agency for Toxic Substances and Disease Registry for site selection and sample collection and analysis in a 2012 investigation of groundwater quality from 29 private domestic water-supply wells in the vicinity of petroleum production in southwestern Indiana. Petroleum hydrocarbons, oil and grease, aromatic volatile organic compounds, methane concentrations greater than 8,800 micrograms per liter, chloride concentrations greater than 250 milligrams per liter, and gross alpha radioactivity greater than 15 picocuries per liter were reported in the analysis of groundwater samples from 11 wells.

Introduction

The U.S. Geological Survey (USGS) provided technical support to the Agency for Toxic Substances and Disease Registry (ATSDR) of the Federal Centers for Disease Control and Prevention in an exposure investigation of groundwater quality from private domestic water-supply wells (hereinafter referred to as "private wells") in the vicinity of petroleum production in southwestern Indiana. The ATSDR was contacted by the Indiana Department of Environmental Management (IDEM) for assistance because analysis of water samples from an IDEM complaint investigation in January 2010 indicated the presence of petroleum hydrocarbons and oilfield brine constituents in private wells (Indiana Department of Environmental Management, 2016). The purpose of the ATSDR exposure investigation in 2012 was to obtain information about groundwater quality from private wells and provide information for reducing risks from exposure to contaminants in the water (Agency for Toxic Substances and Disease Registry, 2016). The USGS provided technical support for selection of sample sites, field activities, and collection and analysis of groundwater samples.

Environmental issues of petroleum production are documented by Kharaka and Dorsey (2005) and Kharaka and Otton (2007). The U.S. Environmental Protection Agency (2012, 2016), Agency for Toxic Substances and Disease Registry (2010, 2011), and U.S. Geological Survey (2016a, 2016b) have ongoing investigations and research regarding these issues. From these references, a conceptual framework was devised to guide the USGS technical support described in this report.

Description of the Study Area

Petroleum oil and natural gas production in southwestern Indiana is part of a regional reserve called the Illinois Basin Oilfield (Higley and others, 2003) that also includes southeastern Illinois and northwestern Kentucky. The Illinois Basin Oilfield also contains quantities of undiscovered, technically recoverable oil and gas resources (Sweezy, 2007, 2009). The study area included a large part of a the Mt. Vernon Consolidated Oilfield (fig. 1), one of an estimated 50 oilfields in this part of southwestern Indiana (Indiana Geological Survey, 2012). The part of the Mt. Vernon Consolidated Oilfield served by a public-water system was not included in the study area. Water supply for domestic use in the study area was from private wells. The IDEM private well sample locations from 2010 were in this study area.

Purpose and Scope

The purposes of this report are (a) to describe the methods for sample-site selection, water-sample collection, determinations and analysis of groundwater quality, and quality control (QC); and (b) to present the water-quality and QC data. The methods and data in this report are for groundwater samples from 29 private wells and 11 QC samples from the exposure investigation in 2012. Interpretations of the sources of the constituents in the water samples and health risks associated with constituent concentrations are beyond the scope of this report.

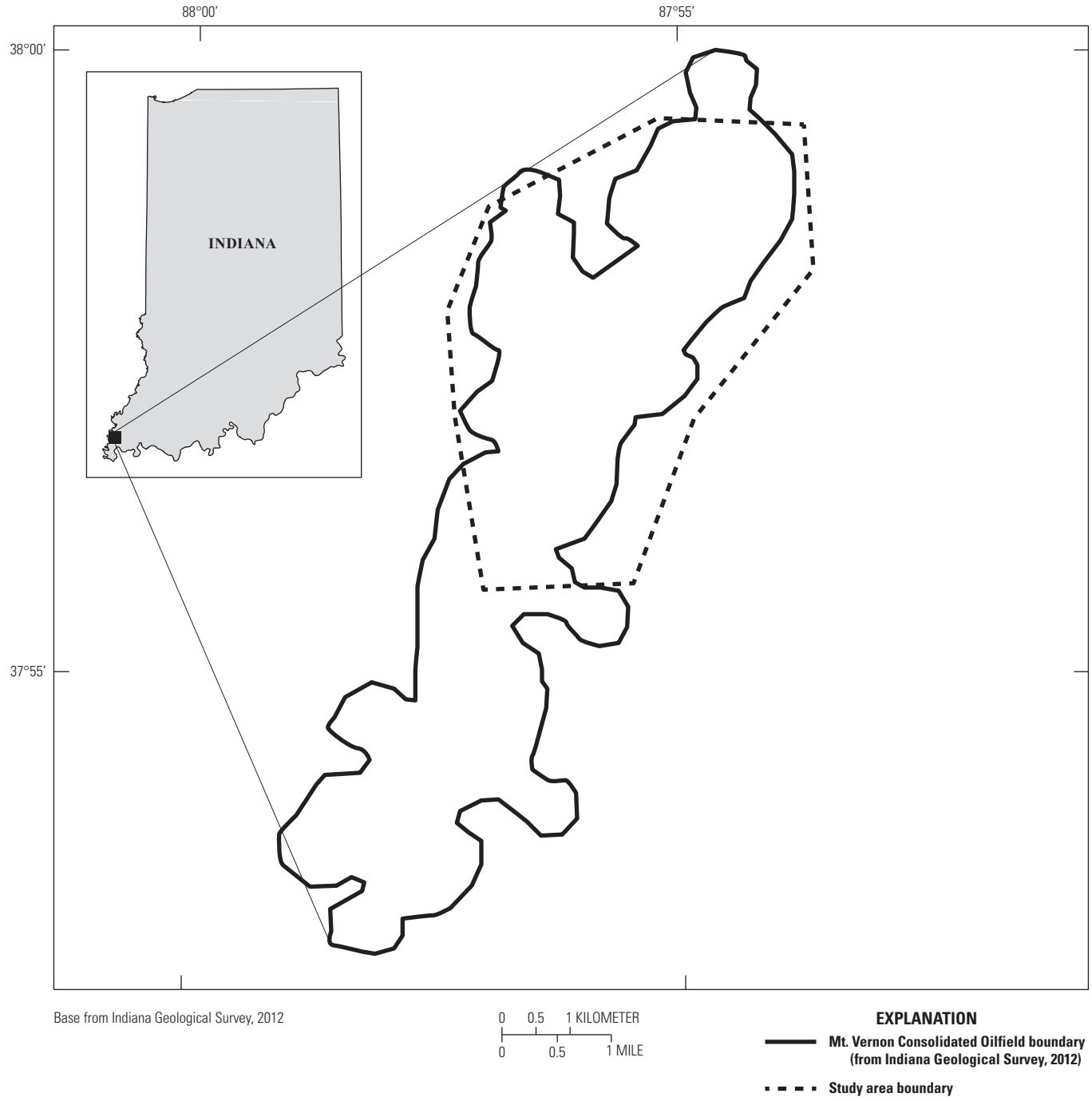

Figure 1. Study area and Mt. Vernon Consolidated Oilfield in southwestern Indiana.

Methods

This section describes the selection of private wells for this study and methods used for sample collection and processing. Methods for determination of water-quality characteristics, analysis of constituents, and preparation of samples for QC are explained.

Private Well Selection

Groundwater supplying private wells in the study area primarily is from a sandstone bedrock aquifer present in southwestern Indiana (Robison, 1977; Unterreiner, 2006). The Indiana water well database (Indiana Department of Natural Resources, 2012) was consulted for available private well records for the study area. Maps and satellite imagery were used to identify all the residences in the study area, including those that seemed to be described in the well records. This information was used to develop a list of candidates for the exposure investigation. A field reconnaissance of the candidates verified the active condition of private wells and permission from well owners to participate in the exposure investigation. From the candidate list, 29 private wells used for domestic water supply, including 7 of the 10 private wells sampled by the IDEM in 2010, were sampled in 2012 and are discussed in this report. The general locations of these private wells are in figure 2. Information in table 1 includes well depth from a well record or reported by the resident; and the open interval, aquifer type, probable aquifer material, and interval of probable aquifer material if documented in a well record. Information in table 1 confirms that the sandstone bedrock aquifer described by Robison (1977) and Unterreiner (2006) was the primary source of groundwater for the wells.

Water-Sample Collection and Processing

Standard USGS methods were used to obtain groundwater representative of the aquifer, to make field determinations of water-quality characteristics, and to collect and process water samples (U.S. Geological Survey, variously dated; DeSimone, 2009; Koterba and others, 1995). Raw, untreated, unfiltered groundwater was obtained through the well pump, pressure tank, and household plumbing of the 29 residences. For this purpose, water was obtained from a threaded faucet, which at most residences was an outside faucet. At two residences, the threaded faucet was indoors near the pressure tank. As needed, any water filter was removed and the water softener was bypassed before the faucet was opened. Field personnel attached a single-use fitting to the faucet to which they connected a valved manifold constructed of fluorocarbon resin with fluorocarbon resin tubing and stainless steel connectors. Water was allowed to run through a discharge line from the manifold, and the flow rate was measured with a graduated cylinder and stopwatch.

An electronic multimeter with a four-probe sonde in a flow-through cell was attached to the manifold. The multimeter probes were calibrated with known standards each day. Water was directed through the manifold to the flow-through cell so that probes measured the water-quality characteristics: pH, water temperature, specific conductance, and dissolved oxygen. Turbidity of the water was measured with a portable meter that was calibrated with known standards each day. Values of these five characteristics were recorded every 5 minutes until the values between five or more sequential measurements stabilized. The criteria for stabilized values were pH ±0.1 standard units, temperature ±0.2 degrees Celsius (°C), specific conductance ±3 percent (about 20 to 50 microsiemens per centimeter at 25 °C [µS/cm at 25 °C]), dissolved oxygen ±0.3 milligram per liter (mg/L), turbidity ±10 percent (0.1 to 1 nephelometric turbidity ratio units). Stabilized values of these characteristics indicated water from the plumbing, pressure tank, and standing volumes in the well casing had been purged; and groundwater from the aquifer was flowing through the manifold. At that time, groundwater samples were collected (tables 1–3).

To collect the groundwater samples, the flow rate was reduced to 0.5 liter per minute and the water was directed with the manifold to a dedicated line from which samples were collected by field personnel wearing disposable gloves and using a trace metals protocol. The groundwater samples received processing and preservation as needed and were placed in new sample containers (table 4). Containers for parameter groups were filled in the following order: dissolved gases, aromatic volatile organic compounds, polycyclic aromatic hydrocarbons, total petroleum hydrocarbons, oil and grease, radioactivity, trace elements, and major ions. Samples were stored in ice chests and shipped to the laboratory each day by overnight delivery. Records for sample site information, field data, analysis request, and chain of custody were completed.

After groundwater was obtained from each well, the manifold, tubing, and flow-through cell were cleaned by pumping or spraying the following sequence of cleaning solutions and rinses: 0.1-percent nonphosphate detergent and deionized (DI) water, DI water, 5-percent hydrochloric acid, DI water, laboratory-grade methanol, and laboratory-grade organic blank water. Cleaned sampling equipment was stored in new plastic bags.

Figure 2. General locations of private domestic water-supply wells sampled in the study.

Table 1. Information for 29 private domestic water-supply wells sampled in the study.

[Private domestic water-supply well data from record at the Indiana Department of Natural Resources (2012) unless otherwise noted; foot, foot below land surface; --, no data]

Field identification number[a]	Sample date	Sample time	Raw water sample location	Reported well depth (foot)	Screened or open interval (foot)	Aquifer type	Probable aquifer material	Interval of probable aquifer material (foot)	Resident reported well depth
PCEI–01[b]	6/5/2012	1035	Outside faucet	177	53–177	Bedrock	Sandstone, limestone	72–177	--
PCEI–02[b]	6/4/2012	1915	Outside faucet	128	44–128	Bedrock	Sandstone	92–98	--
PCEI–03[b]	6/4/2012	1245	Outside faucet	160	115–158	Bedrock	Sandstone	115–158	--
PCEI–04[b]	6/5/2012	1130	Outside faucet	--	--	--	--	--	--
PCEI–05[b]	6/7/2012	1630	Outside faucet	200	168–200	Bedrock	Sandstone	162 -200	--
PCEI–07[b]	6/7/2012	1345	Outside faucet	--	--	--	--	--	--
PCEI–08[b]	6/7/2012	1100	Pressure tank	147	50–147	Bedrock	Sandstone	120–147	--
PCEI–09	6/6/2012	1845	Outside faucet	--	--	--	--	--	290
PCEI–10	6/6/2012	1845	Outside faucet	--	--	--	--	--	170
PCEI–11	6/5/2012	1830	Outside faucet	185	150–180	Bedrock	Sandstone	136–185	--
PCEI–12	6/5/2012	1815	Outside faucet	70	60–70	Unconsolidated	Sand	58–68	--
PCEI–13	6/6/2012	1140	Outside faucet	--	--	--	--	--	150
PCEI–14	6/4/2012	1600	Outside faucet	--	--	--	--	--	80
PCEI–15	6/7/2012	1630	Outside faucet	--	--	--	--	--	130
PCEI–16	6/5/2012	1630	Outside faucet	100	62–100	Bedrock	Sandy shale	62–100	--
PCEI–17	6/7/2012	1330	Outside faucet	--	--	--	--	--	--
PCEI–19	6/7/2012	1700	Outside faucet	--	--	--	--	--	217
PCEI–20	6/5/2012	1330	Outside faucet	--	--	--	--	--	140
PCEI–22	6/4/2012	1700	Pressure tank	--	--	--	--	--	210
PCEI–23	6/4/2012	1930	Outside faucet	192	61–192	Bedrock	Sandstone	168–192	--
PCEI–24	6/6/2012	1345	Outside faucet	--	--	--	--	--	140
PCEI–25	6/6/2012	1630	Outside faucet	--	--	--	--	--	70
PCEI–26	6/6/2012	1645	Outside faucet	--	--	--	--	--	105
PCEI–27	6/6/2012	1100	Outside faucet	--	--	--	--	--	180
PCEI–28	6/5/2012	1330	Outside faucet	--	--	--	--	--	--
PCEI–29	6/7/2012	1830	Outside faucet	--	--	--	--	--	220
PCEI–30	6/5/2012	1630	Outside faucet	--	--	--	--	--	180
PCEI–31	6/6/2012	1400	Outside faucet	--	--	--	--	--	65
PCEI–34	6/5/2012	1945	Outside faucet	--	--	--	--	--	280

[a]Some field identification numbers were for candidates that were not included in this study, so that field identification numbers (prefix PCEI–) 06, 18, 21, 32, and 33 are intentionally missing.

[b]Well water was sampled and analyzed by the Indiana Department of Environmental Management in 2010.

Table 2. Purging times and volumes of groundwater from 29 private domestic water-supply wells in the study.

Field identification number	Purge time (minutes)	Purge rate (liter per minute)	Volume (liter)
PCEI–01	35	3.0	105
PCEI–02	15	3.0	45
PCEI–03	20	2.5	50
PCEI–04	35	1.6	56
PCEI–05	30	1.5	45
PCEI–07	25	7.0	175
PCEI–08	20	2.0	40
PCEI–09	15	4.0	60
PCEI–10	25	1.5	38
PCEI–11	20	1.5	30
PCEI–12	30	1.2	36
PCEI–13	35	1.5	53
PCEI–14	20	3.5	70
PCEI–15	30	1.7	51
PCEI–16	15	1.5	23
PCEI–17	30	1.5	45
PCEI–19	20	2.4	48
PCEI–20	35	1.2	42
PCEI–22	15	1.5	23
PCEI–23	40	1.4	56
PCEI–24	15	6.0	90
PCEI–25	15	1.5	23
PCEI–26	30	1.5	45
PCEI–27	40	3.5	140
PCEI–28	15	6.0	90
PCEI–29	30	2.0	60
PCEI–30	35	2.4	84
PCEI–31	30	1.5	45
PCEI–34	15	1.6	24

Water-Quality Determinations and Analysis

Parameter groups were selected to characterize groundwater quality and include constituents representative of oilfield brine and petroleum hydrocarbons. Four basic parameter groups were analyzed in groundwater samples from all 29 private wells:

1. Major ions are found at different concentrations in freshwater and saline aquifers.
2. Trace elements are found at different concentrations in freshwater and saline aquifers.
3. Gross alpha and gross beta radioactivity are emitted by radioactive elements in water. Some elements have decay products that differ in their emissions of gross alpha and gross beta radioactivity with time, so analysis of water within 72 hours of collection and again after 30 days enabled detection of radioactivity.
4. Aromatic volatile organic compounds are soluble constituents of petroleum. Tentatively identified compounds (TICs) are included, as explained here. The analytical method is sensitive to non-target constituents; and when the instrument response is compared with a digital library of compounds, some of these non-target constituents can become TICs with concentrations estimated.

Following the ATSDR protocol for the investigation, the USGS sampled and analyzed three additional parameter groups in groundwater from a maximum of 10 of the 29 private wells. These 10 private wells were selected based on excessive gas bubbles and observed petroleum odor in the samples.

1. Polycyclic aromatic hydrocarbons include soluble constituents of petroleum from an analytical method group called semivolatile organic compounds.
2. Petroleum hydrocarbons, plus oil and grease, were analyzed by separate, complementary methods. Petroleum hydrocarbon analysis included the diesel oil range (straight chain carbon) C10–C28 hydrocarbons and motor oil range C28–C36 hydrocarbons.
3. Dissolved natural gases include methane, ethane, and ethene.

Analysis of groundwater and QC samples were provided through the USGS National Water Quality Laboratory (NWQL). A list of parameter groups and methods is in table 5. The turnaround time from sample receipt to laboratory reporting was about 30 days or less. Laboratory data was transmitted electronically through the USGS National Water Information System. The constituents from each parameter group and their reporting limits are in table 6. These reporting limits for some constituents are as much as 100 times less than those used for IDEM's analysis of January 2010 samples from private wells (table 7).

Table 3. Characteristics of groundwater from 29 private domestic water-supply wells in the study.

[µS/cm, microsiemen per centimeter; °C, degree Celsius; mg/L, milligram per liter; ±, plus or minus; NTRU, nephelometric turbidity ratio unit; --, no data]

Field identification number	pH, unfiltered water, measured in the field with electrometric probe (standard unit)	Specific conductance, unfiltered water, measured in the field with electrometric probe (µS/cm at 25 °C)	Dissolved oxygen, unfiltered water, measured in the field with membrane electrode probe (mg/L)	Water temperature, unfiltered water, measured in the field with thermistor thermometer probe (°C)	Turbidity, unfiltered water, measured in the field with turbidmeter having a broad band light source (400–680 nanometer) and detectors at multiple angles including 90±30 degrees, ratiometric correction (NTRU)	Gas bubbles	Petroleum odor
PCEI–01	7.5	946	0.3	17.2	1.7	Yes	--
PCEI–02	6.7	842	0.3	16.8	0.5	--	--
PCEI–03	7.3	2,037	0.2	17.0	1.5	Yes	--
PCEI–04	8.2	946	0.3	17.5	2.1	Yes	--
PCEI–05	8.4	1,036	0.2	16.8	0.6	Yes	Yes.
PCEI–07	6.6	2,670	3.8	16.1	1.4	--	--
PCEI–08	8.4	1,078	0.3	15.2	9.8	Yes	--
PCEI–09	7.6	740	0.4	15.2	0.9	Yes	--
PCEI–10	8.2	873	0.8	17.0	5.7	Yes	Yes.
PCEI–11	8.2	784	0.2	17.1	0.9	Yes	Yes.
PCEI–12	6.7	814	0.3	20.0	4.5	--	--
PCEI–13	7.7	748	0.3	16.1	5.0	Yes	--
PCEI–14	7.8	1,002	0.3	18.9	0.9	--	Yes.
PCEI–15	8.8	1,230	0.1	15.4	0.4	Yes	Yes.
PCEI–16	6.9	755	0.3	16.0	0.1	--	--
PCEI–17	6.9	743	0.9	16.3	3.6	--	Yes.
PCEI–19	8.4	2,800	0.2	16.0	1.9	Yes	--
PCEI–20	7.8	924	0.3	18.1	4.0	--	--
PCEI–22	7.8	919	0.7	18.1	4.1	Yes	--
PCEI–23	8.1	1,530	0.4	16.0	10.8	--	--
PCEI–24	6.9	2,200	6.0	18.6	0.5	--	--
PCEI–25	6.9	1,008	3.6	21.3	0.9	--	--
PCEI–26	6.7	873	0.7	15.5	0.7	--	--
PCEI–27	8.2	2,900	0.1	17.0	0.4	Yes	--
PCEI–28	6.9	735	0.4	14.8	0.6	--	--
PCEI–29	8.1	1,210	0.3	19.0	0.8	Yes	Yes.
PCEI–30	7.6	861	1.7	15.5	2.3	--	Yes.
PCEI–31	6.8	812	1.8	16.8	0.5	--	--
PCEI–34	8.8	1,058	0.1	16.3	2.4	--	--

The NWQL treated each sample and each set of constituents in a parameter group individually. The NWQL used the field determinations data submitted with the analytical services request for each sample to identify the samples with levels of pH or specific conductance that indicated potential to degrade analytical equipment integrity and affect successive samples in the same analytical run. Laboratory analysts separated and analyzed these potentially contaminated samples with dilutions, based on the highest constituent concentration. The objective was to detect constituents present at the lowest reporting limits. If a sample was diluted for a specific set of constituents in that parameter group, the reporting limits were raised proportionally for the other constituents from that group analyzed in that sample.

Quality-Control Samples

Routine laboratory procedures included QC samples for each analytical method, plus other measures completed as part of the NWQL quality-assurance plan (D.L Stevenson, U.S. Geological Survey, written commun., 2013; D.L. Stevenson and A.R. Barnard, U.S. Geological Survey, written commun., 2013). A total of 11 QC samples were prepared in the field or transported with water samples to provide measures of sample representativeness, reproducibility, and matrix interferences associated with analytical results. The QC samples were 3 trip blanks, 2 field blanks, 3 laboratory matrix-spike samples, and 3 sequential duplicates. Parameter groups analyzed in the different QC samples vary and are listed in table 8.

Table 4. Sample containers, processing, and preservation for parameter groups.

[LS, U.S. Geological Survey lab schedule; LC, U.S. Geological Survey lab code; mL, milliliter; L, liter; HNO_3, nitric acid; HCl, hydrochloric acid; H_2SO_4, sulfuric acid]

Parameter group	Lab schedule or lab code	Containers	Processing	Preservation[a]
Major ions	LS2701	(1) 250-mL poly	Filtered[b]	None.
	LS2701	(1) 250-mL poly	Filtered[b]	HNO_3.
	LS2701	(1) 250-mL poly	None	None.
	LC3166	(1) 250-mL poly	Filtered[b]	None.
Trace elements	LS2710	(1) 250-mL poly	Filtered[b]	HNO_3.
	LS2710	(1) 250-mL poly	None	None.
Gross alpha and gross beta radioactivity	LC2806	(1) 1-L poly	None	None.
Aromatic volatile organic compounds and tentatively identified compounds	LS4435	(3) 40-mL amber glass septum vials	None	HCl.
Polycyclic aromatic hydrocarbons	LS CIN 50127	(2) 1-L amber glass	None	None.
Petroleum hydrocarbons: diesel oil range organics (C10–C28) and motor oil range organics (C28–C36)	LS CIN 50129, 50247	(2) 1-L amber glass	None	None.
Oil and grease, petroleum hydrocarbons	LS CIN 50136	(2) 1-L amber glass	None	H_2SO_4.
Dissolved natural gases	LS CIN 50131	(3) 40-mL amber glass septum vials	None	HCl.

[a]Preservation with acid to pH less than 2 standard units.

[b]Disposable capsule filter with 0.45-micrometer pore size.

Table 5. Analytical methods for parameter groups.

[LS, U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) lab schedule; LC, USGS NWQL lab code; EPA, U.S. Environmental Protection Agency SW846 method]

Parameter group	Analytical method(s)	Method description	References
Major ions	LS2701, LC3166	Ion chromatography (IC)	Fishman and Friedman (1989), and Fishman (1993).
Trace elements	LS2710	Inductively coupled plasma/mass spectrometry (ICP/MS)	Garbarino (1999), Garbarino and others (2006).
Gross alpha and beta radioactivity (72 hours and 30 days)	LC2806	Gross alpha (Th-230 curve)	U.S. Environmental Protection Agency (2007a, 2007b).
		Gross beta (Cs-137 curve)	U.S. Environmental Protection Agency (2007a, 2007b).
Aromatic volatile organic compounds and tentatively identified compounds	LS4435	Gas chromatography/mass spectrometry (GC/MS)	Connor and others (1998).
Polycyclic aromatic hydrocarbons	EPA8310	High performance liquid chromatography (HPLC)	U.S. Environmental Protection Agency (2008a).
Petroleum hydrocarbons: diesel oil range organics (C10–C28)[a]	EPA8015D	Gas chromatography/flame ionization detector (GC/FID)	U.S. Environmental Protection Agency (2008b).
Petroleum hydrocarbons: motor oil range organics (C28–C36)[a]	EPA8015D	Gas chromatography/flame ionization detector (GC/FID)	U.S. Environmental Protection Agency (2008b).
Petroleum hydrocarbons[a]	EPA1664A	Silica gel treated hexane extractable material (SGT)	U.S. Environmental Protection Agency (1999).
Oil and grease[a]	EPA1664A	Hexane extractable material (HEM)	U.S. Environmental Protection Agency (1999).
Dissolved natural gases[a]	RSK-175	Gas chromatography/flame ionization detector (GC/FID)	Kampbell and Vandergrift (1998).

[a]This parameter group was analyzed in water from 10 private domestic water-supply wells listed in table 1: (prefix PCEI-) 03, 04, 05, 10, 13, 14, 17, 19, 27, 30.

Table 6. Constituents and laboratory reporting limits by parameter group.

[µg/L, microgram per liter; pCi/L, picocurie per liter; mg/L, milligram per liter]

Constituent	Reporting limt	Units
Major ions		
Bromide	10	µg/L
Calcium	22	µg/L
Chloride	60	µg/L
Fluoride	40	µg/L
Magnesium	11	µg/L
Manganese	0.2	µg/L
Potassium	30	µg/L
Silica	18	µg/L
Sodium	60	µg/L
Sulfate	90	µg/L
Trace elements		
Aluminum	2.2	µg/L
Antimony	0.027	µg/L
Arsenic	0.03	µg/L
Barium	0.07	µg/L
Beryllium	0.006	µg/L
Boron	3.0	µg/L
Cadmium	0.016	µg/L
Chromium	0.07	µg/L
Cobalt	0.021	µg/L
Copper	0.80	µg/L
Iron	3.0	µg/L
Lead	0.025	µg/L
Lithium	0.22	µg/L
Manganese	0.13	µg/L
Molybdenum	0.014	µg/L
Nickel	0.09	µg/L
Selenium	0.03	µg/L
Silver	0.01	µg/L
Strontium	0.20	µg/L
Thallium	0.01	µg/L
Uranium	0.004	µg/L
Vanadium	0.08	µg/L
Zinc	1.4	µg/L
Radioactivity		
Gross alpha	3.0	pCi/L
Gross beta	4.0	pCi/L
Aromatic volatile organic compounds		
Methyl *tert*-Butyl ether	0.10	µg/L
Benzene	0.026	µg/L
Toluene	0.02	µg/L
Ethylbenzene	0.036	µg/L
m- and *p*-Xylene	0.08	µg/L

Constituent	Reporting limt	Units
Aromatic volatile organic compounds—Continued		
o-Xylene	0.032	µg/L
Isopropylbenzene	0.042	µg/L
n-Propylbenzene	0.036	µg/L
1,3,5-Trimethylbenzene	0.032	µg/L
2-Ethyl-toluene	0.032	µg/L
tert-Butylbenzene	0.06	µg/L
1,2,4-Trimethylbenzene	0.032	µg/L
sec-Butylbenzene	0.034	µg/L
4-Isopropyl-toluene	0.06	µg/L
1,2,3-Trimethylbenzene	0.06	µg/L
n-Butylbenzene	0.08	µg/L
1,2,3,5-Tetramethylbenzene	0.08	µg/L
1,2,3,4-Tetramethylbenzene	0.10	µg/L
Naphthalene	0.18	µg/L
Polycyclic aromatic hydrocarbons		
1-Methylnaphthalene	0.05	µg/L
2-Methylnaphthalene	0.07	µg/L
Acenaphthene	0.04	µg/L
Acenaphthylene	0.04	µg/L
Anthracene	0.06	µg/L
Benzo[*a*]anthracene	0.03	µg/L
Benzo[*a*]pyrene	0.05	µg/L
Benzo[*b*]fluoranthene	0.05	µg/L
Benzo[*g,h,i*]perylene	0.02	µg/L
Benzo[*k*]fluoranthene	0.02	µg/L
Chrysene	0.03	µg/L
Dibenzo(*a,h*)anthracene	0.05	µg/L
Fluoranthene	0.08	µg/L
9H-Fluorene	0.1	µg/L
Indeno[1,2,3-*cd*]pyrene	0.05	µg/L
Phenanthrene	0.1	µg/L
Pyrene	0.04	µg/L
Petroleum and oil		
Hexane extractable oil and grease	5.0	mg/L
Hexane extractable petroleum	5.0	mg/L
Total petroleum hydrocarbons	0.25	mg/L
Diesel oil range organics	0.25	mg/L
Motor oil range organics	0.50	mg/L
Methane	3.0	µg/L
Ethane	3.0	µg/L
Ethene	3.0	µg/L

Table 7. Comparison of two sets of reporting limits for selected constituents.

[All reporting limits in microgram per liter]

Constituent	U.S. Geological Survey reporting limit	Other reporting limit
Aromatic volatile organic compounds		
Benzene	0.026	1.0[a]
Toluene	0.02	1.0[a]
Ethylbenzene	0.036	1.0[a]
m- and *p*-Xylene	0.08	2.0[a]
o-Xylene	0.032	1.0[a]
Trace elements		
Arsenic	0.03	10[b]
Barium	0.07	2.0[b]
Cadmium	0.016	2.0[b]
Chromium	0.07	3.0[b]
Selenium	0.03	30[b]

[a]Other reporting limit is from Indiana Department of Environmental Management laboratory analysis of water samples from private wells in the study area collected in January 2010; analysis by U.S. Environmental Protection Agency (EPA) Method 8260.

[b]Other reporting limit is from Indiana Department of Environmental Management laboratory analysis of water samples from private wells in the study area collected in January 2010; analysis by EPA Method 6010B.

Table 8. Quality-control samples and parameter groups analyzed.

Quality-control sample	Number of samples[a]	Parameter groups analyzed
Field blank	2	Major ions, trace elements, volatile organic compounds.
Trip blank	3	Volatile organic compounds and dissolved gases in 2 samples; dissolved gases in 1 sample.
Laboratory matrix-spike	3	Volatile organic compounds in 3 samples; add polycyclic aromatic hydrocarbons, petroleum and oil for 1 sample.
Sequential duplicate	3	Major ions, trace elements, volatile organic compounds and radioactivity in 3 samples; polycyclic aromatic hydrocarbons, petroleum and oil, and dissolved gases in 1 sample.

[a]Number of samples for each quality contol type is based on a ratio of 1 field blank and trip blank per sampling team and 2 sampling teams, plus 3 duplicates and matrix spikes per 10 water samples.

Groundwater Quality in Private Domestic Water-Supply Wells

Petroleum hydrocarbons, oil and grease, aromatic volatile organic compounds, methane concentrations greater than 8,800 micrograms per liter (µg/L), chloride concentrations greater than 250 mg/L, and gross alpha radioactivity greater than 15 picocuries per liter (piC/L) were reported in analysis of groundwater samples from 11 of the 29 private wells (table 9; fig. 3). The reference concentrations are explained in the following sections of the report. Two of the 11 private wells, PCEI–03 and PCEI–27, had water with petroleum hydrocarbons, oil and grease, aromatic volatile organic compounds, methane, and chloride greater than 250 mg/L. Groundwater from three private wells (PCEI–03, PCEI–04, and PCEI–24) had chloride concentrations greater than 250 mg/L and gross alpha radioactivity greater than 15 pCi/L.

As previously mentioned, the ATSDR protocol for the investigation used the presence of excessive gas bubbles and petroleum odor to qualify a maximum of 10 groundwater samples from the 29 private wells for analysis of petroleum hydrocarbons, polycyclic aromatic hydrocarbons, and dissolved gases. Of the 10 private wells that qualified (table 9), total petroleum hydrocarbons were detected in groundwater from 8 private wells; oil and grease were reported in water from 10 private wells; and methane was reported in groundwater from all 9 of the private wells where petroleum hydrocarbons and oil and grease were detected. Volatile organic compounds were detected in groundwater from 15 private wells, including 5 samples that also contained petroleum hydrocarbons, oil and grease, and methane. Groundwater from PCEI–24 was not analyzed for these additional constituents because excessive gas bubbles and petroleum odor were not present. Groundwater samples from seven private wells where petroleum hydrocarbons and methane were not analyzed had excessive gas bubbles and some samples also had a petroleum odor in the water (table 3). Because of the limits of this investigation, additional analytical data are not available to know whether petroleum hydrocarbons, polycyclic aromatic hydrocarbons, oil and grease, or dissolved gases (such as methane) were present in groundwater from these other seven private wells.

Table 9. Summary of selected constituent detections in groundwater samples from private domestic water-supply wells.

[TIC, tentatively identified compound; >, greater than; µg/L, microgram per liter; mg/L, milligram per liter; pCi/L, picocurie per liter]

Constituent	Number of wells	Wells with reported concentrations (prefix PCEI–)	Notes
Total petroleum hydrocarbons—sum of diesel oil and motor oil range organics	8	03, 04, 05, 10, 13, 14, 19, 30	Samples from 10 wells analyzed.
Oil and grease	10	03, 04, 05, 10, 13, 14, 17, 19, 27, 30	Samples from 10 wells analyzed.
Methane	9	03, 04, 05, 10, 13, 14, 19, 27, 30	Concentration greater than 8,800 µg/L.
Aromatic volatile organic compounds	3	12, 26, 27	Samples from 29 wells analyzed.
Carbonyl sulfide	9	04, 08, 09, 11, 13, 15, 16, 26, 29	TIC.
Carbon disulfide	3	19, 22, 34	TIC.
Volatile organic compound TICs	4	03, 19, 22, 27	13 TICs at site PCEI–27.
Chloride > 250 mg/L[a]	5	03, 07, 19, 24, 27	Samples from 29 wells analyzed.
Gross alpha radioactivity >15 pCi/L[b]	3	03, 07, 24	Samples from 26 wells analyzed.

[a]Common reference value is U.S. Environmental Protection Agency (2015a) secondary drinking water standard.

[b]Common reference value is U.S. Environmental Protection Agency (2015b) maximum contaminant level.

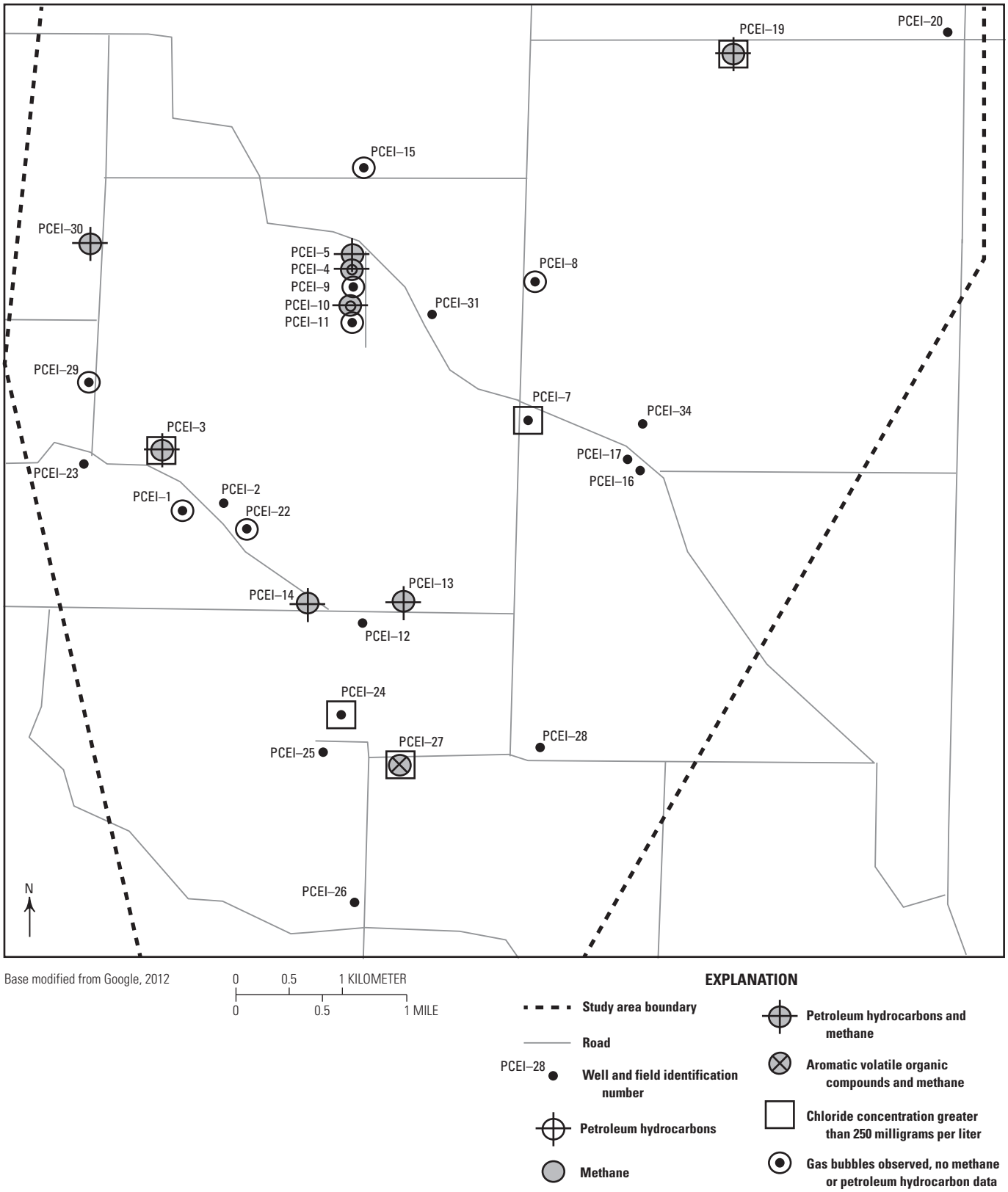

Figure 3. Private domestic water-supply wells with groundwater samples containing petroleum hydrocarbons, methane, aromatic volatile organic compounds, and excessive chloride.

Major Ions

Groundwater samples from all 29 private wells were analyzed for the dissolved major cations calcium, magnesium, potassium, and sodium; the major anions calcium carbonate, chloride, fluoride, and sulfate; and bromide and silica (table 10). Total dissolved solids, generally representing the sum of dissolved cations and anions, were reported in all samples and ranged from 426 to 1,750 mg/L (median 600 mg/L). Total dissolved solids in 24 samples were greater than a common reference value of 500 mg/L, which is the U.S. Environmental Protection Agency (2015a) secondary drinking-water standard. Chloride was detected in all water samples and had a maximum concentration of 705 mg/L and a median of 76 mg/L. Chloride concentrations in five samples were greater than 250 mg/L, which is the U.S. Environmental Protection Agency (2015a) secondary drinking-water standard. One well, PCEI–24, had total dissolved solids, chloride, iron, and manganese concentrations in samples that exceeded the secondary drinking-water standards.

Trace Elements

Groundwater samples from all 29 private wells were analyzed for 23 dissolved trace elements; and each of these constituents was detected in at least 1 sample (appendix 1). Manganese concentrations in five samples exceeded a common reference value, the U.S. Environmental Protection Agency (2015b) secondary drinking-water standard of 50 µg/L. The median manganese concentration was 10 µg/L, four concentrations were greater than 100 µg/L, and the maximum concentration was 803 µg/L. Iron concentrations in nine samples exceeded the secondary drinking-water standard of 300 µg/L. The median iron concentration was 56 µg/L, five concentrations were greater than 600 µg/L, and the maximum concentration was 1,400 µg/L. Three private wells—PCEI–24, PCEI–26, and PCEI–28—had manganese and iron concentrations in samples that exceeded the secondary drinking-water standards.

Radioactivity

Analysis of 72-hour and 30-day gross alpha and gross beta radioactivity was completed for groundwater samples from 26 of the 29 private wells (tables 11 and 12). The 72-hour gross alpha radioactivity in PCEI–03, PCEI–07, and PCEI–24 was approximately twice that of a common reference value, the U.S. Environmental Protection Agency (2015b) maximum contaminant level of 15 pCi/L. The median gross alpha radioactivity from the 72-hour and 30-day analyses was 5.2 and 3.2 pCi/L, respectively. The analyses did not identify the elements that are the source(s) of the radioactivity.

Aromatic Volatile Organic Compounds and Polycyclic Aromatic Hydrocarbons

Groundwater samples from all 29 private wells were analyzed for 23 aromatic volatile organic compounds that were target analytes; there were three detections in the PCEI–26 sample: 0.37 µg/L ethylbenzene, 0.044 µg/L *o*-xylene, and 0.14 µg/L *m*-plus-*p*-xylene (appendix 1). In this analysis, two TICs were frequently detected: an estimated 0.1 to 0.2 µg/L carbon disulfide was detected in three samples, and an estimated 0.2 to 0.8 µg/L carbonyl sulfide was detected in nine other samples, including the sample from PCEI–26. Groundwater from PCEI–27 had an estimated 37.4 µg/L of 13 TICs and samples from four other wells had 0.1 to 2.5 µg/L of a TIC reported. Groundwater samples from 10 wells were analyzed for 17 polycyclic aromatic hydrocarbons and none were detected (appendix 1).

Petroleum Hydrocarbons and Dissolved Gases

Total petroleum hydrocarbons (sum of diesel oil range and motor oil range concentrations) were detected in water from 8 of the 10 private wells sampled and ranged from 281 to 1,100 µg/L (table 13). Concentrations of diesel oil range organic compounds (C10 to C28) were approximately 5 to 7 times greater than motor oil range organic compounds (C28 to C36). In the eight water samples with reported total petroleum hydrocarbons, estimated concentrations of hexane-extractable oil and grease also were reported and ranged from 2.2 to 4.5 mg/L. Field blank data indicated three samples with the lowest concentrations may include oil and grease as sampling artifacts.

Methane was the dominant dissolved gas detected in groundwater from all 10 private wells sampled (table 13). In nine of these samples, the laboratory noted the high amount of dissolved gas was a matrix interference for the analysis and estimated the concentrations could be greater than those reported, ranging from 8,800 to 24,000 µg/L.

Table 10. Dissolved solids and major ions concentrations in groundwater from 29 private domestic water-supply wells in the study.

[mg/L, milligram per liter; <, less than reporting limit listed]

Field identification number	Dissolved solids water, filtered (mg/L)	Calcium, water, filtered (mg/L)	Magnesium, water, filtered (mg/L)	Potassium, water, filtered (mg/L)	Sodium, water, filtered (mg/L)	Hardness as calcium carbonate, water, filtered (mg/L)	Bromide, water, filtered (mg/L)	Chloride, water, filtered (mg/L)	Fluoride, water, filtered (mg/L)	Silica as silicon dioxide, water, filtered (mg/L)	Sulfate, water, filtered (mg/L)
PCEI–01	684	20.8	10.8	1.92	248	96.7	0.486	107	1.50	13.8	1.76
PCEI–02	522	99.3	50.1	0.64	24	455	<0.010	15	0.29	25.1	18.1
PCEI–03	1,240	40.5	13.5	2.70	427	158	<0.020	440	1.05	14.7	6.49
PCEI–04	602	4.94	1.34	1.26	241	18.0	0.346	83	1.68	10.1	<0.09
PCEI–05	682	3.20	0.68	1.34	258	10.9	<0.010	88	1.68	7.94	<0.09
PCEI–07	1,750	183	89.6	0.69	257	826	0.085	705	no data	26.6	65.4
PCEI–08	816	3.08	0.87	1.35	321	11.4	<0.010	174	2.22	8.00	<0.09
PCEI–09	510	16.8	6.51	1.88	167	69.3	0.120	20	0.55	13.7	<0.09
PCEI–10	564	5.39	2.19	1.25	206	22.7	0.309	74	1.62	9.84	<0.09
PCEI–11	540	5.52	2.08	1.19	211	22.6	0.284	69	1.73	10.8	<0.09
PCEI–12	481	99.7	47.3	0.39	17	444	<0.010	31	0.41	33.0	8.48
PCEI–13	479	19.8	7.77	1.23	154	81.9	0.254	54	0.75	14.2	<0.09
PCEI–14	609	12.4	5.90	1.15	229	55.7	0.424	98	1.39	12.4	0.17
PCEI–15	828	1.06	0.31	0.86	328	3.98	<0.010	111	2.21	7.20	<0.09
PCEI–16	448	87.2	24.3	2.39	61	319	<0.010	2	0.13	33.7	4.17
PCEI–17	457	84.9	28.6	2.64	45	331	<0.010	4	0.08	30.1	15.4
PCEI–19	1,720	1.89	0.94	1.87	680	8.75	1.470	387	3.68	6.71	<0.45
PCEI–20	584	14.3	7.42	1.51	212	66.4	0.081	13	0.79	10.3	36.6
PCEI–22	570	14.4	5.66	1.34	213	59.7	0.382	84	1.60	13.6	<0.09
PCEI–23	997	5.85	1.58	1.80	380	21.3	0.997	241	2.05	10.0	<0.45
PCEI–24	1,290	128	78.1	2.78	227	645	1.330	503	0.16	20.7	18.3
PCEI–25	600	122	58.0	0.54	17	545	<0.010	76	0.37	22.4	2.21
PCEI–26	532	105	50.7	0.74	27	470	<0.010	2	0.70	33.0	3.87
PCEI–27	1,640	22.2	16.6	2.02	539	125	1.900	659	1.34	8.66	34.3
PCEI–28	426	85.4	35.6	0.68	42	360	<0.010	3	0.45	30.6	5.28
PCEI–29	786	6.90	2.27	1.52	298	26.8	<0.010	150	1.89	10.2	<0.09
PCEI–30	564	19.9	5.62	1.61	200	73.3	0.327	70	1.80	15.5	<0.09
PCEI–31	500	95.7	50.4	0.29	19	447	0.092	19	0.44	26.2	42.0
PCEI–34	660	1.15	0.40	0.86	268	4.62	0.292	69	2.05	7.89	<0.09

Table 11. Gross alpha radioactivity in groundwater from 26 private domestic water-supply wells in the study.

[pCi/L, picocurie per liter; CSU, combined standard uncertainty; ssMDC, sample specific minimum detectable concentration; ssLc, sample specific critical level; mL, milliliter; mg/L, milligram per liter; ND, not detected at ssLc]

Field identification number[a]	Gross alpha radioactivity, 72 hour (pCi/L)	CSU[b] (pCi/L)	ssMDC[c] (pCi/L)	ssLc[d] (pCi/L)	Sample aliquot[e] (mL)	Gross alpha radioactivity, 30 day (pCi/L)	CSU[b] (pCi/L)	ssMDC[c] (pCi/L)	ssLc[d] (pCi/L)	Sample aliquot[e] (mL)	Dissolved solids (mg/L)
PCEI–01	4.8	1.6	3.9	1.7	85	3.7	1.5	3.9	1.7	85	684
PCEI–02	8.2	1.7	3.2	1.4	90	2.5	1.2	3.5	1.5	90	522
PCEI–03	31.0	5.0	6.8	2.9	60	14.7	3.1	5.0	2.0	60	1,240
PCEI–04	5.2	1.6	3.8	1.7	100	4.5	1.5	3.1	1.3	100	602
PCEI–05	3.3	1.4	3.7	1.6	100	3.6	1.4	3.7	1.6	100	682
PCEI–07	31.6	5.3	8.2	3.6	45	8.8	3.3	8.8	3.9	45	1,750
PCEI–08	ND	1.4	5.5	2.4	83	2.1	1.3	4.0	1.6	83	816
PCEI–09	8.0	1.7	3.1	1.4	120	2.5	0.8	1.6	0.6	300	510
PCEI–10	9.3	1.8	3.1	1.3	120	3.7	1.3	3.5	1.5	120	564
PCEI–11	3.9	1.1	2.5	1.1	120	5.3	1.2	1.8	0.7	120	540
PCEI–12	4.6	1.2	2.6	1.1	150	2.1	0.9	2.3	1.0	150	481
PCEI–13	11.2	1.9	2.8	1.2	135	1.2	1.0	3.1	1.4	135	479
PCEI–14	12.2	2.4	4.3	1.9	90	3.2	1.5	4.2	1.8	90	609
PCEI–15	2.6	1.5	4.7	2.0	80	3.0	1.7	4.5	1.9	80	828
PCEI–16	7.7	1.6	2.8	1.2	120	7.2	1.5	2.1	0.9	120	448
PCEI–17	3.2	1.1	2.9	1.2	110	4.0	1.2	2.8	1.2	110	457
PCEI–22	10.8	2.0	3.1	1.3	110	5.5	1.5	3.5	1.5	110	570
PCEI–23	4.1	1.9	5.5	2.4	70	ND	1.7	6.9	3.0	70	997
PCEI–24	30.9	5.1	6.7	2.9	45	12.9	3.4	7.6	3.3	45	1,290
PCEI–25	8.1	1.7	3.1	1.3	100	2.2	1.3	3.5	1.5	100	600
PCEI–26	4.0	1.2	2.8	1.2	100	1.8	1.2	3.6	1.6	100	532
PCEI–27	2.2	3.0	9.8	4.3	40	0.9	2.7	9.3	4.1	40	1,640
PCEI–28	5.9	1.3	2.5	1.0	120	1.4	0.7	2.0	0.8	120	426
PCEI–30	3.8	1.3	3.2	1.4	120	4.1	1.0	1.5	0.5	120	564
PCEI–31	4.2	1.1	2.5	1.1	130	0.7	0.7	2.2	0.9	130	500
PCEI–34	2.4	1.1	3.1	1.3	100	1.7	1.0	2.5	1.0	100	660

[a]Sample bottle for PCEI–20 was broken in transit; samples PCEI–19 and PCEI–29 were not submitted to the laboratory because holding time for analysis would have been exceeded.

[b]Combined standard uncertainty (CSU) is the 1-sigma (68-percent) uncertainty equivalent to one standard deviation; sample results can be listed as the reported concentration plus or minus the CSU (McCurdy and others, 2008).

[c]Sample specific minimum detectable concentration is compared with the minimum detectable concentration for the laboratory method, 3 pCi/L.

[d]Sample specific critical level is the smallest measured concentration statistically different from analytical blank and serves as the detection threshold used to determine if radioactivity is present in the sample (McCurdy and others, 2008).

[e]Sample aliquot sized selected to keep the sample residues less than or equal to 100 milligrams before analysis; aliquots are reduced according to the dissolved solids present and the sample specific minimum detectable concentration adjusted accordingly.

Table 12. Gross beta radioactivity in groundwater from 26 private domestic water-supply wells in the study.

[pCi/L, picocurie per liter; CSU, combined standard uncertainty; ssMDC, sample specific minimum detectable concentration; ssLc, sample specific critical level; mL, milliliter; mg/L, milligram per liter; ND, not detected at ssLc]

Field identification number[a]	Gross beta radioactivity, 72 hour (pCi/L)	CSU[b] (pCi/L)	ssMDC[c] (pCi/L)	ssLc[d] (pCi/L)	Sample aliquot[e] (mL)	Gross beta radioactivity, 30 day (pCi/L)	CSU[b] (pCi/L)	ssMDC[c] (pCi/L)	ssLc[d] (pCi/L)	Sample aliquot[e] (mL)	Dissolved solids (mg/L)
PCEI–01	1.8	0.7	2.0	1.0	240	2.5	0.7	2.0	1.0	240	684
PCEI–02	2.1	0.6	1.7	0.8	260	2.8	0.5	1.4	0.7	260	522
PCEI–03	4.3	0.6	1.4	0.7	60	8.1	0.8	1.9	0.9	170	1,240
PCEI–04	1.3	0.5	1.5	0.7	280	2.5	0.6	1.6	0.8	280	602
PCEI–05	2.7	0.6	1.7	0.8	250	1.4	0.6	1.9	0.9	250	682
PCEI–07	4.8	1.0	2.9	1.4	115	4.7	1.0	2.8	1.4	115	1,750
PCEI–08	ND	0.7	2.2	1.1	210	1.5	0.7	2.2	1.1	210	816
PCEI–09	4.0	0.7	1.9	0.9	300	2.9	0.4	1.0	0.5	300	510
PCEI–10	1.9	0.5	1.4	0.7	300	2.0	0.4	1.1	0.5	300	564
PCEI–11	1.9	0.5	1.4	0.7	300	2.3	0.5	1.6	0.8	300	540
PCEI–12	ND	0.6	2.0	1.0	150	1.7	0.7	2.1	1.0	150	481
PCEI–13	3.6	0.4	1.1	0.5	300	2.3	0.4	1.2	0.6	300	479
PCEI–14	2.8	0.6	1.6	0.8	260	3.4	0.5	1.4	0.7	260	609
PCEI–15	3.0	0.7	2.0	1.0	200	2.4	1.0	3.0	1.4	200	828
PCEI–16	2.5	0.6	1.9	0.9	300	2.3	0.6	1.7	0.8	300	448
PCEI–17	3.3	0.5	1.5	0.7	300	2.4	0.5	1.4	0.7	300	457
PCEI–22	2.3	0.5	1.5	0.7	300	3.1	0.4	1.1	0.5	300	570
PCEI–23	2.9	1.0	2.9	1.4	200	3.2	0.6	1.6	0.8	200	997
PCEI–24	4.8	0.9	2.7	1.3	115	3.8	0.8	2.5	1.2	115	1,290
PCEI–25	2.4	0.8	2.3	1.1	250	3.8	0.5	1.3	0.7	250	600
PCEI–26	1.4	0.6	1.7	0.8	260	2.1	0.4	1.3	0.6	260	532
PCEI–27	3.6	1.0	2.8	1.4	105	3.8	1.0	3.1	1.5	105	1,640
PCEI–28	2.1	0.5	1.5	0.7	300	1.4	0.5	1.5	0.7	300	426
PCEI–30	2.2	0.5	1.4	0.7	300	2.0	0.5	1.4	0.7	300	564
PCEI–31	1.0	0.5	1.5	0.7	300	1.5	0.3	1.0	0.5	300	500
PCEI–34	0.9	0.5	1.6	0.8	280	1.3	0.7	2.1	1.0	280	660

[a]Sample bottle for PCEI–20 was broken in transit; samples PCEI–19 and PCEI–29 were not submitted to the laboratory because holding time for analysis would have been exceeded.

[b]Combined standard uncertainty (CSU) is the 1-sigma (68-percent) uncertainty equivalent to one standard deviation; sample results can be listed as the reported concentration plus or minus the CSU (McCurdy and others, 2008).

[c]Sample specific minimum detectable concentration is compared with the minimum detectable concentration for the laboratory method, 4 pCi/L.

[d]Sample specific critical level is the smallest measured concentration statistically different from analytical blank and serves as the detection threshold used to determine if radioactivity is present in the sample (McCurdy and others, 2008).

[e]Sample aliquot sized selected to keep the sample residues less than or equal to 100 milligrams before analysis; aliquots are reduced according to the dissolved solids present and the sample specific minimum detectable concentration adjusted accordingly.

Table 13. Petroleum hydrocarbons, oil and grease, and dissolved gases concentrations in groundwater from 10 private domestic water-supply wells in the study.

[E indicates estimated concentration higher than the method detection limit but lower than the reporting limit for all constituents except for methane; methane concentrations are estimated as biased low because of matrix interference. µg/L, microgram per liter; mg/L, milligram per liter; <, less than reporting limit listed]

Field identification number[a]	Diesel oil range organic compounds, water, unfiltered, recoverable (µg/L)	Motor oil range organic compounds, water, unfiltered, recoverable (µg/L)	Total petroleum hydrocarbons, sum of diesel oil and motor oil range, unfiltered (µg/L)	Oil and grease, water, unfiltered, hexane extraction, recoverable (mg/L)[b]	Petroleum hydrocarbons, water, unfiltered, silica gel treated-hexane extractable, recoverable (mg/L)	Methane, water, unfiltered, recoverable (µg/L)	Ethane, water, unfiltered, recoverable (µg/L)	Ethene, water, unfiltered, recoverable (µg/L)
PCEI–03	780	160 E	940	2.6 E	<0.770	10,000 E	0.8	<0.4
PCEI–04	610	94 E	704	3.7 E	<0.780	24,000 E	1.3	<0.4
PCEI–05	690	100 E	790	4.5 E	<0.780	15,000 E	1.1	<0.4
PCEI–10	440	80 E	520	3.4 E	<0.780	11,000 E	0.4 E	<0.4
PCEI–13	220 E	61 E	281 E	3.3 E	<0.770	8,800 E	0.3 E	<0.4
PCEI–14	230 E	55 E	285 E	2.3 E	<0.760	9,300 E	1.3	<0.4
PCEI–17	<240	<480	<480	2.5 E	<0.760	3.2	<0.1	<0.4
PCEI–19	40 E	<480	<480	2.6 E	<0.770	15,000 E	0.9	<0.4
PCEI–27	<240	<490	<490	2.2 E	<0.760	8,900 E	9.1 E	<0.4
PCEI–30	930	170 E	1,100	4.3 E	<0.770	10,000 E	1.2	<0.4

[a]The following sites did not have a sample analyzed for petroleum hydrocarbons and dissolved gases: (prefix PCEI-) 01, 02, 07, 08, 09, 11, 12, 15, 16, 20, 22, 23, 24, 25, 26, 28, 31, 34.

[b]All reported concentrations of hexane extractable oil and grease were estimated at less than the 5.0 milligrams per liter (mg/L) reporting limit; the maximum concentration in two field blanks was 2.4 mg/L, which means than three concentrations less than or equal to 2.5 mg/L may have oil and grease artifacts.

Quality-Control Samples

Analysis was completed for 11 QC samples, which included 3 trip blanks, 2 field blanks, 3 laboratory matrix-spike samples, and 3 sequential duplicates (appendix 1). Trip blanks indicated no artifacts of aromatic volatile organic compounds or dissolved gases greater than the reporting limit were introduced into samples during storage or transportation. Field blanks indicated a potential for low-level artifacts of antimony in 2 samples, manganese in 1 sample, silver in 1 sample, and cobalt in 20 samples. Field blanks indicated a potential for low-level artifacts of hexane-extractable oil and grease in three samples, although the field blanks had no detectable silica gel-treated hexane extractable oil and grease or detectable petroleum hydrocarbons. One field blank had detections of the aromatic volatile organic compounds acetone and methyl ethyl ketone attributed to insufficient removal of methanol from equipment cleaning before the field blank. Detections of these two constituents in four water samples were considered to be artifacts. The three matrix-spike samples analyzed for aromatic volatile organic compounds had a median 93-percent recovery for all constituents and did not indicate a matrix interference that would affect the detections in the PCEI–26 sample. The percent recovery of three surrogate spike volatile organic compounds indicated no bias in analysis of blanks and duplicates. The duplicate samples indicated no systematic bias for trace elements. Hexane-extractable oil and grease and methane had a relative percent difference between duplicates of 25 and 31 percent, respectively, likely related to uncertainty in the concentrations.

Summary

Collection and analysis of groundwater samples from 29 private domestic water-supply wells was completed by the U.S. Geological Survey to support the Agency for Toxic Substances and Disease Registry (ATSDR) exposure investigation in southwestern Indiana during 2012. Groundwater samples were analyzed for parameter groups associated with petroleum production and oilfield brine, consistent with contamination of private wells in the study area identified by the Indiana Department of Environmental Management (IDEM). Methods and data for the water sample analyses are presented in this report, along with quality-control data that qualified the analytical data. Interpretation of the sources or implications of contamination are not included in this report.

At least 11 of the 29 private wells in the study had groundwater samples with petroleum hydrocarbons, oil and grease, aromatic volatile organic compounds, methane greater than 8,800 micrograms per liter, chloride greater than the 250 milligrams per liter (mg/L) secondary drinking-water standard, and gross alpha radioactivity greater than the 15 picocuries per liter maximum contaminant level. The protocol for the investigation used field observations of excessive gas bubbles and petroleum odor to identify a maximum of 10 private well samples to be analyzed for petroleum hydrocarbons, polycyclic aromatic hydrocarbons, and dissolved gases, which included 10 of these 11 private wells. The other private well, PCEI–24, had water with chloride greater than 250 mg/L and gross alpha radioactivity greater than 15 picocuries per liter, but the water was not analyzed for petroleum hydrocarbons, polycyclic aromatic hydrocarbons, or dissolved gases because excessive gas bubbles and petroleum odor were absent. Another seven wells that had water with excessive gas bubbles and petroleum odor were not able to be analyzed for petroleum hydrocarbons or methane because of the protocols of the investigation.

The data presented in this report measured the quality of groundwater from the 29 wells at one point in time in 2012. Groundwater from 7 of the 29 private wells had been sampled and analyzed by the IDEM in 2010. Total petroleum hydrocarbon concentrations in samples from four of the seven private wells in 2012 were similar to those reported by the IDEM in 2010, whereas the other three wells did not have samples analyzed for petroleum hydrocarbons in 2012. Chloride concentrations in water from all seven private wells for 2012 were similar to those reported by the IDEM for 2010. Groundwater quality from other private wells in this study area and in a larger geographic area of petroleum production in this part of Indiana, along with changes with time in this study area, cannot be described with the data from this investigation.

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Appendix 1

Table 1–1. Trace elements concentrations in samples from groundwater from 29 private domestic water-supply wells in the study.

[All concentrations in microgram per liter. <, less than reporting limit listed]

Field identification number	Aluminum, water, filtered	Barium, water, filtered	Beryllium, water, filtered	Cadmium, water, filtered	Chromium, water, filtered	Cobalt, water, filtered[a]	Copper, water, filtered	Iron, water, filtered	Lead, water, filtered
PCEI–01	<2.2	261	0.018	<0.016	0.08	1.06	0.97	6	0.504
PCEI–02	<2.2	602	0.038	<0.016	0.08	0.044	<0.80	758	<0.025
PCEI–03	<2.2	599	0.036	<0.016	<0.07	0.040	<0.80	326	<0.025
PCEI–04	<2.2	143	0.017	<0.016	<0.07	0.109	<0.80	25	0.100
PCEI–05	2.3	108	0.027	<0.016	<0.07	0.029	<0.80	16	0.079
PCEI–07	<6.6	517	<0.018	<0.048	0.24	0.371	4.20	25	0.117
PCEI–08	<2.2	96	0.030	<0.016	<0.07	0.054	2.60	19	0.160
PCEI–09	<2.2	292	0.018	<0.016	<0.07	0.022	<0.80	56	0.090
PCEI–10	<2.2	179	0.022	<0.016	<0.07	0.030	<0.80	27	0.026
PCEI–11	<2.2	163	0.023	<0.016	<0.07	0.025	<0.80	36	<0.025
PCEI–12	<2.2	314	<0.006	0.033	<0.07	0.309	10.2	37	0.224
PCEI–13	<2.2	202	0.020	<0.016	<0.07	0.058	<0.80	566	0.030
PCEI–14	<2.2	184	0.027	<0.016	0.19	0.194	<0.80	102	0.027
PCEI–15	2.3	54	0.025	<0.016	<0.07	0.049	<0.80	7	0.119
PCEI–16	<2.2	868	0.006	<0.016	<0.07	0.037	<0.80	796	<0.025
PCEI–17	<2.2	439	<0.006	<0.016	<0.07	0.058	<0.80	318	0.123
PCEI–19	<6.6	100	0.032	<0.048	<0.21	<0.063	3.30	16	0.198
PCEI–20	13.6	70	0.021	0.042	0.13	0.446	4.60	10	0.138
PCEI–22	<2.2	198	0.031	<0.016	<0.07	0.029	<0.80	83	<0.025
PCEI–23	<2.2	131	0.030	<0.016	<0.07	0.061	0.91	64	0.121
PCEI–24	<2.2	624	0.013	<0.016	<0.07	0.049	<0.80	1,400	0.055
PCEI–25	<2.2	453	<0.006	0.027	<0.07	0.877	<0.80	20	0.043
PCEI–26	<2.2	137	<0.006	<0.016	<0.07	0.730	<0.80	367	0.029
PCEI–27	<6.6	329	0.024	<0.048	<0.21	<0.063	<2.4	130	0.080
PCEI–28	<2.2	251	0.010	<0.016	0.09	0.056	<0.80	758	0.238
PCEI–29	<2.2	131	0.027	<0.016	<0.07	0.031	<0.80	89	<0.025
PCEI–30	<2.2	402	0.023	<0.016	<0.07	0.074	<0.80	951	0.362
PCEI–31	<2.2	332	0.008	0.035	0.64	0.082	1.20	20	0.220
PCEI–34	2.3	85	0.025	<0.016	<0.07	0.032	<0.80	8	<0.025

Table 1–1. Trace elements concentrations in samples from groundwater from 29 private domestic water-supply wells in the study.—Continued

[All concentrations in microgram per liter. <, less than than reporting limit listed]

Field identification number	Lithium, water, filtered	Manganese, water, filtered[b]	Molybdenum, water, filtered	Nickel, water, filtered	Silver, water, filtered[c]	Strontium, water, filtered	Thallium, water, filtered	Vanadium, water, filtered	Zinc, water, filtered
PCEI–01	22.4	32.0	0.141	0.66	<0.005	263	<0.010	0.15	2.5
PCEI–02	31.7	27.8	0.204	0.27	<0.005	505	<0.010	0.56	13.6
PCEI–03	33.2	27.6	0.173	0.25	<0.005	502	<0.010	0.46	13.5
PCEI–04	12.7	4.9	0.110	<0.09	<0.005	68.8	<0.010	<0.08	14.9
PCEI–05	12.0	3.0	0.124	<0.09	<0.005	39.1	<0.010	0.09	<1.4
PCEI–07	12.6	0.6	0.590	1.4	<0.015	250	<0.030	0.49	<4.2
PCEI–08	13.9	2.9	0.297	0.13	<0.005	50.2	<0.010	0.17	<1.4
PCEI–09	17.5	14.6	0.029	<0.09	<0.005	215	<0.010	<0.08	<1.4
PCEI–10	11.6	3.5	0.110	<0.09	<0.005	105	<0.010	<0.08	2.4
PCEI–11	12.1	3.8	0.099	<0.09	<0.005	94.7	<0.010	<0.08	<1.4
PCEI–12	22.4	172	0.881	0.94	<0.005	170	<0.010	<0.08	11.0
PCEI–13	11.0	14.2	0.103	0.21	<0.005	234	<0.010	<0.08	18.7
PCEI–14	14.7	8.2	0.131	0.12	<0.005	181	<0.010	0.13	11.8
PCEI–15	10.9	1.0	0.287	<0.09	<0.005	19.5	<0.010	0.11	<1.4
PCEI–16	20.9	24.2	0.041	0.26	<0.005	786	<0.010	<0.08	2.1
PCEI–17	15.8	42.4	0.099	0.35	<0.005	719	<0.010	<0.08	60.3
PCEI–19	20.0	1.4	0.421	<0.27	0.03	78.4	<0.030	0.27	19.8
PCEI–20	9.9	18.5	5.510	1.4	<0.005	77.8	<0.010	0.25	98.7
PCEI–22	15.6	10.3	0.076	0.18	<0.005	186	<0.010	0.13	<1.4
PCEI–23	21.9	6.2	0.175	<0.09	<0.005	85.7	<0.010	0.36	42.6
PCEI–24	56.3	101	0.382	0.59	<0.005	1,290	<0.010	0.15	<1.4
PCEI–25	11.6	517	0.992	0.57	<0.005	206	0.07	0.11	1.5
PCEI–26	46.8	803	0.173	2.0	<0.005	333	0.01	0.08	22.8
PCEI–27	23.0	8.4	0.264	<0.27	<0.015	707	<0.030	0.43	9.1
PCEI–28	30.6	81	0.424	0.32	<0.005	262	<0.010	<0.08	25.8
PCEI–29	15.7	4.9	0.150	<0.09	<0.005	116	<0.010	0.14	1.7
PCEI–30	20.7	17.9	0.231	0.34	<0.005	219	<0.010	<0.08	237
PCEI–31	11.9	1.0	0.853	0.68	<0.005	179	0.01	0.20	46.7
PCEI–34	9.2	1.7	0.367	0.10	<0.005	29.8	<0.010	<0.08	<1.4

Table 1–1. Trace elements concentrations in samples from groundwater from 29 private domestic water-supply wells in the study.—Continued

[All concentrations in microgram per liter. <, less than than reporting limit listed]

Field identification number	Antimony, water, filtered[d]	Arsenic, water, filtered	Boron, water, filtered	Selenium, water, filtered	Uranium (natural), water, filtered
PCEI–01	0.08	0.20	900	0.05	0.039
PCEI–02	<0.027	0.17	72	0.04	0.011
PCEI–03	<0.027	0.16	974	0.05	0.010
PCEI–04	<0.027	0.04	981	<0.03	<0.004
PCEI–05	<0.027	0.03	856	<0.03	<0.004
PCEI–07	<0.081	0.63	10	0.95	7.89
PCEI–08	<0.027	0.04	1,190	<0.03	<0.004
PCEI–09	<0.027	<0.03	837	<0.03	<0.004
PCEI–10	<0.027	<0.03	932	<0.03	<0.004
PCEI–11	<0.027	0.06	814	<0.03	<0.004
PCEI–12	<0.027	0.29	12	0.09	4.55
PCEI–13	<0.027	0.04	468	<0.03	<0.004
PCEI–14	0.03	0.08	747	<0.03	0.014
PCEI–15	<0.027	0.03	1,240	<0.03	<0.004
PCEI–16	<0.027	0.07	115	<0.03	0.034
PCEI–17	<0.027	<0.03	103	<0.03	0.034
PCEI–19	<0.081	<0.09	1,230	<0.09	<0.012
PCEI–20	0.76	8.0	1,000	0.07	0.242
PCEI–22	<0.027	0.06	849	<0.03	<0.004
PCEI–23	<0.027	0.10	1,140	0.03	0.005
PCEI–24	<0.027	0.12	484	<0.03	0.045
PCEI–25	<0.027	0.50	11	<0.03	10.0
PCEI–26	<0.027	0.31	34	<0.03	8.55
PCEI–27	<0.081	<0.09	1,010	<0.09	<0.012
PCEI–28	<0.027	1.0	167	<0.03	0.070
PCEI–29	<0.027	0.04	1,100	<0.03	<0.004
PCEI–30	<0.027	0.07	851	<0.03	<0.004
PCEI–31	0.04	0.13	67	1.5	3.80
PCEI–34	<0.027	<0.03	47	<0.03	0.005

[a]The maximum cobalt concentration in two field blanks was 0.16 µg/L, so at least 20 concentrations less than or equal to 0.16 µg/L may have cobalt as an artifact.

[b]The maximum manganese concentration in two field blanks was 0.25 µg/L, so the one concentration less than 1.0 µg/L may have manganese as an artifact.

[c]The maximum silver concentration in two field blanks was 0.01 µg/L, so the one reported silver concentration less than 0.01 µg/L may have silver as an artifact.

[d]The maximum antimony concentration in two field blanks was 0.10 µg/L, so three concentrations less than 0.10 µg/L may have antimony as an artifact.

Table 1–2. Aromatic volatile organic compounds concentrations in samples from groundwater from 29 private domestic water-supply wells in the study.

[All concentrations in microgram per liter. Concentrations in *italics* are sampling artifacts based on field blank analysis. <, less than reporting limit listed; E, estimated concentration less than the reporting limit; TICs, tentatively identified compounds; --, no data]

Field identification number	1,2-Dichloroethane, water, unfiltered, recoverable	1,2,3,4-Tetramethylbenzene, water, unfiltered, recoverable	1,2,3,5-Tetramethylbenzene, water, unfiltered, recoverable	1,2,3-Trimethylbenzene, water, unfiltered, recoverable	1,2,4-Trimethylbenzene, water, unfiltered, recoverable	1,3,5-Trimethylbenzene, water, unfiltered, recoverable	2-Ethyltoluene, water, unfiltered, recoverable	4-Isopropyltoluene, water, unfiltered, recoverable	*o*-Xylene, water, unfiltered, recoverable	*sec*-Butylbenzene, water, unfiltered, recoverable	Styrene, water, unfiltered, recoverable	*tert*-Butylbenzene, water, unfiltered, recoverable	Toluene, water, unfiltered, recoverable
PCEI–01	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–02	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–03	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–04	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–05	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–07	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–08	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	0.02 E
PCEI–09	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–10	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–11	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–12	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–13	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–14	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–15	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–16	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–17	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–19	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–20	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–22	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–23	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–24	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–25	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–26	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	0.044	<0.034	<0.042	<0.06	<0.02
PCEI–27	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–28	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–29	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–30	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–31	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02
PCEI–34	<0.08	<0.10	<0.08	<0.06	<0.032	<0.032	<0.032	<0.06	<0.032	<0.034	<0.042	<0.06	<0.02

Table 1–2. Aromatic volatile organic compounds concentrations in samples from groundwater from 29 private domestic water-supply wells in the study.—Continued

[All concentrations in microgram per liter. Concentrations in *italics* are sampling artifacts based on field blank analysis. <, less than reporting limit listed; E, estimated concentration less than the reporting limit; TICs, tentatively identified compounds; --, no data]

Field identification number	Acetone, water, unfiltered, recoverable[a]	Benzene, water, unfiltered, recoverable	Methyl ethyl ketone, water, unfiltered, recoverable[a]	Ethylbenzene, water, unfiltered, recoverable	Isopropylbenzene, water, unfiltered, recoverable	Methyl *tert*-butyl ether, water, unfiltered, recoverable	*m*-Xylene plus *p*-xylene, water, unfiltered, recoverable	Naphthalene, water, unfiltered, recoverable	*n*-Butylbenzene, water, unfiltered, recoverable	*n*-Propylbenzene, water, unfiltered, recoverable	Carbon disulfide, water, unfiltered, recoverable	Carbonyl sulfide, water, unfiltered, tentatively identified	Tentatively identified compounds
PCEI–01	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–02	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–03	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	0.10 C10 alkene
PCEI–04	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	0.83	--
PCEI–05	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	2.52 methylpropanol
PCEI–07	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–08	*1.2*	<0.026	*2.2*	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	0.61	--
PCEI–09	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	0.53	--
PCEI–10	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–11	*2.0*	<0.026	*4.0*	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	0.48	--
PCEI–12	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	0.05 E	<0.18	<0.08	<0.036	<0.01	0.17	--
PCEI–13	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–14	*1.0*	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–15	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	0.32	--
PCEI–16	*1.1*	<0.026	*7.3*	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	0.20	--
PCEI–17	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–19	<3.4	<0.026	*0.9*	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	0.23	<0.01	0.11 C5 alkane
PCEI–20	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–22	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	0.12	<0.01	0.12 C10 alkane
PCEI–23	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–24	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–25	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–26	<3.4	<0.026	<1.6	0.037	<0.042	<0.10	0.14	<0.18	<0.08	<0.036	<0.01	0.40	--
PCEI–27	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	37.4 E 13 TICs[b]
PCEI–28	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–29	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	0.39	--

Table 1–2. Aromatic volatile organic compounds concentrations in samples from groundwater from 29 private domestic water-supply wells in the study.—Continued

[All concentrations in microgram per liter. Concentrations in *italics* are sampling artifacts based on field blank analysis. <, less than reporting limit listed; E, estimated concentration less than the reporting limit; TICs, tentatively identified compounds; --, no data]

Field identification number	Acetone, water, unfiltered, recoverable[a]	Benzene, water, unfiltered, recoverable	Methyl ethyl ketone, water, unfiltered, recoverable[a]	Ethylbenzene, water, unfiltered, recoverable	Isopropylbenzene, water, unfiltered, recoverable	Methyl *tert*-butyl ether, water, unfiltered, recoverable	*m*-Xylene plus *p*-xylene, water, unfiltered, recoverable	Naphthalene, water, unfiltered, recoverable	*n*-Butylbenzene, water, unfiltered, recoverable	*n*-Propylbenzene, water, unfiltered, recoverable	Carbon disulfide, water, unfiltered, recoverable	Carbonyl sulfide, water, unfiltered, tentatively identified	Tentatively identified compounds
PCEI–30	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–31	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	<0.01	<0.01	--
PCEI–34	<3.4	<0.026	<1.6	<0.036	<0.042	<0.10	<0.08	<0.18	<0.08	<0.036	0.15	<0.01	--

[a]Detections of acetone and ethyl methyl ketone in four samples were likely a sampling artifact based on analysis of a field blank; the likely cause was impurities in residual methanol in the sampling line from decontamination.

[b]Tentatively identified compounds detected in water from PCEI–27 total 37.4 µg/L. The compounds and their estimated concentrations in microgram per liter are listed below.

C5 alkane	19.34
C5 alkane	6.47
C6 alkane	0.1
C6 alkane	2.39
C6 alkane	1.71
C7 alkane	0.16
cyclopentane	1.01
C1 cyclopentane	2.89
C2 cyclopentane	0.26
cyclohexane	1.37
C1 cyclohexane	0.25
dimethylhydrazine	0.5
isopropylcyclobutane	0.99

Table 1–3. Polycyclic aromatic hydrocarbons concentrations in samples from groundwater from 10 private domestic water-supply wells in the study.

[All concentrations in microgram per liter. <, less than reporting limit listed]

Field identification number	9*H*-Fluorene, water, unfiltered, recoverable	Acenaphthene, water, unfiltered, recoverable	Acenaphthylene, water, unfiltered, recoverable	Anthracene, water, unfiltered, recoverable	1-Methylnaphthalene, water, unfiltered, recoverable	2-Methyl-naphthalene, water, unfiltered, recoverable	Benzo[*a*] anthracene, water, unfiltered, recoverable	Benzo[*a*] pyrene, water, unfiltered, recoverable
PCEI–03	<0.097	<0.042	<0.042	<0.059	<0.051	<0.071	<0.031	<0.052
PCEI–04	<0.096	<0.042	<0.042	<0.059	<0.051	<0.070	<0.031	<0.051
PCEI–05	<0.096	<0.042	<0.042	<0.059	<0.051	<0.070	<0.031	<0.051
PCEI–10	<0.095	<0.041	<0.042	<0.059	<0.050	<0.070	<0.031	<0.051
PCEI–13	<0.097	<0.042	<0.042	<0.059	<0.051	<0.071	<0.031	<0.052
PCEI–14	<0.095	<0.041	<0.042	<0.058	<0.050	<0.070	<0.030	<0.051
PCEI–17	<0.096	<0.042	<0.042	<0.059	<0.051	<0.071	<0.031	<0.051
PCEI–19	<0.095	<0.041	<0.041	<0.058	<0.050	<0.070	<0.030	<0.051
PCEI–27	<0.095	<0.041	<0.042	<0.058	<0.050	<0.070	<0.030	<0.051
PCEI–30	<0.095	<0.042	<0.042	<0.059	<0.050	<0.070	<0.031	<0.051

Field identification number	Benzo[*b*] fluoranthene, water, unfiltered, recoverable	Benzo[*ghi*] perylene, water, unfiltered, recoverable	Benzo[*k*] fluoranthene, water, unfiltered, recoverable	Chrysene, water, unfiltered, recoverable	Dibenzo[*a,h*] anthracene, water, unfiltered, recoverable	Phenanthrene, water, unfiltered, recoverable	Pyrene, water, unfiltered, recoverable	Fluoranthene, water, unfiltered, recoverable	Indeno[1,2,3-*cd*] pyrene, water, unfiltered, recoverable
PCEI–03	<0.051	<0.019	<0.022	<0.027	<0.053	<0.092	<0.042	<0.079	<0.046
PCEI–04	<0.051	<0.019	<0.022	<0.027	<0.053	<0.091	<0.041	<0.078	<0.045
PCEI–05	<0.051	<0.019	<0.022	<0.027	<0.053	<0.091	<0.041	<0.078	<0.045
PCEI–10	<0.051	<0.019	<0.022	<0.027	<0.052	<0.091	<0.041	<0.078	<0.045
PCEI–13	<0.051	<0.019	<0.022	<0.027	<0.053	<0.092	<0.042	<0.079	<0.046
PCEI–14	<0.050	<0.019	<0.022	<0.027	<0.052	<0.091	<0.041	<0.078	<0.045
PCEI–17	<0.051	<0.019	<0.022	<0.027	<0.053	<0.092	<0.042	<0.079	<0.046
PCEI–19	<0.050	<0.019	<0.022	<0.027	<0.052	<0.091	<0.041	<0.078	<0.045
PCEI–27	<0.050	<0.019	<0.022	<0.027	<0.052	<0.091	<0.041	<0.078	<0.045
PCEI–30	<0.051	<0.019	<0.022	<0.027	<0.053	<0.091	<0.041	<0.078	<0.045

Tables 1–4 through 1–8 are available for download at http://dx.doi.org/10.3133/ofr20161081.

Table 1–4. Quality-control analyses of trip blanks.

Table 1–5. Quality-control analyses of field blanks.

Table 1–6. Quality-control analyses of matrix spikes.

Table 1–7. Quality-control analyses of sequential duplicates

Table 1–8. Quality-control sample information.

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