In cooperation with the City of Houston

Groundwater Quality of the Gulf Coast Aquifer System, Houston, Texas, 2010

Data Series 598

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

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By Jeannette H. Oden, Dexter W. Brown, and Timothy D. Oden

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Conversion Factors, and Datums

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Radioactivity	
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
nanometer (nm)	3.937×10^{-8}	inch (in.)
micrometer (µm)	3.937×10^{-5}	inch (in.)
millimeter (mm)	0.03937	inch (in.)
kilometer (km)	0.6214	mile (mi)
	Volume	
microliter (µL)	3.382×10^{-5}	ounce, fluid (fl. oz)
milliliter (mL)	0.03382	ounce, fluid (fl. oz)
liter (L)	33.82	ounce, fluid (fl. oz)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)

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

$$°F=(1.8\times°C)+32$$

Datums

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm). Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L)

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Abstract

During March–December 2010, the U.S. Geological Survey, in cooperation with the city of Houston, collected source-water samples from 60 municipal supply wells in the Houston area. These data were collected as part of an ongoing study to determine concentrations, spatial extent, and associated geochemical conditions that might be conducive for mobility and transport of selected naturally occurring contaminants (selected trace elements and radionuclides) in the Gulf Coast aquifer system in the Houston area. In the summers of 2007 and 2008, a reconnaissance-level survey of these constituents in untreated water from 28 municipal supply wells was completed in the Houston area. Included in this report are the complete analytical results for 47 of the 60 samples collected in 2010—those results which were received from the laboratories and reviewed by the authors as of December 31, 2010. All of the wells sampled were screened in the Gulf Coast aquifer system; 22 were screened entirely in the Evangeline aquifer, and the remaining 25 wells contained screened intervals that intersected both Evangeline and Chicot aquifers. The data documented in this report were collected as part of an ongoing study to characterize source-water-quality conditions in untreated groundwater prior to drinking-water treatment. An evaluation of contaminant occurrence in source water provides background information regarding the presence of a contaminant in the environment. Because source-water samples were collected prior to any treatment or blending that potentially could alter contaminant concentrations, the water-quality results documented by this report represent the quality of the source water, not the quality of finished drinking water provided to the public.

Samples were analyzed for major ions (calcium, magnesium, potassium, sodium, bromide, chloride, fluoride, silica, and sulfate), residue on evaporation (dissolved solids), trace elements (arsenic, barium, boron, chromium, iron, lithium, manganese, molybdenum, selenium, strontium, and vanadium), and selected radionuclides (gross alpha- and beta-particle activity [at 72 hours and 30 days], carbon-14, radium-226, radon-222, and uranium). Field measurements were made of selected physicochemical (relating to both physical and chemical) properties (oxidation-reduction potential, turbidity, dissolved-oxygen concentration, pH, specific conductance, water temperature, and alkalinity) and unfiltered sulfides.

Similar to the results from the reconnaissance survey, physicochemical properties, major ions, and trace elements varied considerably. The ranges of selected physicochemical properties were as follows: oxidation-reduction potential ranged from -173 to 466 millivolts, dissolved oxygen ranged from less than 0.1 to 4.4 milligrams per liter, pH ranged from 7.2 to 7.8, specific conductance ranged from 439 to 724 microsiemens per centimeter at 25 degrees Celsius, and alkalinity ranged from 159 to 276 milligrams per liter as calcium carbonate. The largest ranges in concentration for filtered major ion constituents were obtained for cations sodium and calcium and for anions chloride and sulfate. Arsenic concentrations measured in samples from the 47 wells ranged from 1.6 to 23.5 micrograms per liter. The maximum concentration of arsenic (23.5 micrograms per liter) was measured in the source-water sample from well LJ-65-12-328.

Quantifiable concentrations of barium, boron, lithium, molybdenum, and strontium were measured in all 47 filtered, source-water samples. Quantifiable concentrations of manganese were measured in 46 source-water samples, and an estimated concentration of manganese was measured in 1 sample. Chromium, iron, selenium, and vanadium were detected in 24 or more of the 47 source-water samples.

Gross alpha-particle activities and beta-particle activities for all 47 samples were analyzed at 72 hours after sample collection and again at 30 days after sample collection, allowing for the measurement of the activity of short-lived isotopes. Gross alpha-particle activities reported in this report were not adjusted for activity contributions by radon or uranium and, therefore, are conservatively high estimates if compared to the U.S. Environmental Protection Agency National Primary Drinking Water Regulation for adjusted gross alpha-particle activity. The gross alpha-particle activities at 30 days in the samples ranged from R0.60 to 25.5 picocuries per liter and at 72 hours ranged from 2.58 to 39.7 picocuries per liter, and the "R" preceding the value of 0.60 picocuries per liter refers to a nondetected result less than the sample-specific critical level. Gross beta-particle activities measured at 30 days ranged from 1.17 to 14.4 picocuries per liter and at 72 hours ranged from 1.97 to 4.4 picocuries per liter. Filtered uranium was detected

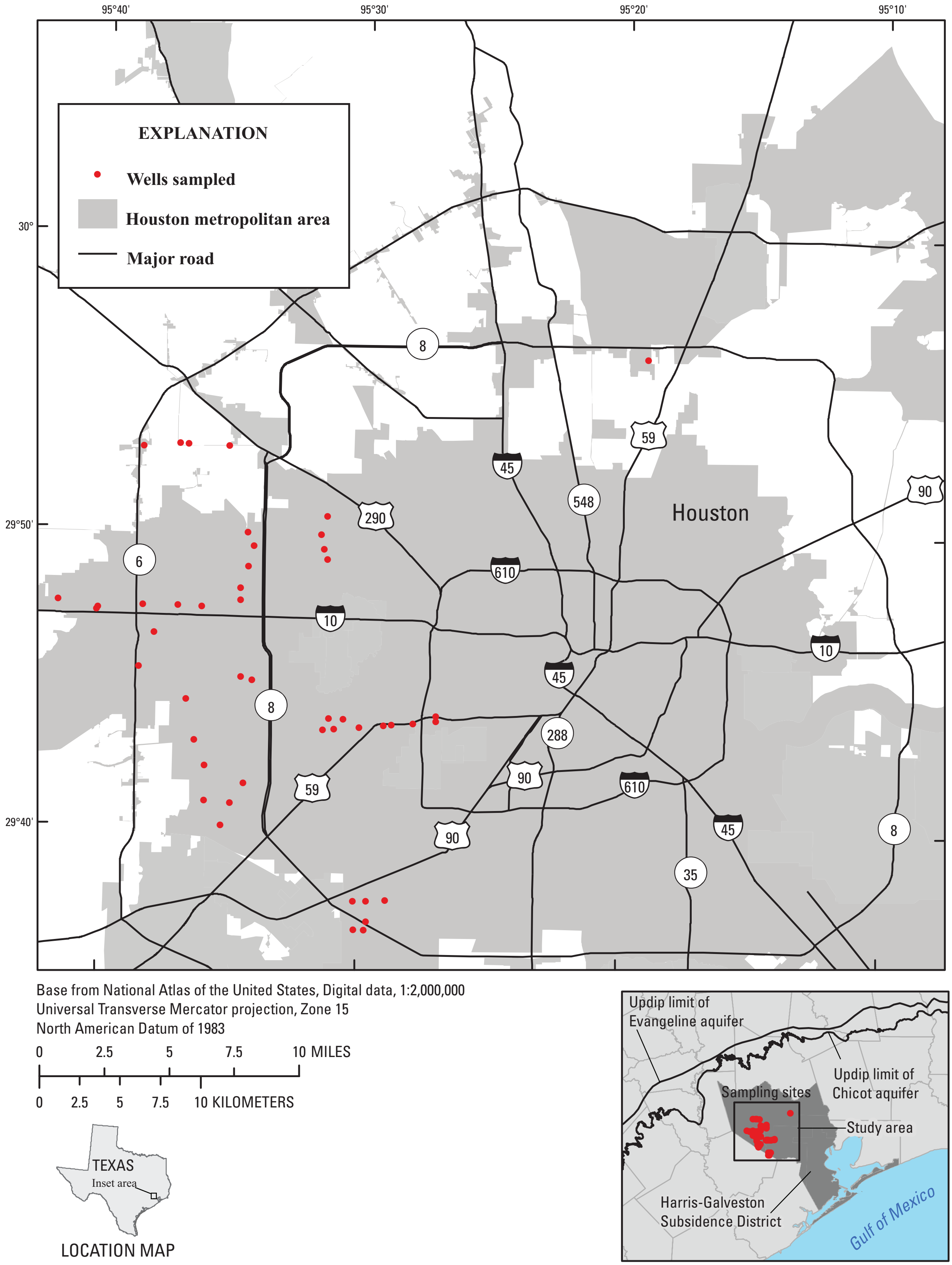
in quantifiable amounts in all of the 47 wells sampled. The uranium concentrations ranged from 0.03 to 42.7 micrograms per liter. One sample was analyzed for carbon-14, and the amount of modern atmospheric carbon was reported as 0.2 percent. Six source-water samples collected from municipal supply wells were analyzed for radium-226, and all of the concentrations were considered detectable concentrations (greater than their associated sample-specific critical level). Three source-water samples collected were analyzed for radon-222, and all of the concentrations were substantially greater than the associated sample-specific critical level.

Introduction

Groundwater is used as the source water (the raw, ambient water collected at a supply well prior to water treatment) for much of the municipal water supply needs of the Houston, Tex., area, and the primary sources of groundwater for the Houston area are the Evangeline and Chicot aquifers of the Gulf Coast aquifer system (fig. 1). During March-December 2010, the U.S. Geological Survey (USGS), in cooperation with the city of Houston, collected water-quality data from wells completed in the Gulf Coast aquifer system in the Houston area. These data were collected as part of an ongoing study to determine concentrations, spatial extent, and associated geochemical conditions that might be conducive for mobility and transport of selected naturally occurring contaminants (selected trace elements and radionuclides) in the Gulf Coast aquifer system in the Houston area. In the summers of 2007 and 2008, a reconnaissance-level survey of most of the same constituents measured in 2010 was completed; the samples collected during 2007-08 were untreated water from 28 municipal supply wells in the Houston area. The results from this initial survey and the methods by which the source-water samples were collected and analyzed for each constituent or constituent group were summarized in Oden and others (2010). For the second phase of the study, source-water samples were collected from 60 municipal supply wells in the Houston area between March-December of 2010. Included in this report are the complete analytical results for 47 of the 60 samples (fig. 1) collected in 2010—those results which were received from the laboratories and reviewed by the authors as of December 31, 2010. Selected physicochemical (relating to both physical and chemical) properties and unfiltered sulfides were measured in the field at the time each sample was collected. Source-water samples were analyzed for major ions, selected chemically related properties, trace elements, and radionuclides. The purpose of this ongoing study is to characterize source-water-quality conditions in untreated groundwater prior to drinking-water treatment. An evaluation of contaminant occurrence in source water provides background information regarding the presence of a contaminant in the environment. Because source-water samples were collected prior to any treatment or blending that potentially could alter contaminant concentrations, the sampled groundwater represents the quality of the source water, not the quality of finished drinking water (water that has passed through all the treatment processes and is ready to be delivered to consumers through a community water system (a public water system with 15 or more connections and serving 25 or more year-round residents and thus subject to U.S. Environmental Agency (USEPA) and State regulations enforcing the Safe Drinking Water Act)) (Hopple and others, 2009; U.S. Environmental Protection Agency, 2004).

Many contaminants in groundwater are naturally occurring in aquifers. In a national survey of more than 6,000 domestic wells used for drinking-water supply, naturally occurring contaminants were many times more prevalent in concentrations of concern than were synthetic organic compounds released to the environment by human activity and considered to pose health risks upon ingestion (DeSimone, 2009). The local geology and geochemistry of an aquifer control the occurrence and distribution of naturally occurring contaminants in groundwater, such as arsenic, other trace elements, and radionuclides (Hem, 1992; Welch and others, 2000; Zapecza and Szabo, 1988). During 1993–2007, the USGS sampled untreated source water from 932 public-supply wells as part of multiple groundwater assessments conducted across the United States and found that naturally occurring contaminants (trace elements and radionuclides) might be present in groundwater at concentrations of potential human-health concern even in undeveloped areas or confined aquifers where contamination usually is not expected (Toccalino and others, 2010). Toccalino and others (2010) also found that trace elements and radionuclides were detected at concentrations greater than benchmarks in samples from confined and unconfined aquifers, which is consistent with the fact that these contaminants originate primarily from aquifer materials.

Because radionuclides are naturally occurring trace elements found in rocks, soils, and waters, varying degrees of exposure to naturally occurring radioactivity occurs universally. Most naturally occurring radionuclides are formed through the decay of uranium-238 and thorium-232 (fig. 2). Uranium and thorium decay produces other radioactive, daughter elements, which in turn undergo still further radioactive decay. These radioactive, daughter elements exhibit different chemical properties, have shorter half-lives, and emit various types of radiation at different rates and energies than the parent isotope. However, the parent isotope may govern the occurrence and distribution of the daughter isotopes (Zapecza and Szabo, 1988). Radioactive decay is the emission of particles and energy from the nucleus of an atom (a radionuclide) with an unstable configuration within the nucleus. The emitted particles are alpha particles (a nucleus of a helium-4 atom) or beta particles (an electron). Energy also is emitted in the form of gamma rays. The half-life of a radionuclide is defined as the time required for one-half of the original amount of the radionuclide to decay (Zapecza and Szabo, 1988). The half-lives may range from long (years) to short (seconds, hours, or a few days) intervals. For example, radium-226 is a derivative of



Base from National Atlas of the United States, Digital data, 1:2,000,000
Universal Transverse Mercator projection, Zone 15
North American Datum of 1983

Figure 1. Location of 47 municipal supply wells in the Houston, Texas, area sampled during 2010.

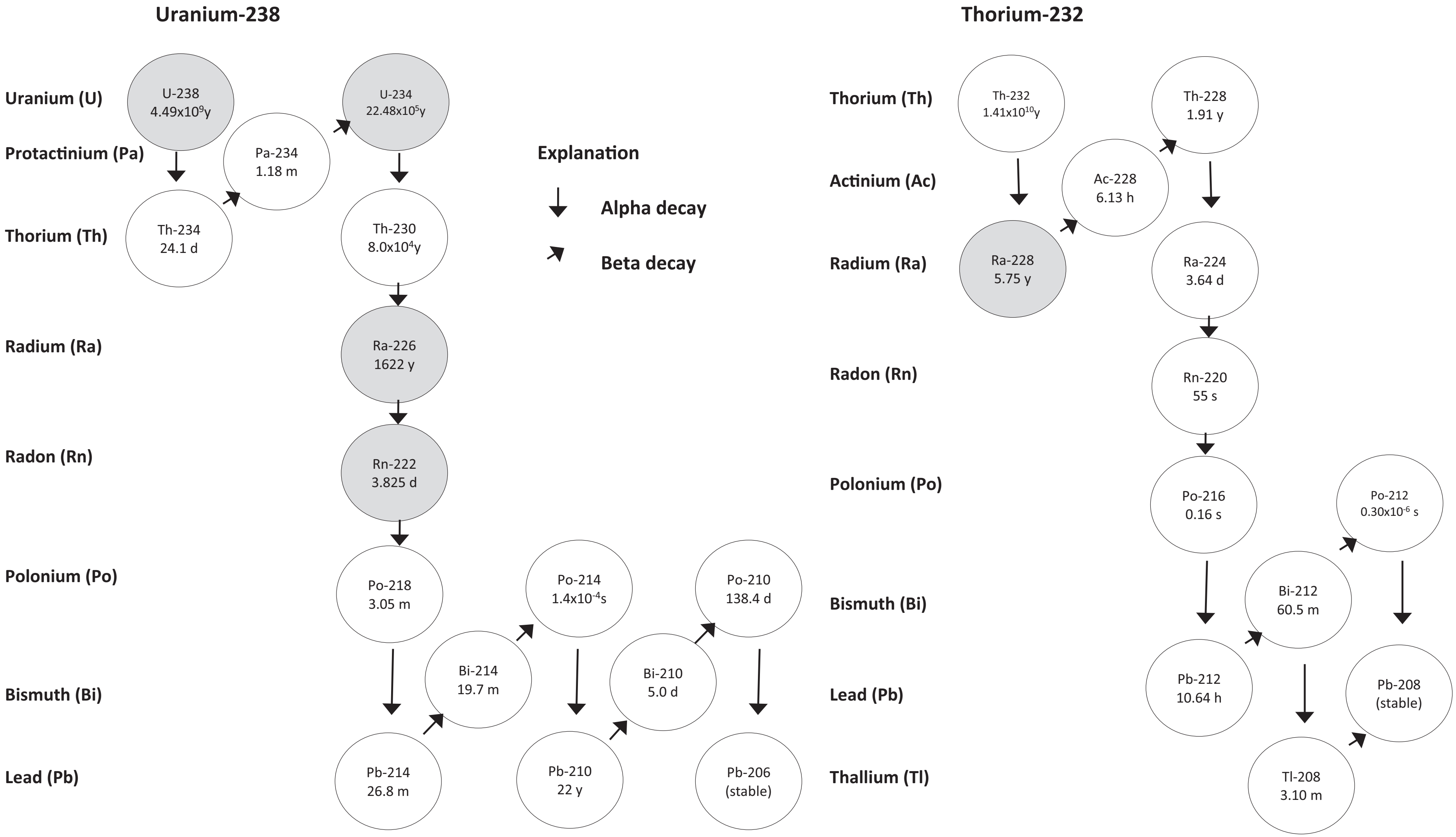


Figure 2. Diagram showing uranium-238 and thorium-232 radioactive decay series. Shading indicates those radionuclides mentioned in report. (Modified from Hall and others, 1985.) [Times shown are half-lives: y, years; d, days; h, hours; m, minutes; s, seconds]

the uranium-238 decay chain and decays by emitting an alpha particle, whereas radium-228 is derived from thorium-232 and emits a beta particle. Radium-228 has a half life of 5.75 years, and the half life of radium-226 is 1,622 years. Radium-226 decays to radon-222, which has a half-life of 3.8 days (fig. 2). The most common radionuclides in groundwater are radium-226, radium-228, radon-222, uranium-238, and uranium-234 (Zapecza and Szabo, 1988). When a gross activity measurement is made, it represents the overall alpha-particle and beta-particle activity of all the radionuclides present in the sample in the given period of time associated with the measurement (U.S. Environmental Protection Agency, 1997). Gross alpha-particle activities and beta-particle activities for this study were analyzed at 72 hours after sample collection and again at 30 days after sample collection, allowing for the measurement of the activity of short-lived isotopes. Szabo and others (1998) found that gross alpha-particle activity measurements differed when gross activities were measured within 72 hours compared to when analyzed with no adherence to strict holding times, and these differences may be attributed to differing concentrations of long-lived and short-lived isotopes present in the water samples measured.

Proposed and implemented changes to drinking-water regulations have increased the number of community water systems that will need to be monitored and receive mitigation for certain naturally occurring contaminants, arsenic and radionuclides (U.S. Environmental Protection Agency, 2000, 2001). The quality of finished drinking water (after treatment and before distribution) from the Nation's public water systems is regulated by the USEPA under the Safe Drinking Water Act (SDWA) (U.S. Environmental Protection Agency, 2004). Water managers' knowledge about the occurrence and distribution of arsenic and radionuclides in source water has become essential for treatment purposes. For example, recent changes to the USEPA public drinking-water regulations for arsenic and a selected number of natural radionuclides have highlighted the necessity for municipal water-supply managers to be concerned about the occurrence and distribution of these constituents in their respective drinking-water resources, primarily pertaining to groundwater. The National Research Council (1999) recommended that the USEPA lower the maximum contaminant level (MCL) for arsenic because of ongoing health research that associated the occurrence of arsenic in water to the increased risk of skin and internal cancers in humans. In 2002, the USEPA lowered the MCL for arsenic in finished drinking water from 50 to 10 micrograms per liter (µg/L) and required municipal supply systems to comply with the new standard by January 23, 2006 (U.S. Environmental Protection Agency, 2001) (table 1).

In December 2000, the USEPA updated the regulations pertaining to radionuclides (except radon-222) in finished drinking water (U.S. Environmental Protection Agency, 2000). The revised radionuclide MCLs are listed in table 1. The new monitoring requirements for the radionuclide contaminants defined in 2000 were phased in between December 2003 and December 31, 2007, the date for all water systems to complete initial monitoring (U.S. Environmental Protection Agency, 2000). The USEPA MCL for adjusted gross alpha-particle activity is 15 picocuries per liter (pCi/L) minus activity caused by uranium and radon, if applicable (U.S. Environmental Protection Agency, 2000). The regulation defines the maximum holding time as 6 months for samples that are analyzed for gross alpha-particle activity, with annual compositing of samples (combining samples collected from the same sampling point from different quarters) allowed. Compositing of samples is done in the laboratory at the time of analysis (U.S. Environmental Protection Agency, 2000). For beta-particle activity, the USEPA states that the water systems must increase monitoring frequency if the gross beta-particle activity minus the naturally occurring potassium-40 activity is equal to or greater than 50 pCi/L, and individual isotopes may be targeted for analysis (U.S. Environmental Protection Agency, 2000). The radium MCL is defined as 5 pCi/L for the sum of the radium isotopes, radium-226 and radium-228 (the sum of which is referred to as combined Ra). The revised monitoring requirements included monitoring for radium-228 as well as radium-226, and required water-system managers to monitor for these radioactive constituents at each entry point into a distribution system. Also, the sampling frequency requirements for radionuclides were changed to be more consistent with those required for other National Primary Drinking Water Regulations. This "radioactivity rule" also established a new MCL of 30 µg/L for uranium, which previously had been unregulated (U.S. Environmental Protection Agency, 2000).

USEPA proposed separate regulation for radon-222 in finished drinking water in 1999, with an MCL of 300 pCi/L

Table 1. U.S. Environmental Protection Agency maximum contaminant levels for arsenic and radionuclides in finished drinking water, February 2011.

[µg/L, micrograms per liter; pCi/L, picocuries per liter; mrem/yr, millirems per year]

Constituent	Maximum contaminant level[1]
Arsenic	10 µg/L
Gross alpha-particle activity	15 pCi/L[2]
Beta/photon emitters	4 mrem/yr (50 pCi/L screen)[3]
Radium-226 plus radium-228 (combined radium)	5 pCi/L
Uranium	30 µg/L
Radon-222 (proposed)	300 or 4,000 pCi/L

[1] Drinking Water Contaminants, National Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 2011).

[2] Excluding uranium and radon.

[3] Dose (millirems per year) determined on basis of individual isotope analyses.

and an alternative MCL (AMCL) of 4,000 pCi/L (U.S. Environmental Protection Agency, 1999) that has yet (2011) to be adopted (table 1). Whether the MCL or AMCL applies to a community water system depends on whether or not the State in which it resides or the community water system itself develops a multimedia mitigation program (MMM) to address health risks from radon in indoor air. The lower proposed MCL for radon would apply to those that do not develop MMM programs; conversely, the proposed AMCL would only apply to those that do (U.S. Environmental Protection Agency, 1999).

Elevated concentrations of arsenic and natural radionuclides in drinking-water sources from groundwater have been documented in several regions of the United States (Focazio and others, 2000; Welch and others, 2000; Focazio and others, 2001; Ryker, 2003; DeSimone, 2009). Targeted reconnaissance sampling by Focazio and others (2001) showed that Texas is one of more than a dozen States with relatively large concentrations of radium in raw-water (untreated) samples from municipal water supplies obtained from aquifers. Chowdhury and others (2006) analyzed the radionuclide data available in the Texas Water Development Board groundwater database for the Gulf Coast aquifer system, which were primarily gross alpha- and beta-particle activity results, with a few radium-226 and radon-222 analyses. The highest gross alpha-particle activities (61 to 210 pCi/L) were measured from wells screened in the Evangeline aquifer, part of the Gulf Coast aquifer system, in Harris County, Tex., and other counties south of Bee County, Tex. (Chowdhury and others, 2006; figs. 5–24). Chowdhury and others (2006) also summarized the arsenic data collected from wells screened in the Gulf Coast aquifer system in Texas and reported that arsenic concentrations ranged from 2 to 569 μg/L for samples obtained from the three aquifers (Chicot, Evangeline, and Jasper) that compose the Gulf Coast aquifer system.

Purpose and Scope

This report presents the results for physicochemical (relating to physical and chemical) properties and water-quality constituents (major ions, selected trace elements, and selected radionuclides) measured in water-quality samples from 47 of the 60 municipal supply wells sampled in the Houston area in between March and December 2010. The ranges of concentrations for the water-quality constituents are described, and the results for arsenic and radionuclides are compared to MCLs defined in the National Primary Drinking Water Regulations established by the USEPA as a reference to provide an initial perspective on the potential significance of contaminants detected in the source water. The methods by which the samples were collected and analyzed are described for each constituent or constituent group, and quality-control results also are summarized. This report documents source-water quality prior to drinking-water treatment, which might differ from the quality of finished drinking water distributed through community water systems. In this study of untreated source waters, contaminant concentrations that are greater than MCLs do not represent MCL violations because MCLs apply to finished drinking water, and all samples were collected from source waters. None of the source-water samples were collected for regulatory compliance purposes; further, compliance with most MCLs is based on running annual average concentrations determined from the results of multiple samples at each entry point to the distribution system (U.S. Environmental Protection Agency, 2000; U.S. Environmental Protection Agency, 2001), not on concentrations detected in single samples as collected in this study.

Description of Study Area

Houston, Tex., is the fourth largest city in the United States and growing rapidly; the population for the Houston metropolitan area as of January 1, 2010, was about 5.9 million, a 25.5 percent increase since the 2000 census (Texas State Data Center, 2010). Historically, the water supply for the city of Houston has been groundwater, and the groundwater withdrawals have increased over time, primarily for municipal use. Steadily increasing groundwater withdrawals in most parts of the greater Houston area for much of the city's history resulted in declining groundwater levels, which in turn has caused land subsidence (Ryder and Ardis, 2002; Kasmarek and others, 2010). The Texas Legislature created the Harris-Galveston Subsidence District in 1975 to regulate groundwater withdrawal in the Houston area because land subsidence was increasing the risk of flooding and fault activity; an increased use of surface water to prevent future subsidence also was mandated (Ryder and Ardis, 2002). Under the 1999 regulatory plan issued by the Harris-Galveston Subsidence District, a goal was established for the northern and western parts of Harris County to reduce groundwater usage 30 percent by 2010; the goal by 2030 is for groundwater to account for less than 20 percent of total water usage in Harris and Galveston Counties (Michel, 2006). Even though the plan is to reduce the amount of groundwater used in the Houston area, the population of the area is expected to continue to grow rapidly. Maintaining the drinking-water quantity and quality of the municipal water supply is a priority for the water-resource managers in the area regardless of the source.

The greater Houston area overlies and obtains groundwater from the Gulf Coast aquifer system. The Gulf Coast aquifer system consists mostly of unconsolidated sediments of Miocene age and younger that lie above and coastward of the Paleocene Catahoula Sandstone. The Gulf Coast aquifer system reflects three depositional environments: continental (alluvial plain), transitional (delta, lagoon, and beach), and marine (continental shelf). Coarser grained nonmarine deposits updip and grade laterally into finer grained material that was deposited in marine environments (Ryder, 1996). The system consists of a fluvial-deltaic wedge of discontinuous beds of sand, silt, and clay sediments deposited in bands that parallel the Gulf of Mexico and range in age from Miocene to Holocene. This wedge of unconsolidated to poorly consolidated sediments increases in thickness and depth toward the Gulf of Mexico (Ryder, 1996). Aquifers typically consist of interbedded sand and clay rather than the massive, areally extensive sand beds or sheet sands common in places such as the Atlantic Coastal Plain aquifers and aquifer systems, which were deposited as beach sands or shallow-shelf sandbars in cyclic progressive/regressive sequences (Hansen, 1971; Sugarman and Miller, 1997). Lenticular sand and clay beds of the aquifer system have lateral and vertical boundaries that are gradational, poorly constrained, and difficult to trace more than a few miles (Renken, 1998). The Chicot aquifer, Evangeline aquifer, Burkeville confining unit, and Jasper aquifer comprise the Gulf Coast aquifer system (fig. 3). The Chicot and underlying Evangeline aquifers are hydraulically connected and not separated by a distinct confining unit; the aquifers are identified on the basis of a gradational decrease in grain size with depth. The Chicot and Evangeline aquifers are the primary sources of groundwater used for drinking water for the City of Houston.

Well Information

The USGS collected source-water samples from 47 municipal supply wells during 2010 (table 2, at end of report). Of these 47 wells, 22 were screened entirely in the Evangeline aquifer. The remaining 25 wells contained screened intervals that intersected both Evangeline and Chicot aquifers. The depths of the 47 wells ranged from 734 to 1,965 feet below land surface (ft bls). The depth to the top of the first screen interval for each well ranged from 372 to 1,146 ft bls, and the depth to the bottom of the last screen interval ranged from 710 to 1,946 ft bls (table 2). When available, the lithologic code summarizes the sand and clay composition of the aquifer material for the total depth of the well as reported in associated drillers' logs. A lithologic code of CLSD describes aquifer material with a greater percentage of clay than sand as compared to a code of SDCL or SNCL, which describes aquifer material with a greater percentage of sand than clay.

Methods

Sample Collection

Samples were collected and processed in accordance with protocols established by the USGS "National Field Manual for the Collection of Water-Quality Data" (U.S. Geological Survey, variously dated). These sampling protocols ensure that a representative sample of groundwater is collected at each site, and samples are collected and processed in a way that minimizes sample contamination. Groundwater samples were collected as near to the wellhead as possible, prior to treatment. Prior to sampling, each well had been pumping for a minimum of 30 minutes. Field measurements of selected physicochemical properties (oxidation reduction potential, turbidity, dissolved-oxygen concentration, pH, specific conductance, and water temperature) were made; each physicochemical property was monitored for stabilization prior to sampling to ensure that the water sampled from the well was representative of water from the aquifer (U.S. Geological Survey, variously dated). Water samples were collected using Teflon tubing, C-Flex tubing, and stainless steel fittings attached to a spigot close to the wellhead and prior to any treatment. Tubing from the spigot was extended into a mobile water-quality laboratory used for sample collection and processing. The tubing inside the mobile laboratory was connected to a Teflon manifold to split water to the sample-collection chamber and to the multiparameter instrument used for measuring field parameters. Water pumped from the well was passed through the manifold and through a flow-through chamber that contained a water-quality monitor, a YSI 600XL multiprobe water-quality sonde. The multiprobe sonde simultaneously measures oxidation-reduction potential, dissolved-oxygen concentration, pH, specific conductance, and water temperature; measurements were recorded every 5 minutes.

Turbidity was measured separately in grab samples collected every 5 minutes using a Hach 2100P benchtop turbidimeter. All sensors on the multiparameter instrument and turbidimeter were calibrated daily. Field measurements were recorded at 5-minute intervals until five sequential readings of field measurements were within the stabilization criteria (Wilde, 2008). In cases where the dissolved-oxygen concentration was less than 2.0 milligrams per liter (mg/L), the final dissolved-oxygen concentration was determined by a spectrophotometric method using the Rhodazine-D colorimetric method to minimize atmospheric interaction with the water sample (Lewis, 2006). When the dissolved oxygen was measured as less than 1.0 mg/L or the oxidation-reduction potential was less than 200 millivolts (mV), unfiltered sulfides also were measured in the field by following the Methylene Blue Method (American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 2005, Section 4500; CHEMetrics, 2008). A V–2000 photometer with CHEMetrics field supplies and method was used to measure unfiltered sulfides (CHEMetrics, 2008). Lastly, alkalinity was determined by the incremental titration method (Rounds, 2006).

All water-quality samples, with the exception of those analyzed for radon-222, were collected and processed inside a field-portable collection chamber inside the dedicated mobile water-quality laboratory. A chamber consists of a frame and a new plastic-bag covering used at each site and discarded after one-time use (U.S. Geological Survey, variously dated). All samples, except those for radon analyses, were filtered during collection. Filtered samples were processed using a 0.45-micrometer polysulfone ether capsule filter. The capsule filter was preconditioned the day of use with 1 liter of American Society for Testing and Materials (ASTM) standard Type I deionized water (ASTM International, 2006a) and stored chilled at 4 degrees Celsius (°C) until use. Polyethylene

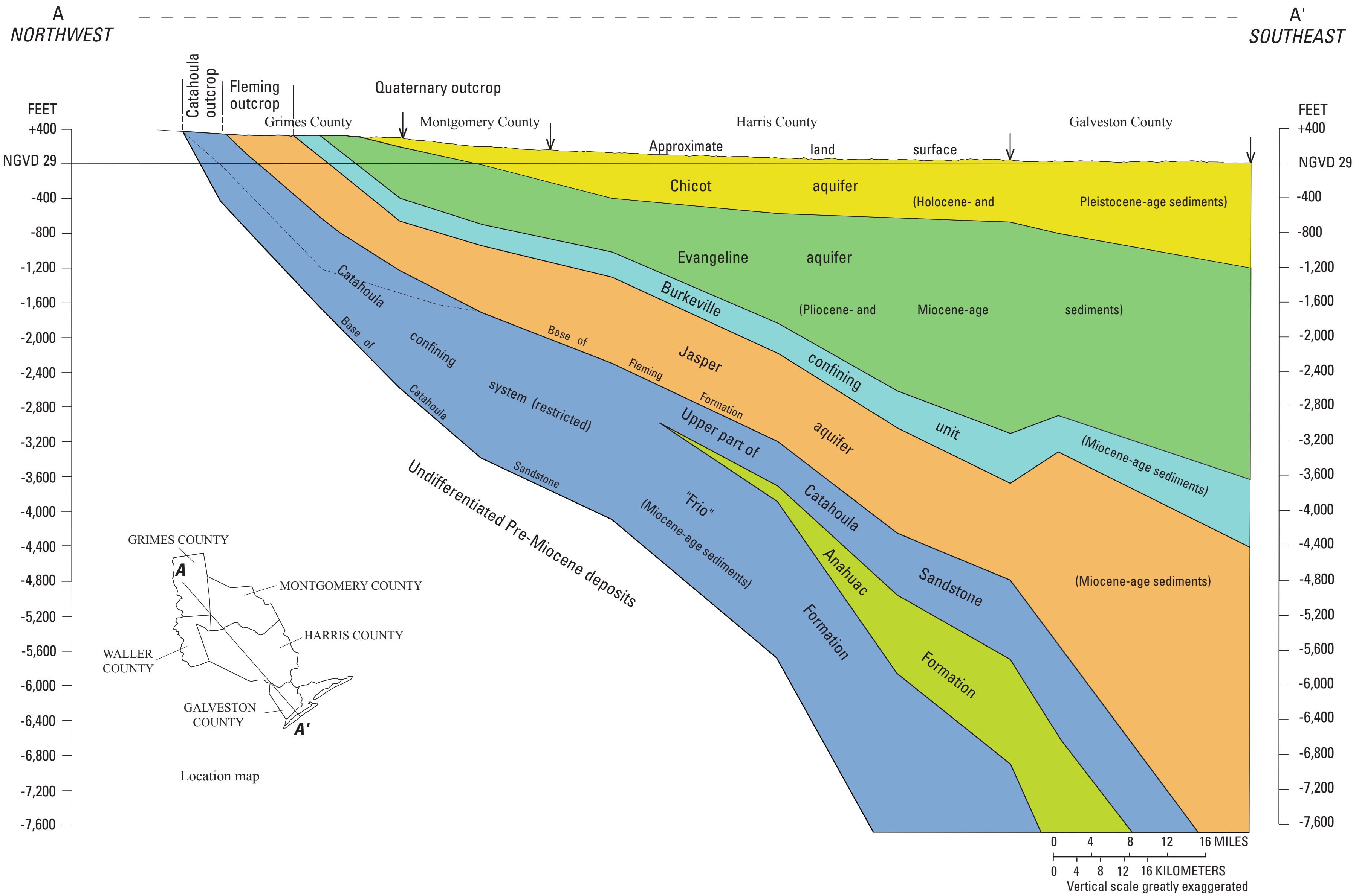


Figure 3. Hydrogeologic section of the Gulf Coast aquifer system in Harris County and adjacent counties, Texas (modified from Baker, 1979, fig. 4).

bottles were preconditioned; each bottle was rinsed three times and transported to the field approximately one-half full of Type I deionized water. Upon attaching the capsule filter to the sample collection line, the air was worked out of the filter, and 100 milliliters (mL) of native water were passed through the filter before collection. The preconditioned polyethylene bottles were emptied and given a one-time 25-mL filtered native water rinse, then filled to the shoulder of the bottle. All samples were preserved after collection, except those for major anions and carbon-14 analyses. When used, preservatives such as nitric acid were added to the samples in a preservation chamber. Ultrapure nitric acid was added to each bottle for cation or trace- element analysis, lowering the pH to 2 or less. All samples were shipped overnight to the analyzing laboratory. Most samples were stored at ambient temperatures until analyzed; those for temperature-sensitive constituents that could change as a result of biological activity were maintained at 4°C until they were analyzed (U.S. Geological Survey, variously dated).

Radon-222 samples were collected outside the chamber using a brass sampling valve with a Teflon septum. The 10-mL sample was collected using a rinsed, glass syringe with a stainless steel needle. The needle was inserted through the septum, and the valve partially closed to fill the syringe under pressure. The 10-mL sample then was injected into a USGS-prepared borosilicate glass scintillation vial prefilled with 10-mL scintillation oil. The vial was sealed with a polycone cap and shaken for 30 seconds to extract the radon into the oil, then placed in a protective cardboard tube, and shipped to the USGS National Water Quality Laboratory (NWQL) in Denver, Colo.

Sample Analysis

Three laboratories analyzed samples for this study. The USGS NWQL in Denver, Colo., was the primary laboratory; two other laboratories were contracted by the NWQL for certain analyses. The NWQL maintains National Environmental Laboratory Accreditation Conference (NELAC) and other certifications (U.S. Geological Survey, 2010a). Samples were analyzed at the NWQL for major ions (calcium, magnesium, potassium, sodium, bromide, chloride, fluoride, silica, and sulfate), residue on evaporation (dissolved solids), trace elements (arsenic, barium, boron, chromium, iron, lithium, manganese, molybdenum, selenium, strontium, and vanadium), radon-222, and uranium. Gross alpha- and beta-particle activities (at 72 hours and 30 days) and radium-226 were analyzed by Eberline Services in Richmond, Calif. One carbon isotope sample was collected and sent to the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) Facility in Woods Hole, Mass., for the carbon-13 to carbon-12 isotopic ratio and carbon-14 analysis. Anion concentrations were measured by ion-exchange chromatography, and major cation concentrations (along with iron concentrations) were measured by inductively coupled plasma-atomic emission spectrometry (ICP–AES) as described by Fishman (1993). Concentrations of filtered arsenic, chromium, selenium, and vanadium were measured using collision-reaction cell inductively coupled plasma-mass spectrometry (cICP–MS) as described by Garbarino and others (2006). The remaining six trace elements (filtered barium, boron, lithium, manganese, molybdenum, and strontium) were measured using inductively coupled plasma-mass spectrometry (ICP–MS) (Faires, 1993; Garbarino, 1999).

Gross alpha- and beta-particle activities were measured by a gas flow proportional planchet counting the residue on evaporation by using USEPA Method 900.0 (U.S. Environmental Protection Agency, 2008). Gross alpha- and beta-particle activities were measured at 72 hours after collection and again 30 days after collection, allowing the activity of short-lived isotopes to be measured (Parsa, 1998; Szabo and others, 2005). Gross alpha- and beta- particle activities are referred to as filtered, alpha or beta radioactivity, 72-hour or 30-day count, in the tables in this report. Isotopic ratio of carbon-13 to carbon-12 was determined by mass spectroscopy, and accelerator mass spectroscopy was used to determine the amount of carbon-14. Radium-226 concentration was measured by radon de-emanation by using USEPA Method 903.1 (U.S. Environmental Protection Agency, 2008). Radon-222 concentration was measured by liquid-scintillation counting (ASTM International, 2006b). Filtered, natural uranium was measured by ICP–MS (Faires, 1993; Garbarino, 1999).

Reporting of Results

The analytical quantification procedure used by the NWQL for reporting results is based on the long-term method detection level (LT–MDL) and laboratory reporting level (LRL). The LT–MDL concentrations are defined as a censoring limit for most analytical methods at the NWQL, and its purpose is to limit the false positive rate to less than or equal to 1 percent. An LT–MDL is a modification of the USEPA 40 Code of Federal Regulations Part 136 definition of the method detection limit (MDL). The LRL is defined as twice the LT–MDL and is established to limit the occurrence of false negative detections to less than or equal to 1 percent (Childress and others, 1999). A constituent concentration is considered estimated by the laboratory when results are greater than the LT–MDL and less than the LRL; that is, a detection is considered likely, but quantification is considered questionable. The remark code of “E” (estimated) is assigned by the laboratory for these results. The presence of a constituent in the sample that can be verified, but the concentration is not enough to be quantified, is reported as a remark code of “M.” Similarly, nonzero concentration values that round to zero are converted to a null value on output and reported by using a remark code of “M” (U.S. Geological Survey, 2009). Beginning in October 2010, the NWQL changed the reporting convention for all inorganic analytes that use the LRL convention. For these constituents, the reporting level was set at the LT-MDL concentration. Concentrations that are less than the LT-MDL are reported as “less than” the LT-MDL concentration (<LT-MDL) and a remark code of “E” (estimated) would

no longer be assigned to results greater than the LT–MDL and less than the LRL (U.S. Geological Survey, 2010b). For this report, inorganic analyses are reported using this new convention for samples collected after October 1, 2010.

Radionuclide results are reported in picocuries per liter, which equals 2.22 radioactive disintegrations per minute per liter of water. As defined in Focazio and others (2001, p. v), picocuries per liter is a unit expressing the concentration (activity) of radionuclides in solution as particles emitted per unit volume (liter) of water. By definition, 1 gram of radium has 1 curie of activity. A picocurie is a millionth of a millionth of a curie. The measured activity of any single isotope is considered a concentration because a mass is linked directly to activity by the radioactive decay equation and half life. The gross activity measurements are considered activities and not concentrations because there is no identifiable half life or isotope mass associated with the measurement. The laboratory reports the unrounded values for all the radionuclide concentrations along with a 1-sigma combined standard uncertainty (CSU) and a sample-specific critical level (ssL_C) for each result. Some of the raw (unrounded) radionuclide results are reported as negative values, indicating the radiation count of the sample over the fixed interval of time when the measurement made was less than the long-term average background radiation reported routinely by the instrument (Troyer and others, 1991). The 1-sigma CSU is a calculated measure of uncertainty of the laboratory analysis; specifically, the sum of the laboratory and counting uncertainty. By definition, the true radionuclide concentration plus or minus the 1-sigma CSU has a 68-percent probability (based on one standard deviation of the radioactivity count) that it is within range of the reported measured value (McCurdy and others, 2008). For each radionuclide analyzed, the laboratory computes a critical level (L_C), which is the minimum quantity of a radionuclide detectable by the counting instrument that is statistically different from the instrument background or analytical blank. It is calculated from typical analytical parameter values. The ssL_C is sample specific because it is calculated for each measurement of a radionuclide constituent using the same analytical parameter values that were used during the analysis of the sample. If the measured concentration is greater than the ssL_C, it is considered a detected value. If the result is less than its associated ssL_C, a remark code of "R" is assigned to indicate that it is a nondetection (McCurdy and others, 2008). The ssL_C is like the LT–MDL for nonradioactive constituents except that the ssL_C calculations use a 5-percent error rate for false detection compared to a 1-percent error rate for false detections used for LT–MDL calculations.

For each radionuclide measurement, the laboratory calculates a sample-specific minimum detectable concentration (ssMDC), which is a performance measure for the laboratory that is approximately twice the L_C (Currie, 1968). The ssMDC is computed individually for each radionuclide sample on the basis of the instrument operating conditions at the time of the measurement and variations in background radioactivity over time (Focazio and others, 2001). In cases where the result is less than its associated ssMDC, the result is considered poorly quantified. Unlike the ssL_C, which addresses the false detection type errors associated with the measurement, the ssMDC addresses false nondetection type errors and is computed by the laboratory after the measurement and the ssL_C criterion are calculated. The ssMDC is used by the laboratory to verify that the *a priori* minimum detectable concentration (MDC) was achieved during analysis; the *a priori* MDC is the method detection concentration calculated before the measurement is made, and is defined as the lowest concentration resulting in a 95-percent confidence level (probability) that the measured value is greater than the L_C (McCurdy and others, 2008).

Quality Control

Quality-control data were collected to assess the precision and accuracy of sample-collection procedures and laboratory analyses (U.S. Geological Survey, variously dated). Quality-control samples consisted of two equipment blank samples with accompanying topical quality-control samples, two field blank samples, and four sequential replicate samples. Topical quality-control samples address specific quality-control needs (U.S. Geological Survey, variously dated). The topical quality-control samples collected for this study were designed to identify equipment contributing to low-level contamination to the equipment blank results. Each set of topical samples represented a specific component of the sampling system; for example, extension tubing blank before manifold and sample tubing plus manifold blank.

On an annual basis before the beginning of each field sampling effort, equipment blanks were collected in a controlled laboratory environment to help verify that none of the sampling equipment used to pump and filter the groundwater samples was contributing appreciable amounts of the constituents of concern measured in the environmental samples. Field blank samples also were collected in conjunction with environmental samples to ensure equipment cleaning done in the field between sites was adequate, and that the collection, processing, or transporting procedures in the field did not contaminate the samples. Results for the equipment and field blank samples are listed in table 3 (at end of report).

Sequential replicate samples are collected to measure the variation in results originating from sampling and analytical methods. Sequential replicate sample results are included in tables 4, 5, and 6 (at end of report) with the environmental sample results for alkalinity, major ions, trace elements, and radionuclides. Inorganic constituent replicates were collected with a new, preconditioned capsule filter. Capsule filters were replaced prior to collecting the sequential replicate in case of filter loading, which might reduce the effective pore size of the filter (Horowitz and others, 1996).

The equipment blank results indicate the sampling equipment did not introduce appreciable amounts of the constituents of interest to the samples; with a few exceptions, most of the equipment blank results were less than the applicable LRLs. Low level concentrations of calcium and barium were detected in some of the equipment blank samples (table 3). Calcium was detected in the equipment blank collected on March 15, 2010, at a concentration of 0.06 mg/L, with a LRL of 0.04 mg/L. The equipment blank sample collected on August 5, 2010, had an estimated calcium concentration of 0.03 mg/L. The concentrations of calcium measured in the environmental samples ranged from 14.4 to 69.7 mg/L (table 4). On the basis of a detected amount of calcium of 0.06 mg/L in an equipment blank, calcium concentrations in environmental samples, at most, might change by less than 1 percent as a result of calcium introduced from the sampling equipment. The barium result for the equipment-blank sample collected on March 15, 2010, was reported as "M," indicating that the constituent was detected but not quantifiable (equal to or greater than the LRL). In the sample collected on August 5, 2010, the concentration for barium was reported as less than the LRL.

The field blank results indicate the sample collection and handling procedures did not introduce appreciable contamination of the constituents of interest to the environmental samples, with a few exceptions, and provided another indication that representative samples were collected from the aquifer. The field blank results included a few estimated results for calcium, potassium, barium, and strontium (table 3). An estimated calcium concentration of 0.02 and 0.03 mg/L were reported in March and April 2010 (LRL 0.04 mg/L), respectively. The potassium result for the field blank collected on March 29, 2010, was E0.06 mg/L, with a LRL of 0.06 mg/L (table 3). Because the concentrations measured in the field blanks were low, the results were not of concern, particularly for calcium and potassium. The calcium and potassium concentrations in the field blanks were much less than the minimum concentrations measured in the environmental samples of 14.4 and 1.53 mg/L, respectively (table 4). The barium results for the field blank samples collected on March 29 and April 8, 2010, were reported as "M," indicating that the constituent was detected but not quantifiable (table 3). The barium LRL was 0.14 µg/L. The strontium result for the field blank sample collected on April 8, 2010 was E0.20 µg/L, with a LRL of 0.40 µg/L. The strontium estimated concentration in the field blank was much less than the minimum concentration measured in the environmental samples of 316 µg/L (table 5).

The blank results collected during 2010 did show some low-level, manganese contamination in the environmental sample concentrations. In all of the equipment and field blanks, there were detectable concentrations of manganese measured (table 3). The concentration of manganese in the equipment blank collected on March 15, 2010, was 2.4 µg/L, which was more than the concentration of manganese measured in 9 of the 40 environmental samples collected between March and May 2010. The concentration of manganese in the equipment blank collected in August 5, 2010, was 1.3 µg/L, which was greater than or equal to two of the seven samples collected between October and November 2010 and included in this report. The concentrations of manganese measured in the 47 environmental samples included in this report ranged from an estimated concentration of 0.2 to 56.3 µg/L (table 5).

Not included in this report are the results for the field blank collected in November 2010, or the results for the topical quality-control samples that were collected during the processing of the equipment blank collected on August 25, 2010. The results for these additional samples were not received in time to be included in this report. Currently (March 2011), the cause of the low-level contamination of manganese in the equipment and field blank data available as of December 31, 2010, is unknown. It is also unknown if the contamination occurred in the blank sample collected in November 2010 for which the data were not received in time to be included in this report. It is unlikely the blank water used to prepare the blank samples was the source of contamination; the certificates of analysis for the certified inorganic blank water and the filters used to process these blank samples did not report detectable amounts of manganese. During the first phase of this project in 2007–08, the manganese concentrations measured in the equipment and field blanks ranged from an estimated concentration of 0.2 µg/L to less than the LRL of 0.2 µg/L (Oden and others, 2010). Also, the instrument blank results at the NWQL for this analysis measured between March 2 and December 30, 2010, ranged from -0.22 to 3.22 µg/L, with a median of 0.01 µg/L, and higher concentrations in blanks appeared to have occurred more frequently between May and October 2010 (Doug Stevenson, U.S. Geological Survey, written commun., 2011). Because the detectable concentrations of manganese occur in the equipment and field blanks, the contamination is likely not introduced during the field processing of samples.

Replicate samples were compared with associated environmental samples to assess the variability of the measured concentrations by computing the relative percent difference (RPD) for each constituent with the following equation:

$$\mathrm{RPD} = |C_1 - C_2|/((C_1 + C_2)/2) \times 100, \qquad (1)$$

where

C_1 is constituent concentration, in milligrams per liter, from the environmental sample; and

C_2 is constituent concentration, in milligrams per liter, from the replicate sample.

Relative percent differences of 10 percent or less indicate good agreement between the paired results for major ion or trace element analyses if the concentrations are sufficiently large compared to their associated LRL. RPDs for replicates with small concentrations are often large; differences between small concentrations result in large RPDs. In table 7 (at end of report), the minimum, average, and maximum RPDs are listed for selected constituents. An RPD was not computed for a replicated constituent if the paired results were censored as estimated or less than their associated LRL. A replicated constituent was included in table 7 if an RPD could be calculated for two or more pairs of replicate results out of the four sequential replicate samples collected during 2010. Some replicated constituents (unfiltered sulfide, filtered chromium and vanadium) had only one pair of replicated results where a detected amount was reported for each member of the pair; the RPDs for these replicate pairs ranged from 0.8 to 46 percent, and these RPD results were not included in the table of minimum, average, and maximum RPDs (table 7). The RPD of 46 percent was for a chromium replicate where the concentrations were not much larger than the LRL. The RPD for unfiltered sulfide was 29 percent, and both concentrations were not much larger than the LRL of 0.20 mg/L. The minimum, average, and maximum RPDs for the remaining constituents are listed in table 7. The RPD for the major ion and trace element constituents ranged from 0 to 17 percent; manganese and selenium, with an RPD of 17 and 15 percent respectively, were the only constituents with an RPD greater than 10 percent. In these instances, the manganese and selenium concentrations were not much larger than their LRLs (table 5).

Each radionuclide concentration or activity is reported as an unrounded value along with its 1-sigma combined standard uncertainty (CSU). The acceptable RPD for radionuclide results was not set to a value but instead determined as acceptable if the unrounded, paired results were within 1 standard deviation (as represented by the 1-sigma CSU for each radionuclide). The RPDs for the radionuclide results ranged from 0 to 32 percent. The concentrations and activities in all but four of the radionuclide result pairs were within 1 standard deviation, indicating the results were within the uncertainty of the analysis. The four replicate pairs that were not within 1-sigma CSU were the gross alpha-particle activity (30-day count) collected on March 23, 2010, the gross alpha-particle activity (72-hour count) collected on March 17, 2010, and the gross beta-particle activity (30-day count) collected on March 17 and April 5, 2010 (table 7).

Groundwater Quality

Results of the physicochemical properties and major ions are presented in table 4, arsenic and other selected trace elements in table 5, and radionuclides in table 6. Carbon-14, radium-226, and radon-222 were measured in a select number of wells and included in table 6. These data are listed by U.S. Geological Survey site number and State well number and in chronological order by the date and time of sampling. One well, LJ-65-12-328, was sampled twice—first on March 17, 2010, and again on May 6, 2010. The additional environmental sample collected on May 6, 2010, was to confirm results of the first environmental sample. So that each well is represented by one set of results, the additional May 2010 results for well LJ-65-12-328 are included in tables 4–6 but are not included in the description of ranges of concentrations for the constituents.

Physicochemical Properties and Major Ion Chemistry

Similar to the results from the reconnaissance survey (Oden and others, 2010), physicochemical properties (oxidation-reduction potential, turbidity, dissolved-oxygen concentration, pH, specific conductance, temperature [air, water], alkalinity, and residue on evaporation [dissolved solids]) and major ions (calcium, magnesium, potassium, sodium, bromide, chloride, fluoride, silica, sulfate, and sulfide) varied more for some groundwater samples than for others (table 4). For the environmental samples from the 47 wells sampled during the study, the ranges of selected physicochemical properties were as follows: oxidation-reduction potential ranged from -173 to 466 mV, dissolved oxygen ranged from less than 0.1 to 4.4 mg/L, pH ranged from 7.2 to 7.8, specific conductance ranged from 439 to 724 microsiemens per centimeter at 25 °C (µS/cm), and alkalinity ranged from 159 to 276 mg/L as calcium carbonate ($CaCO_3$). After review, the oxidation-reduction potential results measured in the samples collected between October 28 and November 9, 2010, were omitted from the report because it was determined that the probe was malfunctioning. The minimum value of -173 mV for oxidation-reduction potential was measured in the source-water sample collected from well LJ–65–20-126 in March 2010; such a relatively small oxidation-reduction potential indicates an environment favorable for the reduction of chemical species (Pankow, 1991). In contrast, the maximum positive value of 466 mV, measured in a source-water sample from well LJ–65–12–817 in March 2010, indicates a geochemical environment with a relatively large oxidizing tendency. In source-water samples with dissolved-oxygen concentrations less than the MRL of 0.1 mg/L, oxidation-reduction potential measurements were all in the negative range.

The dissolved-solids concentrations (filtered residue on evaporation in milligrams per liter, dried at 180 °C) ranged from 225 to 406 mg/L in the groundwater samples. Of the 47 sampled wells, the maximum dissolved-solids concentration was measured in a source-water sample collected from well JY-65-29-107, which also had the maximum specific conductance measurement of 724 µS/cm, maximum chloride concentration of 80.8 mg/L and maximum sulfate concentration of 17.1 milligrams per liter (table 4). The minimum dissolved-solids concentration was measured in a source-water sample collected from well LJ-65-06-528, which also had the minimum specific conductance measurement of 439 µS/cm (table 4).

Similar to the results from the reconnaissance survey (Oden and others, 2010), the largest ranges in concentration for filtered major ion constituents were obtained for the cations sodium and calcium and for the anions chloride and sulfate. The ranges for these constituents are as follows: 30.5 to 110 mg/L for sodium, 14.4 to 69.7 mg/L for calcium, 29.0 to 80.8 mg/L for chloride, and 4.93 to 17.1 mg/L for sulfate (table 4).

Arsenic and Other Trace Elements

Arsenic concentrations measured in source-water samples from the 47 wells ranged from 1.6 to 23.5 µg/L (table 5). The maximum concentration of arsenic (23.5 µg/L) was measured in the source-water sample from well LJ-65-12-328 on March 17, 2010, which was the only source-water sample from a well with a measured concentration greater than 10 µg/L.

To further characterize the water chemistry, the source-water samples collected from the 47 municipal supply wells that are documented in this report also were analyzed for other selected trace elements (barium, boron, chromium, iron, lithium, manganese, molybdenum, selenium, strontium, and vanadium) (table 5). The number of trace elements selected for analysis was reduced from 22 during the 2007–08 reconnaissance survey (Oden and others, 2010) to 11 in 2010. Based on the results from the reconnaissance survey, constituents that were not detected in many source-water samples were excluded from analysis in 2010. Quantifiable concentrations of barium, boron, lithium, molybdenum, and strontium were measured in all 47 filtered, source-water samples in 2010 (table 5). Quantifiable concentrations of manganese were measured in 46 source-water samples, and an estimated concentration of manganese was measured in 1 sample. Chromium, iron, selenium, and vanadium were detected in 24 or more of the 47 source-water samples (table 5). The ranges in concentration for those constituents detected in all 47 source-water samples are as follows: barium ranged from 150 to 411 µg/L, boron ranged from 38 to 190 µg/L, lithium ranged from 10.1 to 24 µg/L, molybdenum ranged from 0.3 to 13.2 µg/L, and strontium ranged from 316 to 738 µg/L (table 5). Manganese ranged from an estimated concentration of 0.2 to 56.3 µg/L (table 5).

Radionuclides

Gross Alpha-Particle and Beta-Particle Activities

Gross alpha-particle activities and beta-particle activities for all 47 source-water samples were analyzed 72 hours after sample collection and again 30 days after sample collection, allowing for the measurement of the activity of short-lived isotopes. These gross activity measurements represent the overall alpha-particle and beta-particle activity of all the radionuclides present in the sample in the given period of time associated with the measurement (U.S. Environmental Protection Agency, 1997). Gross alpha-particle activities reported for source-water samples were not adjusted (reduced) for activity contributions by radon or uranium and, therefore, are conservatively high estimates—an additional factor to keep in mind if the source-water results are compared to the USEPA National Primary Drinking Water Regulation for adjusted gross alpha-particle activity (U.S. Environmental Protection Agency, 2000) (table 1).

The gross alpha-particle activities measured at 30 days were greater than their associated ssL_C for 46 of the 47 source-water samples collected. The gross alpha-particle activities measured at 30 days in the samples ranged from R0.60 to 25.5 pCi/L (the "R" preceding the value of 0.60 pCi/L refers to a nondetected result less than the ssL_C) (table 6). The maximum gross alpha-particle activity at 30 days was measured in the source-water sample obtained from well LJ-65-04-723. The gross alpha-particle activities measured in all of the 47 source-water samples at 72 hours after sample collection were greater than their associated ssL_C. The gross alpha-particle activities at 72 hours ranged from 2.58 to 39.7 pCi/L (table 6). The maximum gross alpha-particle activity was measured at 72 hours in the source-water sample obtained from well LJ-65-04-729. The laboratory assigned remark codes to several of the gross alpha-particle activity results to provide additional quality-control information for the interpretation of the results (table 6). Two of the gross alpha-particle activities measured at 30 days and one result measured at 72 hours had a remark code of "b" to indicate that the associated ssMDC for these measurements was greater than the contractual *a priori* MDC, which is established by NWQL as a data quality objective for each radiological constituent as part of the performance work statement with the contract laboratory (table 6). Six of the gross alpha-particle activities measured at 30 days and 11 results measured at 72 hours had a remark code of "e" to indicate that the associated laboratory blank was greater than the ssL_C and, therefore, a detectable concentration.

All of the 47 source-water samples collected had a gross beta-particle activity at 30 days greater than the associated ssL_C. Gross beta-particle activities at 30 days ranged from 1.17 to 14.4 pCi/L (table 6). The maximum gross-beta activity counted at 30 days of 14.4 pCi/L was measured in the source-water sample from well LJ-65-04-729. Gross beta-particle activities measured at 72 hours also were consistently greater than the associated ssL_C. Gross beta-particle activities at 72 hours ranged from 1.97 to 4.4 pCi/L (table 6). The maximum gross beta-particle activity at 72 hours of 4.4 pCi/L was measured in the source-water sample from well LJ-65-12-633. In addition to the beta-emitting isotopes in the uranium-238 and thorium-232 decay series, a substantial part of the gross beta-particle activity measurements in these source-water samples could be attributed to beta emissions from potassium-40, a weak beta emitter that occurs naturally (Hem, 1992). The potassium concentrations measured in source-water samples from the 47 wells ranged from 1.53 to 2.76 mg/L (table 4).

Twenty-six of the 47 sampled wells had similar gross-alpha particle activities measured at the different time intervals, within plus or minus 5 pCi/L (table 6). Six of these 26 wells were within the uncertainty ranges defined by the associated 1-sigma CSU and, thus, the counts could not be differentiated within the associated analytical error. Although the gross alpha-particle measurements of radioactivity resulted in similar activity values in more than one-half of the samples, 35 of the 47 sampled wells had activity measurements (at 72 hours and 30 days) greater than the ssL_C, and the activity measured at 72 hours was greater than (outside their uncertainty ranges defined by their 1-sigma CSU) the activity measured at 30 days; and conversely, 5 of the 47 sampled wells had activity measurements (at 72 hours and 30 days) greater than the ssL_C and the activity measured at 30 days was greater than (outside their 1-sigma CSU) the activity measured at 72 hours. For the gross alpha-particle activities measured at 30 days after sample collection, six source-water samples had an unadjusted gross alpha-particle activity greater than 15 pCi/L. At 72 hours, 10 source-water samples had unadjusted gross alpha-particle activities equal to or greater than 14.8 pCi/L (table 6). Three of the wells sampled had unadjusted gross alpha-particle activities (at 72 hour and 30 days) greater than 15 pCi/L. For the six source-water samples with a gross alpha-particle activity (at 30 days) greater than 15 pCi/L, the uranium concentrations ranged from 0.12 to 42.7 µg/L (table 6). To convert a uranium concentration in micrograms per liter to an approximate radioactivity concentration in picocuries per liter, a conversion factor of 0.68 pCi/L is used, which is based on the assumption that the uranium-234 and uranium-238 are present in equal activities. This calculation is recognized as a conservative approximation of the uranium radioactivity because the activity ratio varies in groundwater from region to region (U.S. Environmental Protection Agency, 2000).

As with the reconnaissance survey in 2007-08 (Oden and others, 2010), the differences for the gross beta-particle activities measured at different time intervals in 2010 were not as pronounced as the differences for the gross alpha-particle activities measurements at 72 hours and 30 days. Twenty-nine of the 47 wells sampled had similar gross beta-particle activity measurements (at 72 hour and 30 days) within the uncertainty ranges defined by the associated 1-sigma CSU and, thus, the counts could not be differentiated within the associated analytical error (table 6).

Uranium

Filtered uranium was detected in amounts that could be quantified in all of the 47 wells sampled. The uranium concentrations ranged from 0.03 to 42.7 µg/L (table 6). The maximum concentration of 42.7 µg/L was measured in the source-water sample from LJ-65-04-729, which was the only source-water sample collected greater than 30 µg/L.

Other Radionuclides

The source-water sample collected from one well (LJ-65-12-328) was analyzed for carbon-14 (table 6). The amount of modern atmospheric carbon was reported as 0.2 percent. Modern is defined as 95 percent of the radiocarbon activity in 1950, as defined by the standards used during analysis. The “radiocarbon” age is calibrated to this material of known age to correct for variations in the amount of carbon-14 produced in the atmosphere; these variations mostly result from the varying intensity of cosmic rays striking the upper atmosphere and fluctuations in the amount of carbon dioxide in the atmosphere (University of Arizona, 2010). Carbon-14 can be used as a tracer to determine the relative age of recharge of groundwater; because the half life of carbon-14 is 5,730 years, carbon-14 is useful for determining the age of groundwater that was recharged between about 1,000 and 30,000 years ago (Coplen, 1993; Hinkle, 2010).

Six source-water samples collected from municipal supply wells were analyzed for radium-226, and all of the concentrations were greater than their associated ssL_C. The radium-226 concentrations measured in the source-water samples ranged from 0.732 to 2.59 pCi/L (table 6). Three source-water samples were analyzed for radon-222, and all of the concentrations were substantially greater than the associated ssL_C. The radon-222 concentrations for the samples ranged from 1,620 to 2,380 pCi/L (table 6). Concentrations of radon-222 measured in source-water samples from all three wells were greater than 300 pCi/L, and none of the concentrations measured in the samples exceeded 4,000 pCi/L.

Summary

During March-December 2010, the U.S. Geological Survey (USGS), in cooperation with the city of Houston, collected water-quality data from wells completed in the Gulf Coast aquifer system in the Houston area to characterize source-water-quality conditions in untreated groundwater prior to drinking-water treatment. These data were collected as part of an ongoing study to determine concentrations, spatial extent, and associated geochemical conditions that might be conducive for mobility and transport of selected naturally occurring contaminants (selected trace elements and radionuclides) in the Gulf Coast aquifer system in the Houston area. In the summers of 2007 and 2008, a reconnaissance-level survey of most of the same constituents measured in 2010 was completed by the USGS in cooperation with the city of Houston; the samples collected during 2007-08 were untreated water from 28 municipal supply wells in the Houston area. For the second phase of the study, source-water samples were collected from 60 municipal supply wells in the Houston area between March and December of 2010. Included in this report are the complete analytical results for 47 of the 60 samples collected in 2010—those results which were received from the laboratories and reviewed by the authors as of December 31, 2010. Selected physicochemical (relating to both physical and chemical) properties and unfiltered sulfides were measured in the field at the time each sample was collected. Source-water samples were analyzed for major ions, selected chemically related properties, trace elements, and radionuclides. An evaluation of naturally-occurring contaminant occurrence in source water provides background information regarding the presence of a contaminant in the environment. Because source-water samples were collected prior to any treatment or blending that potentially could alter contaminant concentrations, the sampled groundwater represents the quality of the source water, not the quality of finished drinking water (water that has passed through all the treatment processes and is ready to be delivered to consumers through a community water system).

Of the 47 wells for which water-quality results are documented in this report, 22 were screened entirely in the Evangeline aquifer. The remaining 25 wells contained screened intervals that intersected the Evangeline and Chicot aquifers. Samples were collected and processed in accordance with protocols established by the USGS "National Field Manual for the Collection of Water-Quality Data." Prior to sample collection, each well was pumped continuously for at least 30 minutes to ensure that source-water sampled from the well was representative of water from the aquifer. Groundwater samples were collected as near to the wellhead as possible prior to treatment. The source-water samples were analyzed for a variety of physicochemical properties and constituents to characterize the water chemistry of the Gulf Coast aquifer system. Field measurements were made of selected physicochemical properties (oxidation-reduction potential, turbidity, dissolved-oxygen concentration, pH, specific conductance, water temperature, and alkalinity) and unfiltered sulfides. Source-water samples also were analyzed for major ions (calcium, magnesium, potassium, sodium, bromide, chloride, fluoride, silica, and sulfate), residue on evaporation (dissolved solids), other selected trace elements (arsenic, barium, boron, chromium, iron, lithium, manganese, molybdenum, selenium, strontium, and vanadium), and selected radionuclides (gross alpha- and beta-particle activity [at 30 days and 72 hours], carbon-14, radium-226, radon-222, and uranium).

The physicochemical properties, major ion chemistry and trace element chemistry of the groundwater sampled in 2010, varied widely between the wells; results from the 47 wells sampled in 2010 documented in this report are similar to the results from the reconnaissance survey during 2007–08. The range of selected physicochemical properties for the 47 wells sampled in 2010 were as follows: oxidation-reduction potential ranged from -173 to 466 millivolts (mV), dissolved oxygen ranged from less than 0.1 to 4.4 milligrams per liter (mg/L), pH ranged from 7.2 to 7.8, specific conductance ranged from 439 to 724 microsiemens per centimeter at 25 °C (µS/cm), and alkalinity ranged from 159 to 276 mg/L as calcium carbonate ($CaCO_3$). The largest ranges in concentration for filtered major ion constituents were obtained for cations sodium and calcium and for anions chloride and sulfate. Arsenic concentrations measured in source-water samples from the 47 wells ranged from 1.6 to 23.5 micrograms per liter (µg/L). The maximum concentration of arsenic (23.5 µg/L) was measured in the source-water sample from well LJ-65-12-328, which was the only source-water sample from a well with a measured concentration greater than 10 µg/L. Quantifiable concentrations of barium, boron, lithium, molybdenum, and strontium were measured in all 47 filtered samples. Quantifiable concentrations of manganese were measured in 46 source-water samples, and an estimated concentration of manganese was measured in 1 sample. Chromium, iron, selenium, and vanadium were detected in 24 or more of the 47 source-water samples. The ranges in concentration for those constituents detected in all 47 source-water samples are as follows: barium ranged from 150 to 411 µg/L, boron ranged from 38 to 190 µg/L, lithium ranged from 10.1 to 24 µg/L, molybdenum ranged from 0.3 to 13.2 µg/L, and strontium ranged from 316 to 738µg/L. Manganese ranged from an estimated concentration of 0.2 to 56.3 µg/L.

Gross alpha-particle activities and beta-particle activities for all 47 source-water samples were analyzed at 72 hours after sample collection and again at 30 days after sample collection, allowing for the measurement of the activity of short-lived isotopes. Gross alpha-particle activities reported in this study were not adjusted (reduced) for activity contributions by radon or uranium and, therefore, are conservatively high estimates if compared to the U.S. Environmental Protection Agency (USEPA) National Primary Drinking Water Regulation for adjusted gross alpha-particle activity. The unadjusted gross alpha-particle activities measured at 30 days in the source-water samples ranged from R0.60 to 25.5 picocuries per liter (pCi/L) and at 72 hours ranged from 2.58 to 39.7 pCi/L (the "R" preceding the value of 0.60 pCi/L refers to a nondetected result less than the sample-specific critical level [ssL_C]). Gross beta-particle activities measured at 30 days ranged from 1.17 to 14.4 pCi/L and at 72 hours ranged from 1.97 to 4.4 pCi/L. Twenty-six of the 47 sampled wells had similar gross-alpha particle activities measured at the different time intervals, within plus or minus 5 pCi/L. Six of these 26 wells were within the uncertainty ranges defined by the associated 1-sigma standard uncertainty (CSU) and, thus, the counts could not be differentiated within the associated analytical error. For the unadjusted gross alpha-particle activities measured at 30 days after sample collection, six source-water samples had an unadjusted gross alpha-particle activity greater than 15 pCi/L. At 72 hours, 10 source-water samples had unadjusted gross alpha-particle activities equal to or greater than 14.8 pCi/L. Filtered uranium was detected in amounts that could be quantified in all of the 47 wells sampled. The uranium concentrations ranged from 0.03 to 42.7 µg/L. The maximum concentration of 42.7 µg/L was measured in the source water sample from LJ-65-04-729, which was the only source-water sample collected greater than 30 µg/L. The source-water sample collected from one well (LJ-65-12-328) was analyzed for carbon-14. The amount of modern atmospheric carbon was reported as 0.2 percent. Six source-water samples collected from municipal supply wells were analyzed for radium-226, and all of the concentrations were greater than their associated ssL_C. Three source-water samples collected were analyzed for radon-222, and all of the concentrations were substantially greater than their associated ssL_C. Concentrations of radon-222 measured in source-water samples from all three wells were greater than 300 pCi/L, and none of the concentrations measured in the samples exceeded 4,000 pCi/L.

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Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010.

[ft bls, feet below land surface; 112CEVG, Chicot and Evangeline aquifers; --, no data available; 121EVGL, Evangeline aquifer; SNCL; sand with some clay; SDCL, sand clay; CLSD, clay sand]

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
294921095312907	LJ-65-12-633	Harris	734	372	392	9/30/1988	112CEVG	--
				448	496			
				524	554			
				562	572			
				616	636			
				650	660			
				680	710			
294900095312101	LJ-65-12-619	Harris	1,451	630	640	1/1/1964[1]	112CEVG	--
				650	675			
				695	720			
				795	820			
				860	915			
				935	1,000			
				1,040	1,055			
				1,075	1,090			
				1,165	1,200			
				1,240	1,270			
				1,315	1,335			
				1,365	1,440			
295027095312301	LJ-65-12-328	Harris	1,475	1,062	1,090	10/27/1996	121EVGL	--
				1,100	1,126			
				1,167	1,184			
				1,200	1,205			
				1,230	1,235			
				1,258	1,263			
				1,288	1,332			
				1,348	1,376			
				1,388	1,404			
				1,426	1,450			
294950095313701	LJ-65-12-622	Harris	1,485	610	680	1/1/1968[1]	112CEVG	--
				724	744			
				767	797			
				838	888			
				945	978			
				1,010	1,020			
				1,130	1,175			
				1,188	1,245			
				1,278	1,298			
				1,330	1,375			
				1,440	1,470			

Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
294340095311103	LJ-65-20-321	Harris	1,432	659	677	1/3/1973	112CEVG	CLSD
				679	718			
				729	745			
				747	780			
				810	825			
				841	855			
				857	894			
				905	936			
				1,057	1,088			
				1,099	1,130			
				1,154	1,170			
				1,254	1,287			
				1,289	1,326			
				1,379	1,415			
294348095303702	LJ-65-20-319	Harris	1,335	630	650	1969	112CEVG	--
				665	690			
				700	720			
				730	740			
				760	780			
				800	820			
				880	905			
				920	940			
				1,020	1,050			
				1,060	1,100			
				1,120	1,150			
				1,210	1,250			
				1,275	1,320			
294348095270401	LJ-65-21-202	Harris	1,965	1,069	1,150	7/22/1953	121EVGL	--
				1,168	1,190			
				1,259	1,304			
				1,415	1,487			
				1,720	1,736			
				1,765	1,810			
				1,825	1,875			
				1,905	1,946			
294338095270401	LJ-65-21-201	Harris	1,051	554	574	7/4/1953	112CEVG	--
				580	590			
				600	671			
				741	791			
				811	881			
				910	931			
				980	1,011			
				1,021	1,031			

Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
294333095275602	LJ-65-21-143	Harris	1,510	716	738	7/17/1974	112CEVG	--
				748	762			
				790	850			
				860	914			
				955	985			
				1,010	1,040			
				1,060	1,116			
				1,210	1,230			
				1,240	1,266			
				1,330	1,344			
				1,380	1,408			
				1,460	1,492			
294329095284602	LJ-65-21-148	Harris	1,505	699	709	2/12/1981	112CEVG	--
				711	745			
				774	789			
				791	830			
				924	942			
				949	982			
				989	1,010			
				1,025	1,065			
				1,130	1,170			
				1,172	1,205			
				1,225	1,250			
				1,290	1,304			
				1,355	1,390			
				1,440	1,467			
				1,469	1,490			
294319095305901	LJ-65-20-303	Harris	1,469	560	610	1/11/1946	112CEVG	--
				630	730			
				750	775			
				826	846			
				875	905			
				933	963			
				1,045	1,065			
				1,086	1,129			
				1,147	1,165			
				1,295	1,341			
				1,405	1,445			
294317095313001	LJ-65-20-304	Harris	1,612	755	795	6/24/1955	121EVGL	--
				850	880			
				895	925			
				940	985			
				1,090	1,115			
				1,130	1,150			

Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
294317095313001—Continued				1,180	1,260			
				1,280	1,330			
				1,390	1,425			
				1,532	1,552			
294328095290402	LJ-65-21-149	Harris	1,518	796	832	6/7/1982	121EVGL	--
				840	874			
				918	964			
				970	1,050			
				1,120	1,164			
				1,170	1,198			
				1,200	1,228			
				1,230	1,250			
				1,280	1,306			
				1,370	1,394			
				1,410	1,424			
				1,430	1,498			
294323095300103	LJ-65-20-325	Harris	1,184	756	784	2/16/1988	121EVGL	--
				862	918			
				940	968			
				994	1,030			
				1,050	1,085			
				1,097	1,134			
				1,146	1,154			
				1,156	1,174			
294201095355601	LJ-65-20-405	Harris	1,621	632	656	1969	112CEVG	--
				695	735			
				751	783			
				795	831			
				849	881			
				901	931			
				1,056	1,099			
				1,150	1,192			
				1,219	1,280			
				1,302	1,314			
				1,318	1,334			
				1,404	1,416			
				1,474	1,494			
				1,510	1,520			
				1,550	1,570			
				1,589	1,610			
293732095300601	LJ-65-20-911	Harris	1,200	645	698	1/1/1974[1]	112CEVG	--
				719	794			
				846	956			

Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
293732095300601—Continued				978	1,002			
				1,012	1,072			
				1,082	1,188			
293734095293701	LJ-65-21-708	Harris	1,204	632	651	9/1/1972[1]	112CEVG	--
				653	688			
				698	733			
				735	767			
				770	803			
				828	868			
				878	920			
				931	958			
				961	995			
				1,010	1,039			
				1,042	1,080			
				1,082	1,096			
				1,106	1,118			
				1,120	1,158			
				1,160	1,182			
293736095285301	LJ-65-21-709	Harris	1,190	644	679	9/1/1972[1]	112CEVG	--
				681	698			
				708	718			
				721	758			
				760	797			
				811	823			
				833	838			
				840	875			
				895	916			
				918	956			
				1,016	1,032			
				1,034	1,070			
				1,073	1,109			
				1,111	1,148			
				1,151	1,169			
294002095351001	LJ-65-20-414	Harris	1,038	709	739	12/1/1978[1]	112CEVG	--
				748	760			
				774	799			
				810	844			
				850	880			
				899	969			
				984	994			
				1,008	1,028			
294414095364202	LJ-65-20-126	Harris	1,322	970	1,025	8/20/1983	121EVGL	--
				1,060	1,125			
				1,130	1,203			

Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
294414095364202—Continued				1,230	1,260			
				1,260	1,280			
				1,300	1,322			
294456095341101	LJ-65-12-820	Harris	1,345	594	752	7/30/2001	112CEVG	SDCL
				752	1,345			
294501095343601	LJ-65-12-817	Harris	967	597	637	4/1/1979[1]	112CEVG	--
				654	732			
				748	772			
				794	811			
				892	957			
294519095383201	LJ-65-11-918	Harris	1,316	550	690	7/20/1983	112CEVG	--
				752	788			
				810	860			
				890	920			
				940	1,054			
				1,070	1,100			
				1,130	1,152			
295246095351301	LJ-65-04-723	Harris	1,509	599	613	6/5/1982	112CEVG	--
				641	649			
				661	713			
				717	743			
				747	759			
				769	787			
				816	834			
				840	852			
				861	873			
				903	915			
				951	995			
				1,013	1,041			
				1,079	1,127			
				1,135	1,158			
				1,192	1,225			
				1,261	1,272			
				1,355	1,367			
				1,401	1,413			
				1,431	1,489			
295249095364701	LJ-65-04-728	Harris	1,438	825	858	7/11/1985	121EVGL	SNCL
				950	974			
				982	998			
				1,012	1,062			
				1,121	1,132			
				1,174	1,188			

Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
295249095364701—Continued				1,207	1,263			
				1,290	1,366			
				1,376	1,418			
295249095370701	LJ-65-04-729	Harris	1,080	580	600	8/18/1986	112CEVG	--
				626	686			
				758	774			
				792	800			
				822	856			
				955	1,006			
				1,022	1,066			
295243095383101	LJ-65-03-916	Harris	1,379	769	790	11/20/1989	121EVGL	SNCL
				800	834			
				918	942			
				1,012	1,020			
				1,040	1,050			
				1,098	1,128			
				1,150	1,162			
				1,208	1,232			
				1,288	1,354			
294712095401301	LJ-65-11-803	Harris	1,394	742	804	1/8/1974	121EVGL	--
				804	820			
				856	912			
				994	1,018			
				1,050	1,072			
				1,150	1,170			
				1,170	1,188			
				1,208	1,226			
				1,348	1,384			
294717095401001	LJ-65-11-804	Harris	1,641	610	682	2/29/1980	112CEVG	--
				748	820			
				832	842			
				866	944			
				995	1,020			
				1,050	1,080			
				1,134	1,176			
				1,182	1,192			
				1,212	1,222			
				1,348	1,389			
				1,528	1,554			
				1,562	1,574			
				1,604	1,626			

Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
294952095342601	LJ-65-12-519	Harris	1,200	634	699	10/3/1979	112CEVG	SNCL
				771	804			
				807	845			
				847	885			
				919	949			
				952	990			
				1,020	1,050			
				1,130	1,159			
				1,160	1,184			
294925095341201	LJ-65-12-520	Harris	1,528	831	866	2/15/1980	121EVGL	--
				868	906			
				940	958			
				969	980			
				982	1,014			
				1,150	1,164			
				1,180	1,206			
				1,210	1,230			
				1,270	1,287			
				1,390	1,429			
				1,045	1,060			
				1,343	1,359			
				1,369	1,389			
				1,431	1,455			
				1,485	1,510			
294844095342401	LJ-65-12-522	Harris	1,556	847	853	9/2/1999	121EVGL	--
				865	870			
				882	902			
				929	934			
				962	972			
				984	1,014			
				1,036	1,063			
				1,072	1,110			
				1,133	1,138			
				1,162	1,166			
				1,195	1,200			
				1,240	1,245			
				1,275	1,280			
				1,310	1,320			
				1,352	1,357			
				1,402	1,411			
				1,416	1,442			
				1,513	1,530			

Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
294800095344101	LJ-65-12-516	Harris	1,165	705	742	10/1/1976[1]	121EVGL	--
				783	798			
				859	914			
				924	944			
				950	1,044			
				1,060	1,088			
				1,090	1,150			
294735095344001	LJ-65-12-521	Harris	1,374	804	818	3/20/2000	121EVGL	SNCL
				854	862			
				895	904			
				946	972			
				981	996			
				1,035	1,049			
				1,074	1,086			
				1,094	1,146			
				1,152	1,163			
				1,195	1,200			
				1,240	1,245			
				1,278	1,283			
				1,315	1,320			
				1,326	1,349			
294627095375801	LJ-65-11-914	Harris	1,135	762	778	1/16/1976	121EVGL	--
				786	826			
				862	890			
				906	1,026			
				1,044	1,074			
				1,102	1,120			
294721095361001	LJ-65-12-719	Harris	1,135	558	588	1970	112CEVG	SNCL
				636	678			
				720	748			
				808	828			
				848	1,023			
				1,083	1,117			
294723095370501	LJ-65-12-730	Harris	1,712	685	770	1/17/1984	121EVGL	SNCL
				788	820			
				830	1,012			
				1,080	1,098			
				1,150	1,160			
				1,240	1,256			
				1,300	1,328			
				1,410	1,436			
				1,470	1,522			
				1,550	1,588			
				1,600	1,692			

Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
294723095382601	LJ-65-11-920	Harris	1,238	627	1,238	7/7/1993	121EVGL	CLSD
294731095414201	LJ-65-11-514	Harris	1,336	796	846	2/10/1992	121EVGL	--
				902	920			
				954	962			
				996	1,006			
				1,018	1,058			
				1,066	1,088			
				1,096	1,126			
				1,140	1,148			
				1,174	1,182			
				1,214	1,244			
				1,250	1,256			
				1,276	1,316			
295553095191201	LJ-65-06-528	Harris	1,680	800	1,680	10/1/1982	121EVGL	--
293636095300401	JY-65-28-309	Fort Bend	1,032	770	800	5/31/1969	121EVGL	--
				820	840			
				930	1,020			
293635095294101	JY-65-29-107	Fort Bend	1,220	750	790	11/1/1979[1]	121EVGL	--
				860	890			
				950	965			
				985	1,005			
				1,025	1,105			
				1,120	1,140			
				1,150	1,170			
				1,180	1,205			
293652095293601	LJ-65-29-108	Harris	1,190	750	765	10/4/1982	121EVGL	--
				780	820			
				850	890			
				892	930			
				940	964			
				965	1,000			
				1,024	1,069			
				1,089	1,109			
				1,129	1,170			
294252095362101	LJ-65-20-125	Harris	1,610	704	752	1/11/1983	112CEVG	--
				760	784			
				790	820			
				826	842			
				854	874			
				880	902			
				958	986			

Table 2. Well information for municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	County	Well depth (ft bls)	Depth to top of open interval (ft bls)	Depth to bottom of open interval (ft bls)	Date of construction	Aquifer code	Lithology code
294252095362101—Continued				1,010	1,046			
				1,054	1,072			
				1,092	1,110			
				1,134	1,170			
				1,190	1,210			
				1,218	1,240			
				1,246	1,276			
				1,330	1,370			
				1,414	1,442			
				1,492	1,512			
				1,560	1,590			
294127095342502	LJ-65-20-519	Harris	1,450	1,146	1,164	7/12/1979	121EVGL	--
				1,232	1,282			
				1,336	1,440			
294047095345601	LJ-65-20-516	Harris	960	710	960	11/1/1975[1]	112CEVG	CLSD
294050095355501	LJ-65-20-416	Harris	872	584	606	--	112CEVG	--
				612	622			
				638	646			
				678	708			
				734	764			
				792	806			
				812	848			
				856	866			

[1] Construction date was not reported, so the first day of the month was assigned arbitrarily.

Table 3. Results of major ion, trace element, and radionuclide analyses from quality-control samples, equipment blanks, and field blanks collected in association with municipal supply wells sampled in the Houston, Texas, area, 2010.

[USGS TWSC, U.S. Geological Survey Texas Water Science Center; mg/L, milligrams per liter; SiO_2, silicon dioxide; °C, degrees Celsius; µg/L, micrograms per liter; Th, thorium; pCi/L, picocuries per liter; CSU, combined standard uncertainty; ssL_C, sample-specific critical level; Cs, cesium; <, less than; E, estimated; M, presence verified but not quantified; R, radchem non-detect, below ssL_C]

U.S. Geological Survey site number	Site name or State well number	Date	Sample start time	Sample type	Calcium, water, filtered (mg/L)	Magnesium, water, filtered (mg/L)	Potassium, water, filtered (mg/L)	Sodium, water, filtered (mg/L)	Bromide, water, filtered (mg/L)	Chloride, water, filtered (mg/L)	Fluoride, water, filtered (mg/L)	Silica, water, filtered (mg/L as SiO_2)
301056095265000	USGS TWSC, Gulf Coast Program Office Laboratory, Shenandoah, Tex.	3/15/2010	1359	Equipment blank	0.06	<0.016	<0.06	<0.10	<0.02	<0.12	<0.08	<0.06
294002095351001	LJ-65-20-414	3/29/2010	1059	Field blank	E.02	<.016	E.06	<.10	<.02	<.12	<.08	<.06
294731095414201	LJ-65-11-514	4/8/2010	0959	Field blank	E.03	<.016	<.06	<.10	<.02	<.12	<.08	<.06
301056095265000	USGS TWSC, Gulf Coast Program Office Laboratory, Shenandoah, Tex.	8/5/2010	0859	Equipment blank	E.03	<.016	<.06	<.10	<.02	<.12	<.08	<.06

U.S. Geological Survey site number	Site name or State well number	Date	Sample start time	Sample type	Sulfate, water, filtered (mg/L)	Residue on evaporation, dried at 180 °C, water, filtered (mg/L)	Arsenic, water, filtered (µg/L)	Barium, water, filtered (µg/L)	Boron, water, filtered (µg/L)	Chromium, water, filtered (µg/L)	Iron, water, filtered (µg/L)	Lithium, water, filtered (µg/L)
301056095265000	USGS TWSC, Gulf Coast Program Office Laboratory, Shenandoah, Tex.	3/15/2010	1359	Equipment blank	<0.18	<10	<0.04	M	<3	<0.12	<6	<0.4
294002095351001	LJ-65-20-414	3/29/2010	1059	Field blank	<.18	<10	<.04	M	<3	<.12	<6	<.4
294731095414201	LJ-65-11-514	4/8/2010	0959	Field blank	<.18	<10	<.04	M	<3	<.12	<6	<.4
301056095265000	USGS TWSC, Gulf Coast Program Office Laboratory, Shenandoah, Tex.	8/5/2010	0859	Equipment blank	<.18	<10	<.04	<0.14	<3	<.12	<6	<.4

Table 3. Results of major ion, trace element, and radionuclide analyses from quality-control samples, equipment blanks, and field blanks collected in association with municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	Site name or State well number	Date	Sample start time	Sample type	Manganese, water, filtered (µg/L)	Molybdenum, water, filtered (µg/L)	Selenium, water, filtered (µg/L)	Strontium, water, filtered (µg/L)	Vanadium, water, filtered (µg/L)	Alpha radioactivity, 30-day count, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 30-day count, 1-sigma CSU, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 30-day count, ssL_c, water, filtered, Th-230 curve (pCi/L)
301056095265000	USGS TWSC, Gulf Coast Program Office Laboratory, Shenandoah, Tex.	3/15/2010	1359	Equipment blank	2.4	<0.028	<0.04	<0.40	<0.16	-0.04	0.11	0.17
294002095351001	LJ-65-20-414	3/29/2010	1059	Field blank	1.8	<.028	<.04	<.40	<.16	--	--	--
294731095414201	LJ-65-11-514	4/8/2010	0959	Field blank	.6	<.028	<.04	E.20	<.16	--	--	--
301056095265000	USGS TWSC, Gulf Coast Program Office Laboratory, Shenandoah, Tex.	8/5/2010	0859	Equipment blank	1.3	<.028	<.04	<.40	<.16	.10	.17	.25

U.S. Geological Survey site number	Site name or State well number	Date	Sample start time	Sample type	Alpha radioactivity, 30-day count, remark code	Alpha radioactivity, 72-hour count, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count, 1-sigma CSU, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count, ssL_c, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count, remark code	Beta radioactivity, 30-day count, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 30-day count, 1-sigma CSU, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 30-day count, ssL_c, water, filtered, Cs-137 curve (pCi/L)
301056095265000	USGS TWSC, Gulf Coast Program Office Laboratory, Shenandoah, Tex.	3/15/2010	1359	Equipment blank	R	-0.070	0.085	0.15	R	0.06	0.34	0.55
294002095351001	LJ-65-20-414	3/29/2010	1059	Field blank	--	--	--	--	--	--	--	--
294731095414201	LJ-65-11-514	4/8/2010	0959	Field blank	--	--	--	--	--	--	--	--
301056095265000	USGS TWSC, Gulf Coast Program Office Laboratory, Shenandoah, Tex.	8/5/2010	0859	Equipment blank	R	-.19	.12	.23	R	-.13	.36	.6

Table 3. Results of major ion, trace element, and radionuclide analyses from quality-control samples, equipment blanks, and field blanks collected in association with municipal supply wells sampled in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	Site name or State well number	Date	Sample start time	Sample type	Beta radio-activity, 30-day count, remark code	Beta radio-activity, 72-hour count, water, filtered, Cs-137 curve (pCi/L)	Beta radio-activity, 72-hour count, 1-sigma CSU, water, filtered, Cs-137 curve (pCi/L)	Beta radio-activity, 72-hour count, ssL$_c$, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 72-hour count, remark code	Uranium (natural), water, filtered (µg/L)	Uranium (natural), LRL, water, filtered (µg/L)	Uranium (natural) remark code
301056095265000	USGS TWSC, Gulf Coast Program Office Laboratory, Shenandoah, Tex.	3/15/2010	1359	Equipment blank	R	0.05	0.34	0.55	R	0.01	0.008	<
294002095351001	LJ-65-20-414	3/29/2010	1059	Field blank	--	--	--	--	--	.01	.008	<
294731095414201	LJ-65-11-514	4/8/2010	0959	Field blank	--	--	--	--	--	.01	.008	<
301056095265000	USGS TWSC, Gulf Coast Program Office Laboratory, Shenandoah, Tex.	8/5/2010	0859	Equipment blank	R	-.27	.39	.64	R	.01	.008	<

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010.

[nm, nanometers; NTRU, Nephelometric Turbidity Ratio Unit; mg/L, milligrams per liter; °C, degrees Celsius; E, estimated; --, no data available; <, less than; $CaCO_3$, calcium carbonate; SiO_2, silicon dioxide; U, analyzed for but not detected; M, presence verified but not quantified]

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Oxidation reduction potential (ORP), reference electrode not specified (millivolts)	Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 30 degrees, ratiometric correction (NTRU)	Barometric pressure (millimeters of mercury)	Dissolved oxygen, water, unfiltered (mg/L)	pH, water, unfiltered, field (standard units)	Specific conductance, water, unfiltered (microsiemens per centimeter at 25 °C)	Temperature, air (°C)	Temperature, water (°C)
294921095312907	LJ-65-12-633	3/16/2010	1041	Environmental	123	0.6	765	3.5	7.2	562	18.0	22.9
294900095312101	LJ-65-12-619	3/16/2010	1257	Environmental	24.0	.9	765	1.2	7.4	516	15.5	24.5
295027095312301	LJ-65-12-328	3/17/2010	0927	Environmental	-131	.2	764	.9	7.7	649	14.5	24.1
295027095312301	*LJ-65-12-328*	*3/17/2010*	*0928*	*Sequential replicate*	--	--	--	--	--	--	--	--
294950095313701	LJ-65-12-622	3/17/2010	1114	Environmental	-55.7	.5	764	1.2	7.4	519	18.5	25.0
294340095311103	LJ-65-20-321	3/18/2010	0952	Environmental	148	.2	764	.5	7.6	488	14.5	25.2
294348095303702	LJ-65-20-319	3/18/2010	1147	Environmental	53.7	.6	764	.5	7.6	481	19.0	24.7
294348095270401	LJ-65-21-202	3/22/2010	1002	Environmental	-134	.1	764	<.1	7.8	575	14.0	28.2
294338095270401	LJ-65-21-201	3/22/2010	1129	Environmental	4.7	.1	764	1.3	7.2	531	17.0	23.9
294333095275602	LJ-65-21-143	3/22/2010	1304	Environmental	-9.6	.1	763	.1	7.6	504	20.5	25.6
294329095284602	LJ-65-21-148	3/23/2010	1001	Environmental	165	.1	761	.7	7.5	521	19.8	25.2
294329095284602	*LJ-65-21-148*	*3/23/2010*	*1002*	*Sequential replicate*	--	--	--	--	--	--	--	--
294319095305901	LJ-65-20-303	3/23/2010	1123	Environmental	85.0	.1	761	2.5	7.3	526	22.4	24.4
294317095313001	LJ-65-20-304	3/23/2010	1252	Environmental	-8.9	.1	761	.2	7.8	485	--	25.9

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Oxidation reduction potential (ORP), reference electrode not specified (millivolts)	Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 30 degrees, ratiometric correction (NTRU)	Barometric pressure (millimeters of mercury)	Dissolved oxygen, water, unfiltered (mg/L)	pH, water, unfiltered, field (standard units)	Specific conductance, water, unfiltered (microsiemens per centimeter at 25 °C)	Temperature, air (°C)	Temperature, water (°C)
294328095290402	LJ-65-21-149	3/24/2010	1036	Environmental	40.7	1.1	759	0.4	7.5	497	--	25.3
294323095300103	LJ-65-20-325	3/24/2010	1151	Environmental	-79.5	.9	759	.2	7.8	500	--	25.3
294201095355601	LJ-65-20-405	3/24/2010	1343	Environmental	25.3	.1	757	2.9	7.3	528	19.0	24.4
293732095300601	LJ-65-20-911	3/25/2010	0932	Environmental	96.5	.1	760	.4	7.4	531	21.7	25.4
293734095293701	LJ-65-21-708	3/25/2010	1130	Environmental	-38.7	.1	761	<.1	7.5	531	19.7	26.0
293736095285301	LJ-65-21-709	3/25/2010	1257	Environmental	-100	.2	760	<.1	7.5	518	--	26.0
294002095351001	LJ-65-20-414	3/29/2010	1108	Environmental	156	.1	763	.8	7.4	504	20.5	25.5
294414095364202	LJ-65-20-126	3/29/2010	1313	Environmental	-173	.1	762	<.1	7.6	487	25.5	26.5
294456095341101	LJ-65-12-820	3/30/2010	0906	Environmental	124	.3	761	2.6	7.4	498	18.3	24.7
294501095343601	LJ-65-12-817	3/30/2010	1021	Environmental	466	.5	762	3.5	7.4	501	23.1	24.2
294519095383201	LJ-65-11-918	3/30/2010	1154	Environmental	178	.2	761	4.2	7.4	487	27.0	24.1
295246095351301	LJ-65-04-723	3/31/2010	0913	Environmental	-11.3	.7	759	1.1	7.4	473	24.0	25.3
295249095364701	LJ-65-04-728	3/31/2010	1113	Environmental	-163	.4	759	<.1	7.7	539	22.0	26.7
295249095370701	LJ-65-04-729	3/31/2010	1228	Environmental	-59.9	2.0	758	1.0	7.4	476	25.5	25.2
295243095383101	LJ-65-03-916	4/1/2010	0941	Environmental	-117	.3	758	.3	7.5	489	19.5	25.9

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Oxidation reduction potential (ORP), reference electrode not specified (millivolts)	Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 30 degrees, ratiometric correction (NTRU)	Barometric pressure (millimeters of mercury)	Dissolved oxygen, water, unfiltered (mg/L)	pH, water, unfiltered, field (standard units)	Specific conductance, water, unfiltered (microsiemens per centimeter at 25 °C)	Temperature, air (°C)	Temperature, water (°C)
294712095401301	LJ-65-11-803	4/1/2010	1124	Environmental	-134	0.1	759	<.1	7.5	498	26.0	25.3
294717095401001	LJ-65-11-804	4/1/2010	1229	Environmental	-135	.4	758	<.1	7.6	496	26.5	25.8
294952095342601	LJ-65-12-519	4/5/2010	1030	Environmental	-89.6	.2	762	<.1	7.5	484	24.5	24.8
294952095342601	*LJ-65-12-519*	*4/5/2010*	*1031*	*Sequential replicate*	--	--	--	--	--	--	--	--
294925095341201	LJ-65-12-520	4/5/2010	1202	Environmental	-149	.2	762	<.1	7.5	527	30.3	27.2
294844095342401	LJ-65-12-522	4/5/2010	1338	Environmental	-135	.1	761	<.1	7.5	516	28.2	27.2
294800095344101	LJ-65-12-516	4/6/2010	0920	Environmental	-145	.1	758	<.1	7.6	472	23.0	25.6
294735095344001	LJ-65-12-521	4/6/2010	1042	Environmental	-121	.1	758	<.1	7.6	502	26.0	27.5
294627095375801	LJ-65-11-914	4/6/2010	1216	Environmental	-79.6	.2	758	<.1	7.5	495	27.0	26.3
294721095361001	LJ-65-12-719	4/7/2010	0909	Environmental	82.0	1.4	755	2.0	7.4	492	26.0	24.5
294723095370501	LJ-65-12-730	4/7/2010	1040	Environmental	-61.8	.7	755	<.1	7.5	485	24.5	25.9
294723095382601	LJ-65-11-920	4/7/2010	1209	Environmental	-92.0	.1	755	<.1	7.5	493	28.0	26.5
294731095414201	LJ-65-11-514	4/8/2010	1016	Environmental	-105	.1	762	<.1	7.7	617	14.5	26.8
295553095191201	LJ-65-06-528	4/8/2010	1331	Environmental	-125	.5	762	<.1	7.5	439	21.0	25.9
295027095312301	LJ-65-12-328	5/6/2010	0940	Environmental	-158	.3	758	<.1	7.8	652	32.5	28.1

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Oxidation reduction potential (ORP), reference electrode not specified (millivolts)	Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 30 degrees, ratiometric correction (NTRU)	Barometric pressure (millimeters of mercury)	Dissolved oxygen, water, unfiltered (mg/L)	pH, water, unfiltered, field (standard units)	Specific conductance, water, unfiltered (microsiemens per centimeter at 25 °C)	Temperature, air (°C)	Temperature, water (°C)
293636095300401	JY-65-28-309	10/28/2010	1011	Environmental	--	0.2	768	<0.1	7.3	521	25.0	25.8
293635095294101	JY-65-29-107	10/28/2010	1225	Environmental	--	.2	768	<.1	7.3	724	29.5	26.1
293652095293601	LJ-65-29-108	10/28/2010	1350	Environmental	--	.2	767	<.1	7.3	596	27.0	25.8
294252095362101	LJ-65-20-125	11/3/2010	1033	Environmental	--	.3	759	3.4	7.4	501	14.0	24.7
294127095342502	LJ-65-20-519	11/4/2010	0945	Environmental	--	.3	764	<.1	7.8	509	16.0	27.2
294127095342502	*LJ-65-20-519*	*11/4/2010*	*0946*	*Sequential replicate*	--	--	--	--	--	--	--	--
294047095345601	LJ-65-20-516	11/4/2010	1114	Environmental	--	.2	763	2.1	7.3	516	18.0	25.1
294050095355501	LJ-65-20-416	11/9/2010	1159	Environmental	--	.3	758	4.4	7.3	568	26.0	24.1

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Calcium, water, filtered (mg/L)	Magnesium, water, filtered (mg/L)	Potassium, water, filtered (mg/L)	Sodium, water, filtered (mg/L)	Alkalinity, water, filtered, inflection-point titration method (incremental titration method), field (mg/L as $CaCO_3$)	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	Bromide, water, filtered (mg/L)	Chloride, water, filtered (mg/L)
294921095312907	LJ-65-12-633	3/16/2010	1041	Environmental	64.8	8.64	1.72	31.1	210	255	0.15	49.2
294900095312101	LJ-65-12-619	3/16/2010	1257	Environmental	43.3	12.0	2.30	39.1	169	206	.17	47.0
295027095312301	LJ-65-12-328	3/17/2010	0927	Environmental	18.6	5.10	2.48	108	235	285	.22	54.5
295027095312301	*LJ-65-12-328*	*3/17/2010*	*0928*	*Sequential replicate*	*17.7*	*5.15*	*2.52*	*113*	--	--	*.22*	*55.3*
294950095313701	LJ-65-12-622	3/17/2010	1114	Environmental	46.5	11.2	2.30	36.7	169	206	.18	47.3
294340095311103	LJ-65-20-321	3/18/2010	0952	Environmental	22.9	4.97	1.67	68.8	230	279	.13	31.1
294348095303702	LJ-65-20-319	3/18/2010	1147	Environmental	28.8	5.85	1.74	59.4	179	218	.13	31.5
294348095270401	LJ-65-21-202	3/22/2010	1002	Environmental	14.4	3.73	1.85	110	276	333	.14	38.8
294338095270401	LJ-65-21-201	3/22/2010	1129	Environmental	48.4	12.3	2.31	41.3	190	230	.14	42.9
294333095275602	LJ-65-21-143	3/22/2010	1304	Environmental	24.3	5.76	1.90	72.3	190	230	.12	33.5
294329095284602	LJ-65-21-148	3/23/2010	1001	Environmental	33.8	7.03	1.97	64.4	190	230	.13	37.7
294329095284602	*LJ-65-21-148*	*3/23/2010*	*1002*	*Sequential replicate*	*33.3*	*6.89*	*1.97*	*60.3*	*190*	*230*	*.13*	*37.7*
294319095305901	LJ-65-20-303	3/23/2010	1123	Environmental	52.2	8.66	1.88	40.3	190	230	.14	41.4
294317095313001	LJ-65-20-304	3/23/2010	1252	Environmental	20.2	4.22	1.59	75.4	179	217	.10	29.0
294328095290402	LJ-65-21-149	3/24/2010	1036	Environmental	34.7	7.06	1.93	56.9	169	206	.12	35.0
294323095300103	LJ-65-20-325	3/24/2010	1151	Environmental	20.3	4.41	1.58	80.7	184	223	.11	30.8

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Calcium, water, filtered (mg/L)	Magnesium, water, filtered (mg/L)	Potassium, water, filtered (mg/L)	Sodium, water, filtered (mg/L)	Alkalinity, water, filtered, inflection-point titration method (incremental titration method), field (mg/L as $CaCO_3$)	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	Bromide, water, filtered (mg/L)	Chloride, water, filtered (mg/L)
294201095355601	LJ-65-20-405	3/24/2010	1343	Environmental	60.1	10.6	1.89	33.4	174	212	0.15	47.1
293732095300601	LJ-65-20-911	3/25/2010	0932	Environmental	43.2	7.51	2.04	53.8	200	243	.12	35.8
293734095293701	LJ-65-21-708	3/25/2010	1130	Environmental	33.0	5.74	1.85	68.0	200	243	.12	34.3
293736095285301	LJ-65-21-709	3/25/2010	1257	Environmental	38.3	6.31	1.90	58.6	195	236	.11	32.5
294002095351001	LJ-65-20-414	3/29/2010	1108	Environmental	46.8	8.20	2.03	34.7	240	292	.14	39.0
294414095364202	LJ-65-20-126	3/29/2010	1313	Environmental	36.0	7.95	2.42	47.9	174	212	.14	37.7
294456095341101	LJ-65-12-820	3/30/2010	0906	Environmental	44.4	8.27	2.00	41.6	200	243	.13	38.9
294501095343601	LJ-65-12-817	3/30/2010	1021	Environmental	48.5	8.23	1.82	38.3	174	212	.10	41.1
294519095383201	LJ-65-11-918	3/30/2010	1154	Environmental	53.7	7.08	1.53	30.5	164	200	.15	44.9
295246095351301	LJ-65-04-723	3/31/2010	0913	Environmental	52.5	6.26	2.19	31.1	215	261	.14	42.1
295249095364701	LJ-65-04-728	3/31/2010	1113	Environmental	28.7	6.77	2.76	72.0	190	230	.16	45.5
295249095370701	LJ-65-04-729	3/31/2010	1228	Environmental	50.1	6.24	2.19	34.2	159	193	.14	41.1
295243095383101	LJ-65-03-916	4/1/2010	0941	Environmental	40.3	8.37	2.62	43.2	235	285	.14	41.3
294712095401301	LJ-65-11-803	4/1/2010	1124	Environmental	45.9	7.36	2.25	39.8	169	206	.16	45.4
294717095401001	LJ-65-11-804	4/1/2010	1229	Environmental	42.9	7.07	2.18	43.1	169	206	.15	44.7

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Calcium, water, filtered (mg/L)	Magnesium, water, filtered (mg/L)	Potassium, water, filtered (mg/L)	Sodium, water, filtered (mg/L)	Alkalinity, water, filtered, inflection-point titration method (incremental titration method), field (mg/L as $CaCO_3$)	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	Bromide, water, filtered (mg/L)	Chloride, water, filtered (mg/L)
294952095342601	LJ-65-12-519	4/5/2010	1030	Environmental	38.3	11.4	2.45	41.5	*169*	206	0.13	36.3
294952095342601	*LJ-65-12-519*	*4/5/2010*	*1031*	*Sequential replicate*	*37.4*	*11.1*	*2.37*	*40.0*	*179*	*218*	*.13*	*36.4*
294925095341201	LJ-65-12-520	4/5/2010	1202	Environmental	35.3	7.16	2.44	56.5	190	230	.16	43.4
294844095342401	LJ-65-12-522	4/5/2010	1338	Environmental	36.8	8.03	2.54	49.6	184	224	.16	42.5
294800095344101	LJ-65-12-516	4/6/2010	0920	Environmental	35.3	8.81	2.25	43.4	174	212	.12	31.2
294735095344001	LJ-65-12-521	4/6/2010	1042	Environmental	33.5	7.63	2.44	54.0	184	224	.14	38.2
294627095375801	LJ-65-11-914	4/6/2010	1216	Environmental	41.0	7.28	2.17	49.0	169	206	.15	42.7
294721095361001	LJ-65-12-719	4/7/2010	0909	Environmental	42.2	11.9	2.26	37.1	182	221	.11	35.9
294723095370501	LJ-65-12-730	4/7/2010	1040	Environmental	44.5	7.92	2.22	42.1	169	206	.14	38.7
294723095382601	LJ-65-11-920	4/7/2010	1209	Environmental	39.5	7.34	2.30	44.8	174	212	.15	40.9
294731095414201	LJ-65-11-514	4/8/2010	1016	Environmental	25.6	4.40	1.89	93.3	225	273	.16	49.8
295553095191201	LJ-65-06-528	4/8/2010	1331	Environmental	35.0	6.29	1.97	40.9	164	200	.12	33.9
295027095312301	LJ-65-12-328	5/6/2010	0940	Environmental	19.2	4.99	2.23	113	250	303	.21	53.6
293636095300401	JY-65-28-309	10/28/2010	1011	Environmental	50.3	7.93	2.14	46.9	225	274	.10	33.5
293635095294101	JY-65-29-107	10/28/2010	1225	Environmental	49.2	8.02	2.22	86.0	210	255	.16	80.8
293652095293601	LJ-65-29-108	10/28/2010	1350	Environmental	51.3	8.73	2.16	61.7	195	237	.13	51.1

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Calcium, water, filtered (mg/L)	Magnesium, water, filtered (mg/L)	Potassium, water, filtered (mg/L)	Sodium, water, filtered (mg/L)	Alkalinity, water, filtered, inflection-point titration method (incremental titration method), field (mg/L as $CaCO_3$)	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	Bromide, water, filtered (mg/L)	Chloride, water, filtered (mg/L)
294252095362101	LJ-65-20-125	11/3/2010	1033	Environmental	54.3	8.71	1.86	33.2	230	280	0.16	45.3
294127095342502	LJ-65-20-519	11/4/2010	0945	Environmental	20.1	5.22	1.82	77.5	169	205	.13	35.8
294127095342502	*LJ-65-20-519*	*11/4/2010*	*0946*	*Sequential replicate*	*19.8*	*5.11*	*1.81*	*78.8*	*174*	*211*	*.12*	*36.0*
294047095345601	LJ-65-20-516	11/4/2010	1114	Environmental	53.2	9.33	1.95	34.8	169	206	.16	43.1
294050095355501	LJ-65-20-416	11/9/2010	1159	Environmental	69.7	11.2	1.65	35.1	174	212	.18	54.9

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Fluoride, water, filtered (mg/L)	Silica, water, filtered (mg/L as SiO_2)	Sulfate, water, filtered (mg/L)	Hydrogen sulfide, water, unfiltered (mg/L)[1]	Sulfide, water, unfiltered, field (mg/L)	Residue on evaporation, dried at 180 °C, water, filtered (mg/L)
294921095312907	LJ-65-12-633	3/16/2010	1041	Environmental	0.19	30.2	6.41	U	--	307
294900095312101	LJ-65-12-619	3/16/2010	1257	Environmental	.22	24.5	12.5	U	0.40	284
295027095312301	LJ-65-12-328	3/17/2010	0927	Environmental	.62	19.2	4.93	M	.20	385
295027095312301	*LJ-65-12-328*	*3/17/2010*	*0928*	*Sequential replicate*	*.62*	*19.9*	*5.00*	--	*.30*	*413*
294950095313701	LJ-65-12-622	3/17/2010	1114	Environmental	.22	24.5	13.0	U	--	294
294340095311103	LJ-65-20-321	3/18/2010	0952	Environmental	.42	20.6	14.6	U	<.20	284
294348095303702	LJ-65-20-319	3/18/2010	1147	Environmental	.37	22.2	14.8	U	<.20	280
294348095270401	LJ-65-21-202	3/22/2010	1002	Environmental	.61	17.5	10.5	M	<.20	340
294338095270401	LJ-65-21-201	3/22/2010	1129	Environmental	.23	25.7	12.3	U	--	306
294333095275602	LJ-65-21-143	3/22/2010	1304	Environmental	.45	19.3	13.0	U	<.20	292
294329095284602	LJ-65-21-148	3/23/2010	1001	Environmental	.39	22.6	12.3	U	<.20	306
294329095284602	*LJ-65-21-148*	*3/23/2010*	*1002*	*Sequential replicate*	*.39*	*22.4*	*12.3*	--	*<.20*	*293*
294319095305901	LJ-65-20-303	3/23/2010	1123	Environmental	.26	28.5	9.86	U	--	307
294317095313001	LJ-65-20-304	3/23/2010	1252	Environmental	.45	20.5	15.5	U	--	282

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Fluoride, water, filtered (mg/L)	Silica, water, filtered (mg/L as SiO_2)	Sulfate, water, filtered (mg/L)	Hydrogen sulfide, water, unfiltered (mg/L)[1]	Sulfide, water, unfiltered, field (mg/L)	Residue on evaporation, dried at 180 °C, water, filtered (mg/L)
294328095290402	LJ-65-21-149	3/24/2010	1036	Environmental	0.37	23.6	14.0	U	<0.20	287
294323095300103	LJ-65-20-325	3/24/2010	1151	Environmental	.56	19.0	14.9	U	<.20	299
294201095355601	LJ-65-20-405	3/24/2010	1343	Environmental	.22	28.9	9.88	U	--	307
293732095300601	LJ-65-20-911	3/25/2010	0932	Environmental	.43	26.7	13.4	U	<.20	308
293734095293701	LJ-65-21-708	3/25/2010	1130	Environmental	.49	24.1	15.5	U	<.20	314
293736095285301	LJ-65-21-709	3/25/2010	1257	Environmental	.46	25.1	14.7	U	<.20	307
294002095351001	LJ-65-20-414	3/29/2010	1108	Environmental	.25	27.3	14.1	U	<.20	287
294414095364202	LJ-65-20-126	3/29/2010	1313	Environmental	.27	21.1	14.9	M	<.20	272
294456095341101	LJ-65-12-820	3/30/2010	0906	Environmental	.24	27.0	12.0	U	--	296
294501095343601	LJ-65-12-817	3/30/2010	1021	Environmental	.22	29.3	10.3	U	--	306
294519095383201	LJ-65-11-918	3/30/2010	1154	Environmental	.20	32.0	8.61	U	--	290
295246095351301	LJ-65-04-723	3/31/2010	0913	Environmental	.19	24.5	12.6	U	<.20	278
295249095364701	LJ-65-04-728	3/31/2010	1113	Environmental	.33	21.0	11.8	M	<.20	312
295249095370701	LJ-65-04-729	3/31/2010	1228	Environmental	.20	24.1	13.1	U	--	274

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Fluoride, water, filtered (mg/L)	Silica, water, filtered (mg/L as SiO_2)	Sulfate, water, filtered (mg/L)	Hydrogen sulfide, water, unfiltered (mg/L)[1]	Sulfide, water, unfiltered, field (mg/L)	Residue on evaporation, dried at 180 °C, water, filtered (mg/L)
295243095383101	LJ-65-03-916	4/1/2010	0941	Environmental	0.22	22.7	13.5	M	<0.20	279
294712095401301	LJ-65-11-803	4/1/2010	1124	Environmental	.22	22.0	14.1	M	<.20	289
294717095401001	LJ-65-11-804	4/1/2010	1229	Environmental	.22	21.9	14.6	M	<.20	281
294952095342601	LJ-65-12-519	4/5/2010	1030	Environmental	.28	23.5	15.5	U	<.20	272
294952095342601	*LJ-65-12-519*	*4/5/2010*	*1031*	*Sequential replicate*	*.31*	*22.8*	*15.2*	--	*<.20*	*273*
294925095341201	LJ-65-12-520	4/5/2010	1202	Environmental	.32	19.1	12.2	M	<.20	298
294844095342401	LJ-65-12-522	4/5/2010	1338	Environmental	.26	20.1	14.4	U	<.20	294
294800095344101	LJ-65-12-516	4/6/2010	0920	Environmental	.28	23.5	16.8	M	<.20	269
294735095344001	LJ-65-12-521	4/6/2010	1042	Environmental	.30	19.8	15.7	U	<.20	289
294627095375801	LJ-65-11-914	4/6/2010	1216	Environmental	.25	20.3	14.5	U	<.20	279
294721095361001	LJ-65-12-719	4/7/2010	0909	Environmental	.22	26.2	8.65	U	--	282
294723095370501	LJ-65-12-730	4/7/2010	1040	Environmental	.23	21.0	13.3	U	<.20	276
294723095382601	LJ-65-11-920	4/7/2010	1209	Environmental	.28	20.3	14.6	U	<.20	277
294731095414201	LJ-65-11-514	4/8/2010	1016	Environmental	.51	18.8	12.3	M	<.20	349

Table 4. Physicochemical properties and results of major ions analyses in water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Fluoride, water, filtered (mg/L)	Silica, water, filtered (mg/L as SiO_2)	Sulfate, water, filtered (mg/L)	Hydrogen sulfide, water, unfiltered (mg/L)[1]	Sulfide, water, unfiltered, field (mg/L)	Residue on evaporation, dried at 180 °C, water, filtered (mg/L)
295553095191201	LJ-65-06-528	4/8/2010	1331	Environmental	0.22	19.5	6.40	M	<0.20	225
295027095312301	LJ-65-12-328	5/6/2010	0940	Environmental	.63	18.0	5.03	M	--	370
293636095300401	JY-65-28-309	10/28/2010	1011	Environmental	.38	22.2	14.9	M	<.20	295
293635095294101	JY-65-29-107	10/28/2010	1225	Environmental	.44	22.6	17.1	M	<.20	406
293652095293601	LJ-65-29-108	10/28/2010	1350	Environmental	.34	22.6	15.5	M	<.20	330
294252095362101	LJ-65-20-125	11/3/2010	1033	Environmental	.21	28.4	10.3	U	--	283
294127095342502	LJ-65-20-519	11/4/2010	0945	Environmental	.54	18.4	15.9	M	<.20	299
294127095342502	*LJ-65-20-519*	*11/4/2010*	*0946*	*Sequential replicate*	*.55*	*16.6*	*15.9*	--	*<.20*	*294*
294047095345601	LJ-65-20-516	11/4/2010	1114	Environmental	.24	30.7	12.1	U	--	298
294050095355501	LJ-65-20-416	11/9/2010	1159	Environmental	.22	32.1	8.77	U	--	334

[1] Serendipitous sniff test, unacidified sample.

Table 5. Results of trace elements analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010.

[µg/L, micrograms per liter; <, less than; E, estimated; --, no data available]

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Arsenic, water, filtered (µg/L)	Barium, water, filtered (µg/L)	Boron, water, filtered (µg/L)	Chromium, water, filtered (µg/L)	Iron, water, filtered (µg/L)	Lithium, water, filtered (µg/L)
294921095312907	LJ-65-12-633	3/16/2010	1041	Environmental	1.9	302	48	1.5	10	12.7
294900095312101	LJ-65-12-619	3/16/2010	1257	Environmental	2.4	220	50	.27	10	18.4
295027095312301	LJ-65-12-328	3/17/2010	0927	Environmental	23.5	320	182	<.12	225	23.2
295027095312301	*LJ-65-12-328*	*3/17/2010*	*0928*	*Sequential replicate*	*23.5*	*329*	*204*	*<.12*	*222*	*26.1*
294950095313701	LJ-65-12-622	3/17/2010	1114	Environmental	1.9	214	46	.31	31	19.1
294340095311103	LJ-65-20-321	3/18/2010	0952	Environmental	4.7	185	94	.77	E4	18.6
294348095303702	LJ-65-20-319	3/18/2010	1147	Environmental	4.2	196	96	1.0	7	21.4
294348095270401	LJ-65-21-202	3/22/2010	1002	Environmental	4.9	236	173	<.12	22	21.1
294338095270401	LJ-65-21-201	3/22/2010	1129	Environmental	2.7	237	56	2.0	<6	19.0
294333095275602	LJ-65-21-143	3/22/2010	1304	Environmental	5.1	308	108	.26	<6	18.8
294329095284602	LJ-65-21-148	3/23/2010	1001	Environmental	4.4	238	101	.69	7	19.7
294329095284602	*LJ-65-21-148*	*3/23/2010*	*1002*	*Sequential replicate*	*4.5*	*239*	*107*	*1.3*	*E6*	*21.4*
294319095305901	LJ-65-20-303	3/23/2010	1123	Environmental	4.4	231	59	2.8	<6	16.7
294317095313001	LJ-65-20-304	3/23/2010	1252	Environmental	3.8	168	99	<.12	11	19.8
294328095290402	LJ-65-21-149	3/24/2010	1036	Environmental	4.1	237	84	.79	13	17.3
294323095300103	LJ-65-20-325	3/24/2010	1151	Environmental	3.9	191	122	E.09	57	18.1
294201095355601	LJ-65-20-405	3/24/2010	1343	Environmental	2.5	234	52	1.8	<6	13.7

Table 5. Results of trace elements analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Arsenic, water, filtered (µg/L)	Barium, water, filtered (µg/L)	Boron, water, filtered (µg/L)	Chromium, water, filtered (µg/L)	Iron, water, filtered (µg/L)	Lithium, water, filtered (µg/L)
293732095300601	LJ-65-20-911	3/25/2010	0932	Environmental	2.7	175	80	0.95	<6	15.6
293734095293701	LJ-65-21-708	3/25/2010	1130	Environmental	3.4	184	101	.43	E4	16.7
293736095285301	LJ-65-21-709	3/25/2010	1257	Environmental	2.8	186	90	<.12	46	16.6
294002095351001	LJ-65-20-414	3/29/2010	1108	Environmental	3.8	197	47	1.7	<6	13.3
294414095364202	LJ-65-20-126	3/29/2010	1313	Environmental	3.0	214	59	<.12	448	19.5
294456095341101	LJ-65-12-820	3/30/2010	0906	Environmental	3.1	219	54	2.1	7	15.6
294501095343601	LJ-65-12-817	3/30/2010	1021	Environmental	3.4	219	50	2.9	E4	14.1
294519095383201	LJ-65-11-918	3/30/2010	1154	Environmental	2.5	235	53	1.7	<6	12.5
295246095351301	LJ-65-04-723	3/31/2010	0913	Environmental	2.7	228	41	.29	44	14.9
295249095364701	LJ-65-04-728	3/31/2010	1113	Environmental	3.2	260	72	<.12	203	20.3
295249095370701	LJ-65-04-729	3/31/2010	1228	Environmental	2.5	224	47	.25	59	16.1
295243095383101	LJ-65-03-916	4/1/2010	0941	Environmental	2.7	250	47	<.12	154	17.9
294712095401301	LJ-65-11-803	4/1/2010	1124	Environmental	2.5	197	47	<.12	311	15.2
294717095401001	LJ-65-11-804	4/1/2010	1229	Environmental	2.8	205	49	<.12	162	15.4
294952095342601	LJ-65-12-519	4/5/2010	1030	Environmental	2.4	203	55	<.12	214	20.1
294952095342601	*LJ-65-12-519*	*4/5/2010*	*1031*	*Sequential replicate*	*2.4*	*204*	*57*	*<.12*	*201*	*20.4*
294925095341201	LJ-65-12-520	4/5/2010	1202	Environmental	4.1	278	79	<.12	145	20.8
294844095342401	LJ-65-12-522	4/5/2010	1338	Environmental	2.9	230	66	<.12	183	20.9

Table 5. Results of trace elements analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Arsenic, water, filtered (µg/L)	Barium, water, filtered (µg/L)	Boron, water, filtered (µg/L)	Chromium, water, filtered (µg/L)	Iron, water, filtered (µg/L)	Lithium, water, filtered (µg/L)
294800095344101	LJ-65-12-516	4/6/2010	0920	Environmental	5.2	189	54	<0.12	391	19.1
294735095344001	LJ-65-12-521	4/6/2010	1042	Environmental	3.4	233	71	<.12	117	21.0
294627095375801	LJ-65-11-914	4/6/2010	1216	Environmental	2.7	231	60	<.12	58	19.9
294721095361001	LJ-65-12-719	4/7/2010	0909	Environmental	1.9	232	58	.75	27	20.3
294723095370501	LJ-65-12-730	4/7/2010	1040	Environmental	3.2	227	58	<.12	70	20.3
294723095382601	LJ-65-11-920	4/7/2010	1209	Environmental	3.0	221	61	<.12	102	20.0
294731095414201	LJ-65-11-514	4/8/2010	1016	Environmental	4.7	150	122	<.12	57	24.0
295553095191201	LJ-65-06-528	4/8/2010	1331	Environmental	2.6	411	56	<.12	277	13.9
295027095312301	LJ-65-12-328	5/6/2010	0940	Environmental	22.3	340	234	E.10	220	24.6
293636095300401	JY-65-28-309	10/28/2010	1011	Environmental	2.1	197	62	.11	404	15.8
293635095294101	JY-65-29-107	10/28/2010	1225	Environmental	3.5	218	190	<.06	183	21.2
293652095293601	LJ-65-29-108	10/28/2010	1350	Environmental	3.0	233	85	<.06	304	18.5
294252095362101	LJ-65-20-125	11/3/2010	1033	Environmental	2.1	260	41	1.9	7	13.1
294127095342502	LJ-65-20-519	11/4/2010	0945	Environmental	1.6	195	116	<.06	114	19.5
294127095342502	*LJ-65-20-519*	*11/4/2010*	*0946*	*Sequential replicate*	*1.7*	*195*	*111*	*<.06*	*114*	*18.3*
294047095345601	LJ-65-20-516	11/4/2010	1114	Environmental	2.6	234	39	3.3	4	11.7
294050095355501	LJ-65-20-416	11/9/2010	1159	Environmental	2.3	267	38	4.5	4	10.1

Table 5. Results of trace elements analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Manganese, water, filtered (µg/L)	Molybdenum, water, filtered (µg/L)	Selenium, water, filtered (µg/L)	Strontium, water, filtered (µg/L)	Vanadium, water, filtered (µg/L)
294921095312907	LJ-65-12-633	3/16/2010	1041	Environmental	1.6	0.3	0.77	465	5.0
294900095312101	LJ-65-12-619	3/16/2010	1257	Environmental	5.5	1.3	14.1	738	.91
295027095312301	LJ-65-12-328	3/17/2010	0927	Environmental	6.7	12.9	<.04	507	.19
295027095312301	*LJ-65-12-328*	*3/17/2010*	*0928*	*Sequential replicate*	*6.9*	*13.2*	*<.04*	*510*	*E.14*
294950095313701	LJ-65-12-622	3/17/2010	1114	Environmental	5.4	1.3	2.3	632	.97
294340095311103	LJ-65-20-321	3/18/2010	0952	Environmental	3.6	2.8	.97	380	4.5
294348095303702	LJ-65-20-319	3/18/2010	1147	Environmental	1.9	2.2	3.8	415	7.7
294348095270401	LJ-65-21-202	3/22/2010	1002	Environmental	7.2	5.0	.11	360	.20
294338095270401	LJ-65-21-201	3/22/2010	1129	Environmental	E.2	1.1	7.3	731	6.5
294333095275602	LJ-65-21-143	3/22/2010	1304	Environmental	4.3	2.4	.74	484	3.7
294329095284602	LJ-65-21-148	3/23/2010	1001	Environmental	1.1	2.3	1.7	466	8.9
294329095284602	*LJ-65-21-148*	*3/23/2010*	*1002*	*Sequential replicate*	*1.4*	*2.3*	*1.8*	*477*	*9.0*
294319095305901	LJ-65-20-303	3/23/2010	1123	Environmental	1.0	1.0	5.3	510	17.0
294317095313001	LJ-65-20-304	3/23/2010	1252	Environmental	8.3	2.9	2.4	316	2.2
294328095290402	LJ-65-21-149	3/24/2010	1036	Environmental	3.2	2.1	3.9	486	8.3
294323095300103	LJ-65-20-325	3/24/2010	1151	Environmental	7.6	3.2	.41	344	.87
294201095355601	LJ-65-20-405	3/24/2010	1343	Environmental	.5	.8	4.5	531	4.6
293732095300601	LJ-65-20-911	3/25/2010	0932	Environmental	4.5	2.5	4.6	388	8.1

Table 5. Results of trace elements analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Manganese, water, filtered (µg/L)	Molybdenum, water, filtered (µg/L)	Selenium, water, filtered (µg/L)	Strontium, water, filtered (µg/L)	Vanadium, water, filtered (µg/L)
293734095293701	LJ-65-21-708	3/25/2010	1130	Environmental	7.0	3.8	2.1	337	4.9
293736095285301	LJ-65-21-709	3/25/2010	1257	Environmental	14.1	3.0	.48	337	10.5
294002095351001	LJ-65-20-414	3/29/2010	1108	Environmental	1.4	1.2	7.2	545	12.6
294414095364202	LJ-65-20-126	3/29/2010	1313	Environmental	20.8	2.1	<.04	683	E.11
294456095341101	LJ-65-12-820	3/30/2010	0906	Environmental	3.3	1.4	1.2	544	4.9
294501095343601	LJ-65-12-817	3/30/2010	1021	Environmental	.7	1.1	2.3	513	6.0
294519095383201	LJ-65-11-918	3/30/2010	1154	Environmental	2.3	.5	2.7	427	5.1
295246095351301	LJ-65-04-723	3/31/2010	0913	Environmental	7.3	1.2	16.8	423	2.8
295249095364701	LJ-65-04-728	3/31/2010	1113	Environmental	10.7	2.3	<.04	589	.17
295249095370701	LJ-65-04-729	3/31/2010	1228	Environmental	10.9	1.4	12.1	446	4.0
295243095383101	LJ-65-03-916	4/1/2010	0941	Environmental	9.0	1.7	<.04	704	E.14
294712095401301	LJ-65-11-803	4/1/2010	1124	Environmental	14.9	1.9	<.04	596	E.13
294717095401001	LJ-65-11-804	4/1/2010	1229	Environmental	13.2	2.2	<.04	588	E.12
294952095342601	LJ-65-12-519	4/5/2010	1030	Environmental	13.6	2.2	.04	692	E.16
294952095342601	*LJ-65-12-519*	*4/5/2010*	*1031*	*Sequential replicate*	*13.6*	*2.2*	*.05*	*686*	*E.15*
294925095341201	LJ-65-12-520	4/5/2010	1202	Environmental	9.7	1.8	<.04	640	<.16
294844095342401	LJ-65-12-522	4/5/2010	1338	Environmental	12.9	1.7	<.04	697	<.16
294800095344101	LJ-65-12-516	4/6/2010	0920	Environmental	11.0	2.3	<.04	597	<.16

Table 5. Results of trace elements analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Manganese, water, filtered (µg/L)	Molybdenum, water, filtered (µg/L)	Selenium, water, filtered (µg/L)	Strontium, water, filtered (µg/L)	Vanadium, water, filtered (µg/L)
294735095344001	LJ-65-12-521	4/6/2010	1042	Environmental	13.7	2.7	<0.04	658	<0.16
294627095375801	LJ-65-11-914	4/6/2010	1216	Environmental	13.5	2.2	<.04	632	.28
294721095361001	LJ-65-12-719	4/7/2010	0909	Environmental	4.5	1.4	4.9	668	2.5
294723095370501	LJ-65-12-730	4/7/2010	1040	Environmental	12.7	1.9	<.04	632	<.16
294723095382601	LJ-65-11-920	4/7/2010	1209	Environmental	9.6	2.3	<.04	603	<.16
294731095414201	LJ-65-11-514	4/8/2010	1016	Environmental	14.5	4.7	<.04	412	<.16
295553095191201	LJ-65-06-528	4/8/2010	1331	Environmental	36.4	1.7	1.0	478	.63
295027095312301	LJ-65-12-328	5/6/2010	0940	Environmental	6.9	12.9	<.04	563	.50
293636095300401	JY-65-28-309	10/28/2010	1011	Environmental	56.3	2.2	<.03	381	<.08
293635095294101	JY-65-29-107	10/28/2010	1225	Environmental	45.1	13.2	<.03	404	<.08
293652095293601	LJ-65-29-108	10/28/2010	1350	Environmental	42.3	5.0	<.03	434	<.08
294252095362101	LJ-65-20-125	11/3/2010	1033	Environmental	1.3	.9	3.0	570	2.7
294127095342502	LJ-65-20-519	11/4/2010	0945	Environmental	14.2	5.2	<.03	442	<.08
294127095342502	*LJ-65-20-519*	*11/4/2010*	*0946*	*Sequential replicate*	*14.2*	*5.2*	*<.03*	*443*	*<.08*
294047095345601	LJ-65-20-516	11/4/2010	1114	Environmental	1.8	.8	11.4	574	8.4
294050095355501	LJ-65-20-416	11/9/2010	1159	Environmental	.4	.3	2.0	522	4.9

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010.

[Contaminant concentrations that are greater than U.S. Environmental Protection Agency maximum contaminant level (MCL) do not represent MCL violations because MCLs apply to finished water, and all samples were collected from source waters. None of the source-water samples were collected for regulatory compliance purposes; further, compliance with most MCLs is based on running average concentrations, not on concentrations detected in single samples as collected in this study. Rounding of each radionuclide result is unique, based on significant digits of the associated combined standard uncertainty (CSU). Th, thorium; pCi/L, picocuries per liter; ssL_C, sample-specific critical level; R, nondetected result less than ssL_C; b, sample-specific minimum detectable concentration greater than contractual a priori method detectable concentration; --, no data available; Cs, cesium; e, laboratory blank greater than the ssL_C; <, less than; c, analyses counted 4 days after sample collection; LRL, laboratory reporting level; LT-MDL, long term method detection level; µg/L, micrograms per liter]

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Alpha radioactivity, 30-day count, water, filtered, Th-230 curve (pCi/L)[1]	Alpha radioactivity, 30-day count, 1-sigma CSU, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 30-day count, ssL_C, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 30-day count (remark code)	Alpha radioactivity, 72-hour count, water, filtered, Th-230 curve (pCi/L)[1]	Alpha radioactivity, 72-hour count, 1-sigma CSU, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count, ssLC, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count (remark code)
294921095312907	LJ-65-12-633	3/16/2010	1041	Environmental	8.6	1.8	1.9	b	20.1	2.8	1.9	b
294900095312101	LJ-65-12-619	3/16/2010	1257	Environmental	9.5	1.4	.61	--	12.3	1.7	.62	--
295027095312301	LJ-65-12-328	3/17/2010	0927	Environmental	4.43	.88	.41	--	6.6	1.2	.75	--
295027095312301	*LJ-65-12-328*	*3/17/2010*	*0928*	*Sequential replicate*	*3.01*	*.72*	*.54*	--	*9.8*	*1.5*	*.73*	--
294950095313701	LJ-65-12-622	3/17/2010	1114	Environmental	8.6	1.3	.54	--	15	2	.65	--
294340095311103	LJ-65-20-321	3/18/2010	0952	Environmental	4.32	.92	.85	--	8.0	1.2	.58	--
294348095303702	LJ-65-20-319	3/18/2010	1147	Environmental	7	1	.31	--	12.5	1.7	.57	--
294348095270401	LJ-65-21-202	3/22/2010	1002	Environmental	4.26	.83	.68	--	4.36	.83	.57	--
294338095270401	LJ-65-21-201	3/22/2010	1129	Environmental	9.8	1.3	.49	--	13.7	1.7	.41	--
294333095275602	LJ-65-21-143	3/22/2010	1304	Environmental	8.4	1.2	.69	--	6.12	.98	.55	--
294329095284602	LJ-65-21-148	3/23/2010	1001	Environmental	20.9	2.5	.39	--	12.9	1.7	.53	--
294329095284602	*LJ-65-21-148*	*3/23/2010*	*1002*	*Sequential replicate*	*16.1*	*2.2*	*.97*	--	*13.6*	*1.8*	*.59*	--
294319095305901	LJ-65-20-303	3/23/2010	1123	Environmental	6.1	1.1	.76	--	13.2	1.8	.54	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Alpha radioactivity, 30-day count, water, filtered, Th-230 curve (pCi/L)[1]	Alpha radioactivity, 30-day count, 1-sigma CSU, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 30-day count, ssL_C, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 30-day count (remark code)	Alpha radioactivity, 72-hour count, water, filtered, Th-230 curve (pCi/L)[1]	Alpha radioactivity, 72-hour count, 1-sigma CSU, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count, ssLC, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count (remark code)
294317095313001	LJ-65-20-304	3/23/2010	1252	Environmental	5	1	0.79	--	8.6	1.3	0.65	--
294328095290402	LJ-65-21-149	3/24/2010	1036	Environmental	6.7	1.1	.56	--	14.8	2.2	.76	--
294323095300103	LJ-65-20-325	3/24/2010	1151	Environmental	4.45	.84	.49	--	7.7	1.2	.55	--
294201095355601	LJ-65-20-405	3/24/2010	1343	Environmental	6	1	.64	--	13	2	.69	--
293732095300601	LJ-65-20-911	3/25/2010	0932	Environmental	7.9	1.3	.96	--	11.9	1.7	.71	--
293734095293701	LJ-65-21-708	3/25/2010	1130	Environmental	7.3	1.2	.61	--	10.7	1.5	.5	--
293736095285301	LJ-65-21-709	3/25/2010	1257	Environmental	7.0	1.2	.84	--	15	2	.46	--
294002095351001	LJ-65-20-414	3/29/2010	1108	Environmental	10.6	1.5	.66	--	16.0	2.1	.68	--
294414095364202	LJ-65-20-126	3/29/2010	1313	Environmental	1.66	.53	.58	--	2.58	.66	.61	--
294456095341101	LJ-65-12-820	3/30/2010	0906	Environmental	6.8	1.1	.57	--	10.3	1.4	.59	--
294501095343601	LJ-65-12-817	3/30/2010	1021	Environmental	5.6	.9	.53	--	7.9	1.2	.56	--
294519095383201	LJ-65-11-918	3/30/2010	1154	Environmental	4.90	.82	.52	--	10.7	1.4	.52	--
295246095351301	LJ-65-04-723	3/31/2010	0913	Environmental	25.5	3.9	.96	--	31.0	3.5	.6	--
295249095364701	LJ-65-04-728	3/31/2010	1113	Environmental	6.7	1.1	.57	--	6.8	1.1	.61	--
295249095370701	LJ-65-04-729	3/31/2010	1228	Environmental	21.7	3.5	1.1	--	39.7	4.4	.44	--
295243095383101	LJ-65-03-916	4/1/2010	0941	Environmental	10.6	1.5	.62	--	8.8	1.3	.67	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Alpha radioactivity, 30-day count, water, filtered, Th-230 curve (pCi/L)[1]	Alpha radioactivity, 30-day count, 1-sigma CSU, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 30-day count, ssL_C, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 30-day count (remark code)	Alpha radioactivity, 72-hour count, water, filtered, Th-230 curve (pCi/L)[1]	Alpha radioactivity, 72-hour count, 1-sigma CSU, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count, ssLC, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count (remark code)
294712095401301	LJ-65-11-803	4/1/2010	1124	Environmental	20.4	2.5	0.58	--	13.1	1.7	0.61	--
294717095401001	LJ-65-11-804	4/1/2010	1229	Environmental	10.4	1.5	.54	--	12.8	1.7	.66	--
294952095342601	LJ-65-12-519	4/5/2010	1030	Environmental	4.32	.79	.53	--	7	1	.47	e
294952095342601	*LJ-65-12-519*	*4/5/2010*	*1031*	*Sequential replicate*	*4.44*	*.84*	*.57*	--	*5.26*	*.92*	*.54*	*e*
294925095341201	LJ-65-12-520	4/5/2010	1202	Environmental	16.5	2.1	.55	--	7.6	1.4	1.4	e
294844095342401	LJ-65-12-522	4/5/2010	1338	Environmental	12.4	1.6	.44	--	7.4	1.1	.5	e
294800095344101	LJ-65-12-516	4/6/2010	0920	Environmental	3.18	.73	.6	--	5.73	.99	.59	e
294735095344001	LJ-65-12-521	4/6/2010	1042	Environmental	4.26	.83	.58	--	10.4	1.5	.45	e
294627095375801	LJ-65-11-914	4/6/2010	1216	Environmental	3.04	.68	.57	--	6.9	1.1	.6	e
294721095361001	LJ-65-12-719	4/7/2010	0909	Environmental	6	1	.61	e	11.6	1.6	.56	e
294723095370501	LJ-65-12-730	4/7/2010	1040	Environmental	3.73	.71	.54	e	6	1	.62	e
294723095382601	LJ-65-11-920	4/7/2010	1209	Environmental	3.88	.76	.57	e	7.3	1.1	.49	e
294731095414201	LJ-65-11-514	4/8/2010	1016	Environmental	2.5	1.4	2	e,b	5.7	1.1	.76	e
295553095191201	LJ-65-06-528	4/8/2010	1331	Environmental	2.48	.56	.47	e	5.03	.87	.55	e
295027095312301	LJ-65-12-328	5/6/2010	0940	Environmental	--	--	--	--	--	--	--	--
293636095300401	JY-65-28-309	10/28/2010	1011	Environmental	13.4	1.9	.76	--	13.2	1.8	.67	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Alpha radioactivity, 30-day count, water, filtered, Th-230 curve (pCi/L)[1]	Alpha radioactivity, 30-day count, 1-sigma CSU, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 30-day count, ssL$_C$, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 30-day count (remark code)	Alpha radioactivity, 72-hour count, water, filtered, Th-230 curve (pCi/L)[1]	Alpha radioactivity, 72-hour count, 1-sigma CSU, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count, ssLC, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count (remark code)
293635095294101	JY-65-29-107	10/28/2010	1225	Environmental	8.2	1.4	0.85	--	16.9	2.4	0.87	--
293652095293601	LJ-65-29-108	10/28/2010	1350	Environmental	16.1	2.7	1.2	--	29.1	3.5	.78	--
294252095362101	LJ-65-20-125	11/3/2010	1033	Environmental	5.9	1.4	1	e	10.5	1.5	.64	c
294127095342502	LJ-65-20-519	11/4/2010	0945	Environmental	.60	.65	.87	R	3.07	.77	.67	--
294127095342502	*LJ-65-20-519*	*11/4/2010*	*0946*	*Sequential replicate*	*2.3*	*1.2*	*1.2*	*b*	*4.8*	*1.2*	*1*	--
294047095345601	LJ-65-20-516	11/4/2010	1114	Environmental	6.7	1.1	.73	--	17.9	2.3	.73	--
294050095355501	LJ-65-20-416	11/9/2010	1159	Environmental	2.97	.95	.85	--	11.5	1.7	.78	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Beta radioactivity, 30-day count, water, filtered, Cs-137 curve (pCi/L)[1]	Beta radioactivity, 30-day count, 1-sigma CSU, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 30-day count, ssLC, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 30-day count (remark code)	Beta radioactivity, 72-hour count, water, filtered, Cs-137 curve (pCi/L)[1]	Beta radioactivity, 72-hour count, 1-sigma CSU, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 72-hour count, ssL$_C$, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 72-hour count (remark code)
294921095312907	LJ-65-12-633	3/16/2010	1041	Environmental	3.72	0.59	0.79	--	4.4	0.6	0.79	--
294900095312101	LJ-65-12-619	3/16/2010	1257	Environmental	4.0	.5	.61	--	3.22	.47	.6	--
295027095312301	LJ-65-12-328	3/17/2010	0927	Environmental	3.11	.58	.78	--	3.73	.59	.75	--
295027095312301	*LJ-65-12-328*	*3/17/2010*	*0928*	*Sequential replicate*	*4.56*	*.65*	*.92*	--	*2.87*	*.62*	*.91*	--
294950095313701	LJ-65-12-622	3/17/2010	1114	Environmental	6.66	.62	.66	--	2.64	.43	.58	--
294340095311103	LJ-65-20-321	3/18/2010	0952	Environmental	5.9	.6	.63	--	2.37	.42	.58	--
294348095303702	LJ-65-20-319	3/18/2010	1147	Environmental	3.63	.47	.6	--	2.43	.41	.57	--
294348095270401	LJ-65-21-202	3/22/2010	1002	Environmental	2.31	.37	.49	--	1.97	.39	.54	--
294338095270401	LJ-65-21-201	3/22/2010	1129	Environmental	5.97	.52	.5	--	3.74	.46	.58	--
294333095275602	LJ-65-21-143	3/22/2010	1304	Environmental	4.6	.6	.83	--	2.49	.38	.49	--
294329095284602	LJ-65-21-148	3/23/2010	1001	Environmental	6.20	.65	.74	--	3.54	.46	.56	--
294329095284602	*LJ-65-21-148*	*3/23/2010*	*1002*	*Sequential replicate*	*5.81*	*.64*	*.64*	--	*2.87*	*.51*	*.71*	--
294319095305901	LJ-65-20-303	3/23/2010	1123	Environmental	4.13	.52	.65	--	3.03	.67	.98	--
294317095313001	LJ-65-20-304	3/23/2010	1252	Environmental	2.74	.52	.78	--	2.5	.4	.54	--
294328095290402	LJ-65-21-149	3/24/2010	1036	Environmental	4.64	.49	.58	--	3.30	.53	.68	--
294323095300103	LJ-65-20-325	3/24/2010	1151	Environmental	2.83	.41	.54	--	1.99	.48	.7	--
294201095355601	LJ-65-20-405	3/24/2010	1343	Environmental	4.70	.46	.5	--	3.11	.58	.81	--
293732095300601	LJ-65-20-911	3/25/2010	0932	Environmental	4.4	.6	.72	--	2.8	.5	.69	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Beta radioactivity, 30-day count, water, filtered, Cs-137 curve (pCi/L)[1]	Beta radioactivity, 30-day count, 1-sigma CSU, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 30-day count, ssLC, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 30-day count (remark code)	Beta radioactivity, 72-hour count, water, filtered, Cs-137 curve (pCi/L)[1]	Beta radioactivity, 72-hour count, 1-sigma CSU, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 72-hour count, ssL$_C$, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 72-hour count (remark code)
293734095293701	LJ-65-21-708	3/25/2010	1130	Environmental	3.69	0.52	0.66	--	2.89	0.49	0.65	--
293736095285301	LJ-65-21-709	3/25/2010	1257	Environmental	4.48	.65	.92	--	2.47	.49	.68	--
294002095351001	LJ-65-20-414	3/29/2010	1108	Environmental	7.72	.66	.62	--	3.49	.49	.61	--
294414095364202	LJ-65-20-126	3/29/2010	1313	Environmental	2.20	.46	.68	--	2.67	.47	.67	--
294456095341101	LJ-65-12-820	3/30/2010	0906	Environmental	3.4	.4	.49	--	3.3	.4	.48	--
294501095343601	LJ-65-12-817	3/30/2010	1021	Environmental	3.06	.43	.57	--	3.86	.45	.57	--
294519095383201	LJ-65-11-918	3/30/2010	1154	Environmental	2.45	.34	.43	--	2.56	.35	.43	--
295246095351301	LJ-65-04-723	3/31/2010	0913	Environmental	9.31	.99	.9	--	4.29	.46	.49	--
295249095364701	LJ-65-04-728	3/31/2010	1113	Environmental	3.72	.41	.49	--	2.84	.52	.78	--
295249095370701	LJ-65-04-729	3/31/2010	1228	Environmental	14.4	1.2	.92	--	3.73	.42	.45	--
295243095383101	LJ-65-03-916	4/1/2010	0941	Environmental	3.00	.48	.65	--	3.66	.49	.62	--
294712095401301	LJ-65-11-803	4/1/2010	1124	Environmental	6.49	.61	.65	--	3.20	.53	.76	--
294717095401001	LJ-65-11-804	4/1/2010	1229	Environmental	2.67	.67	.98	--	3.07	.45	.57	--
294952095342601	LJ-65-12-519	4/5/2010	1030	Environmental	3.94	.47	.6	--	2.96	.53	.76	--
294952095342601	*LJ-65-12-519*	*4/5/2010*	*1031*	*Sequential replicate*	*3.08*	*.38*	*.47*	--	*3.50*	*.41*	*.49*	--
294925095341201	LJ-65-12-520	4/5/2010	1202	Environmental	7.5	.6	.52	--	3.66	.42	.5	--
294844095342401	LJ-65-12-522	4/5/2010	1338	Environmental	5.33	.58	.73	--	3.24	.38	.46	--
294800095344101	LJ-65-12-516	4/6/2010	0920	Environmental	3.03	.46	.6	--	2.68	.45	.6	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Beta radioactivity, 30-day count, water, filtered, Cs-137 curve (pCi/L)[1]	Beta radioactivity, 30-day count, 1-sigma CSU, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 30-day count, ssLC, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 30-day count (remark code)	Beta radioactivity, 72-hour count, water, filtered, Cs-137 curve (pCi/L)[1]	Beta radioactivity, 72-hour count, 1-sigma CSU, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 72-hour count, ssL_C, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 72-hour count (remark code)
294735095344001	LJ-65-12-521	4/6/2010	1042	Environmental	3.20	0.63	0.93	--	3.22	0.52	0.72	--
294627095375801	LJ-65-11-914	4/6/2010	1216	Environmental	2.63	.39	.52	--	2.61	.39	.51	--
294721095361001	LJ-65-12-719	4/7/2010	0909	Environmental	3.42	.49	.66	--	3.00	.44	.57	--
294723095370501	LJ-65-12-730	4/7/2010	1040	Environmental	2.48	.35	.45	--	3.25	.53	.76	--
294723095382601	LJ-65-11-920	4/7/2010	1209	Environmental	2.94	.39	.5	--	3.64	.39	.44	--
294731095414201	LJ-65-11-514	4/8/2010	1016	Environmental	1.17	.47	.73	--	2.22	.51	.74	--
295553095191201	LJ-65-06-528	4/8/2010	1331	Environmental	1.76	.32	.46	--	1.99	.49	.73	--
295027095312301	LJ-65-12-328	5/6/2010	0940	Environmental	--	--	--	--	--	--	--	--
293636095300401	JY-65-28-309	10/28/2010	1011	Environmental	3.08	.82	1.3	--	3.69	.63	.83	--
293635095294101	JY-65-29-107	10/28/2010	1225	Environmental	3.47	.63	.91	--	3.49	.77	1.1	--
293652095293601	LJ-65-29-108	10/28/2010	1350	Environmental	3.42	.92	1.3	--	2.63	.62	.84	--
294252095362101	LJ-65-20-125	11/3/2010	1033	Environmental	3.89	.68	.92	--	3.0	.5	.68	c
294127095342502	LJ-65-20-519	11/4/2010	0945	Environmental	1.48	.61	.93	--	2.42	.52	.8	--
294127095342502	*LJ-65-20-519*	*11/4/2010*	*0946*	*Sequential replicate*	*1.65*	*.76*	*1.1*	--	*1.82*	*.51*	*.77*	--
294047095345601	LJ-65-20-516	11/4/2010	1114	Environmental	6.18	.65	.72	--	3.68	.54	.72	--
294050095355501	LJ-65-20-416	11/9/2010	1159	Environmental	3.25	.82	1.2	--	2.59	.67	1	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Carbon-14 counting error, water, filtered (percent modern)	Carbon-14, water, filtered (percent modern)	Carbon-13/carbon-12 ratio, water, unfiltered (per mil)	Carbon-13/carbon-12 ratio (remark code)	Radium-226, water, filtered, radon method (pCi/L)	Radium-226, 1-sigma CSU, water, filtered, radon method (pCi/L)	Radium-226, ssL$_c$, water, filtered, radon method (pCi/L)	Radium-226 (remark code)
294921095312907	LJ-65-12-633	3/16/2010	1041	Environmental	--	--	--	--	--	--	--	--
294900095312101	LJ-65-12-619	3/16/2010	1257	Environmental	--	--	--	--	--	--	--	--
295027095312301	LJ-65-12-328	3/17/2010	0927	Environmental	--	--	--	--	--	--	--	--
295027095312301	*LJ-65-12-328*	*3/17/2010*	*0928*	*Sequential replicate*	--	--	--	--	--	--	--	--
294950095313701	LJ-65-12-622	3/17/2010	1114	Environmental	--	--	--	--	--	--	--	--
294340095311103	LJ-65-20-321	3/18/2010	0952	Environmental	--	--	--	--	--	--	--	--
294348095303702	LJ-65-20-319	3/18/2010	1147	Environmental	--	--	--	--	--	--	--	--
294348095270401	LJ-65-21-202	3/22/2010	1002	Environmental	--	--	--	--	--	--	--	--
294338095270401	LJ-65-21-201	3/22/2010	1129	Environmental	--	--	--	--	--	--	--	--
294333095275602	LJ-65-21-143	3/22/2010	1304	Environmental	--	--	--	--	--	--	--	--
294329095284602	LJ-65-21-148	3/23/2010	1001	Environmental	--	--	--	--	0.732	0.069	0.026	--
294329095284602	*LJ-65-21-148*	*3/23/2010*	*1002*	*Sequential replicate*	--	--	--	--	--	--	--	--
294319095305901	LJ-65-20-303	3/23/2010	1123	Environmental	--	--	--	--	--	--	--	--
294317095313001	LJ-65-20-304	3/23/2010	1252	Environmental	--	--	--	--	--	--	--	--
294328095290402	LJ-65-21-149	3/24/2010	1036	Environmental	--	--	--	--	--	--	--	--
294323095300103	LJ-65-20-325	3/24/2010	1151	Environmental	--	--	--	--	--	--	--	--
294201095355601	LJ-65-20-405	3/24/2010	1343	Environmental	--	--	--	--	--	--	--	--
293732095300601	LJ-65-20-911	3/25/2010	0932	Environmental	--	--	--	--	--	--	--	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Carbon-14 counting error, water, filtered (percent modern)	Carbon-14, water, filtered (percent modern)	Carbon-13/carbon-12 ratio, water, unfiltered (per mil)	Carbon-13/carbon-12 ratio (remark code)	Radium-226, water, filtered, radon method (pCi/L)	Radium-226, 1-sigma CSU, water, filtered, radon method (pCi/L)	Radium-226, ssL_c, water, filtered, radon method (pCi/L)	Radium-226 (remark code)
293734095293701	LJ-65-21-708	3/25/2010	1130	Environmental	--	--	--	--	--	--	--	--
293736095285301	LJ-65-21-709	3/25/2010	1257	Environmental	--	--	--	--	--	--	--	--
294002095351001	LJ-65-20-414	3/29/2010	1108	Environmental	--	--	--	--	--	--	--	--
294414095364202	LJ-65-20-126	3/29/2010	1313	Environmental	--	--	--	--	--	--	--	--
294456095341101	LJ-65-12-820	3/30/2010	0906	Environmental	--	--	--	--	--	--	--	--
294501095343601	LJ-65-12-817	3/30/2010	1021	Environmental	--	--	--	--	--	--	--	--
294519095383201	LJ-65-11-918	3/30/2010	1154	Environmental	--	--	--	--	--	--	--	--
295246095351301	LJ-65-04-723	3/31/2010	0913	Environmental	--	--	--	--	--	--	--	--
295249095364701	LJ-65-04-728	3/31/2010	1113	Environmental	--	--	--	--	--	--	--	--
295249095370701	LJ-65-04-729	3/31/2010	1228	Environmental	--	--	--	--	--	--	--	--
295243095383101	LJ-65-03-916	4/1/2010	0941	Environmental	--	--	--	--	1.65	0.14	0.022	--
294712095401301	LJ-65-11-803	4/1/2010	1124	Environmental	--	--	--	--	2.23	.19	.025	--
294717095401001	LJ-65-11-804	4/1/2010	1229	Environmental	--	--	--	--	1.97	.17	.028	--
294952095342601	LJ-65-12-519	4/5/2010	1030	Environmental	--	--	--	--	--	--	--	--
294952095342601	*LJ-65-12-519*	*4/5/2010*	*1031*	*Sequential replicate*	--	--	--	--	--	--	--	--
294925095341201	LJ-65-12-520	4/5/2010	1202	Environmental	--	--	--	--	2.59	.22	.026	--
294844095342401	LJ-65-12-522	4/5/2010	1338	Environmental	--	--	--	--	1.60	.14	.029	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Carbon-14 counting error, water, filtered (percent modern)	Carbon-14, water, filtered (percent modern)	Carbon-13/carbon-12 ratio, water, unfiltered (per mil)	Carbon-13/carbon-12 ratio (remark code)	Radium-226, water, filtered, radon method (pCi/L)	Radium-226, 1-sigma CSU, water, filtered, radon method (pCi/L)	Radium-226, ssL_C, water, filtered, radon method (pCi/L)	Radium-226 (remark code)
294800095344101	LJ-65-12-516	4/6/2010	0920	Environmental	--	--	--	--	--	--	--	--
294735095344001	LJ-65-12-521	4/6/2010	1042	Environmental	--	--	--	--	--	--	--	--
294627095375801	LJ-65-11-914	4/6/2010	1216	Environmental	--	--	--	--	--	--	--	--
294721095361001	LJ-65-12-719	4/7/2010	0909	Environmental	--	--	--	--	--	--	--	--
294723095370501	LJ-65-12-730	4/7/2010	1040	Environmental	--	--	--	--	--	--	--	--
294723095382601	LJ-65-11-920	4/7/2010	1209	Environmental	--	--	--	--	--	--	--	--
294731095414201	LJ-65-11-514	4/8/2010	1016	Environmental	--	--	--	--	--	--	--	--
295553095191201	LJ-65-06-528	4/8/2010	1331	Environmental	--	--	--	--	--	--	--	--
295027095312301	LJ-65-12-328	5/6/2010	0940	Environmental	0.02	0.20	-12.71	--	--	--	--	--
293636095300401	JY-65-28-309	10/28/2010	1011	Environmental	--	--	--	--	--	--	--	--
293635095294101	JY-65-29-107	10/28/2010	1225	Environmental	--	--	--	--	--	--	--	--
293652095293601	LJ-65-29-108	10/28/2010	1350	Environmental	--	--	--	--	--	--	--	--
294252095362101	LJ-65-20-125	11/3/2010	1033	Environmental	--	--	--	--	--	--	--	--
294127095342502	LJ-65-20-519	11/4/2010	0945	Environmental	--	--	--	--	--	--	--	--
294127095342502	*LJ-65-20-519*	*11/4/2010*	*0946*	*Sequential replicate*	--	--	--	--	--	--	--	--
294047095345601	LJ-65-20-516	11/4/2010	1114	Environmental	--	--	--	--	--	--	--	--
294050095355501	LJ-65-20-416	11/9/2010	1159	Environmental	--	--	--	--	--	--	--	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Radon-222, water, unfiltered (pCi/L)	Radon-222, 1-sigma CSU, water, unfiltered (pCi/L)	Radon-222, ssL$_C$, water, unfiltered (pCi/L)	Radon-222 (remark code)	Uranium (natural), water, filtered (µg/L)	Uranium (natural), LRL, water, filtered (µg/L)	Uranium (natural), LT-MDL, water, filtered (µg/L)	Uranium (natural) (remark code)
294921095312907	LJ-65-12-633	3/16/2010	1041	Environmental	--	--	--	--	3.78	0.008	--	--
294900095312101	LJ-65-12-619	3/16/2010	1257	Environmental	--	--	--	--	4.01	.008	--	--
295027095312301	LJ-65-12-328	3/17/2010	0927	Environmental	--	--	--	--	.32	.008	--	--
295027095312301	*LJ-65-12-328*	*3/17/2010*	*0928*	*Sequential replicate*	--	--	--	--	*.32*	*.008*	--	--
294950095313701	LJ-65-12-622	3/17/2010	1114	Environmental	--	--	--	--	11.9	.008	--	--
294340095311103	LJ-65-20-321	3/18/2010	0952	Environmental	--	--	--	--	1.72	.008	--	--
294348095303702	LJ-65-20-319	3/18/2010	1147	Environmental	--	--	--	--	2.59	.008	--	--
294348095270401	LJ-65-21-202	3/22/2010	1002	Environmental	--	--	--	--	.38	.008	--	--
294338095270401	LJ-65-21-201	3/22/2010	1129	Environmental	--	--	--	--	8.14	.008	--	--
294333095275602	LJ-65-21-143	3/22/2010	1304	Environmental	--	--	--	--	1.69	.008	--	--
294329095284602	LJ-65-21-148	3/23/2010	1001	Environmental	--	--	--	--	6.48	.008	--	--
294329095284602	*LJ-65-21-148*	*3/23/2010*	*1002*	*Sequential replicate*	--	--	--	--	*6.50*	*.008*	--	--
294319095305901	LJ-65-20-303	3/23/2010	1123	Environmental	--	--	--	--	7.82	.008	--	--
294317095313001	LJ-65-20-304	3/23/2010	1252	Environmental	--	--	--	--	1.40	.008	--	--
294328095290402	LJ-65-21-149	3/24/2010	1036	Environmental	--	--	--	--	6.96	.008	--	--
294323095300103	LJ-65-20-325	3/24/2010	1151	Environmental	--	--	--	--	1.21	.008	--	--
294201095355601	LJ-65-20-405	3/24/2010	1343	Environmental	--	--	--	--	6.94	.008	--	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Radon-222, water, unfiltered (pCi/L)	Radon-222, 1-sigma CSU, water, unfiltered (pCi/L)	Radon-222, ssL$_C$, water, unfiltered (pCi/L)	Radon-222 (remark code)	Uranium (natural), water, filtered (µg/L)	Uranium (natural), LRL, water, filtered (µg/L)	Uranium (natural), LT-MDL, water, filtered (µg/L)	Uranium (natural) (remark code)
293732095300601	LJ-65-20-911	3/25/2010	0932	Environmental	--	--	--	--	7.04	0.008	--	--
293734095293701	LJ-65-21-708	3/25/2010	1130	Environmental	--	--	--	--	4.56	.008	--	--
293736095285301	LJ-65-21-709	3/25/2010	1257	Environmental	--	--	--	--	6.40	.008	--	--
294002095351001	LJ-65-20-414	3/29/2010	1108	Environmental	--	--	--	--	17.5	.008	--	--
294414095364202	LJ-65-20-126	3/29/2010	1313	Environmental	--	--	--	--	.27	.008	--	--
294456095341101	LJ-65-12-820	3/30/2010	0906	Environmental	--	--	--	--	3.67	.008	--	--
294501095343601	LJ-65-12-817	3/30/2010	1021	Environmental	--	--	--	--	3.92	.008	--	--
294519095383201	LJ-65-11-918	3/30/2010	1154	Environmental	--	--	--	--	3.91	.008	--	--
295246095351301	LJ-65-04-723	3/31/2010	0913	Environmental	--	--	--	--	23.2	.008	--	--
295249095364701	LJ-65-04-728	3/31/2010	1113	Environmental	--	--	--	--	.80	.008	--	--
295249095370701	LJ-65-04-729	3/31/2010	1228	Environmental	--	--	--	--	42.7	.008	--	--
295243095383101	LJ-65-03-916	4/1/2010	0941	Environmental	--	--	--	--	.56	.008	--	--
294712095401301	LJ-65-11-803	4/1/2010	1124	Environmental	--	--	--	--	1.76	.008	--	--
294717095401001	LJ-65-11-804	4/1/2010	1229	Environmental	--	--	--	--	.73	.008	--	--
294952095342601	LJ-65-12-519	4/5/2010	1030	Environmental	--	--	--	--	2.36	.008	--	--
294952095342601	*LJ-65-12-519*	*4/5/2010*	*1031*	*Sequential replicate*	--	--	--	--	*2.43*	*.008*	--	--
294925095341201	LJ-65-12-520	4/5/2010	1202	Environmental	--	--	--	--	.12	.008	--	--
294844095342401	LJ-65-12-522	4/5/2010	1338	Environmental	--	--	--	--	.32	.008	--	--

Table 6. Results of radionuclide analyses of water samples collected from municipal supply wells in the Houston, Texas, area, 2010—Continued.

U.S. Geological Survey site number	State well number	Date	Sample start time	Sample type	Radon-222, water, unfiltered (pCi/L)	Radon-222, 1-sigma CSU, water, unfiltered (pCi/L)	Radon-222, ssL$_c$, water, unfiltered (pCi/L)	Radon-222 (remark code)	Uranium (natural), water, filtered (µg/L)	Uranium (natural), LRL, water, filtered (µg/L)	Uranium (natural), LT-MDL, water, filtered (µg/L)	Uranium (natural) (remark code)
294800095344101	LJ-65-12-516	4/6/2010	0920	Environmental	--	--	--	--	0.90	0.008	--	--
294735095344001	LJ-65-12-521	4/6/2010	1042	Environmental	--	--	--	--	.38	.008	--	--
294627095375801	LJ-65-11-914	4/6/2010	1216	Environmental	--	--	--	--	.38	.008	--	--
294721095361001	LJ-65-12-719	4/7/2010	0909	Environmental	--	--	--	--	4.03	.008	--	--
294723095370501	LJ-65-12-730	4/7/2010	1040	Environmental	--	--	--	--	1.23	.008	--	--
294723095382601	LJ-65-11-920	4/7/2010	1209	Environmental	--	--	--	--	.45	.008	--	--
294731095414201	LJ-65-11-514	4/8/2010	1016	Environmental	--	--	--	--	.30	.008	--	--
295553095191201	LJ-65-06-528	4/8/2010	1331	Environmental	--	--	--	--	.15	.008	--	--
295027095312301	LJ-65-12-328	5/6/2010	0940	Environmental	--	--	--	--	.29	.008	--	--
293636095300401	JY-65-28-309	10/28/2010	1011	Environmental	1,700	94	12.004	--	1.80	--	0.004	--
293635095294101	JY-65-29-107	10/28/2010	1225	Environmental	1,620	90	11.963	--	1.62	--	.004	--
293652095293601	LJ-65-29-108	10/28/2010	1350	Environmental	2,380	130	11.988	--	3.88	--	.004	--
294252095362101	LJ-65-20-125	11/3/2010	1033	Environmental	--	--	--	--	7.58	--	.004	--
294127095342502	LJ-65-20-519	11/4/2010	0945	Environmental	--	--	--	--	.03	--	.004	--
294127095342502	*LJ-65-20-519*	*11/4/2010*	*0946*	*Sequential replicate*	--	--	--	--	*.03*	--	*.004*	--
294047095345601	LJ-65-20-516	11/4/2010	1114	Environmental	--	--	--	--	12.6	--	.004	--
294050095355501	LJ-65-20-416	11/9/2010	1159	Environmental	--	--	--	--	3.99	--	.004	--

[1] All time dependent analyses were completed within holding time limit except where otherwise noted. Analyses for alpha and beta radioactivity, 30-day count, were completed within 29 to 35 days after sample collection.

Table 7. Relative percent differences (RPD) between sequential replicate and environmental samples analyzed for major ions, trace elements, and radionuclides and collected in association with municipal supply wells sampled in the Houston, Texas, area, 2010.

[RPDs are percentages; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; SiO_2, silicon dioxide; °C, degrees Celsius; µg/L, micrograms per liter; Th, thorium; pCi/L, picocuries per liter; Cs, cesium; N/A, not applicable]

	Major Ions											
	Calcium, water, filtered (mg/L)	Magnesium, water, filtered (mg/L)	Potassium, water, filtered (mg/L)	Sodium, water, filtered (mg/L)	Alkalinity, water, filtered, inflection-point titration method (incremental titration method), field (mg/L as $CaCO_3$)	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	Bromide, water, filtered (mg/L)	Chloride, water, filtered (mg/L)	Fluoride, water, filtered (mg/L)	Silica, water, filtered (mg/L as SiO_2)	Sulfate, water, filtered (mg/L)	Residue on evaporation, dried at 180 °C, water, filtered (mg/L)
Number of pairs with detected values	4	4	4	4	3	3	4	4	4	4	4	4
Minimum RPD	1.0	.7	0	1.1	0	0	0	0	0	.6	0	.2
Average RPD	1.7	1.3	.9	2.7	1.9	1.9	1.3	.4	2.0	2.9	.6	2.2
Maximum RPD	3.3	1.8	2.2	4.3	3.9	3.8	5.3	1.0	6.9	6.7	1.3	4.7

	Trace elements								
	Arsenic, water, filtered (µg/L)	Barium, water, filtered (µg/L)	Boron, water, filtered (µg/L)	Iron, water, filtered (µg/L)	Lithium, water, filtered (µg/L)	Manganese, water, filtered (µg/L)	Molybdenum, water, filtered (µg/L)	Selenium, water, filtered (µg/L)	Strontium, water, filtered (µg/L)
Number of pairs with detected values	4	4	4	3	4	4	4	2	4
Minimum RPD	0	0	2.4	0	1.0	0	0	3.8	.2
Average RPD	1.4	.6	4.2	1.7	4.7	4.7	.4	9.6	.7
Maximum RPD	4.1	1.9	7.7	4.1	8.0	17	1.5	15	1.6

	Radionuclides				
	Alpha radioactivity, 30-day count, water, filtered, Th-230 curve (pCi/L)	Alpha radioactivity, 72-hour count, water, filtered, Th-230 curve (pCi/L)	Beta radioactivity, 30-day count, water, filtered, Cs-137 curve (pCi/L)	Beta radioactivity, 72-hour count, water, filtered, Cs-137 curve (pCi/L)	Uranium (natural), water, filtered (µg/L)
Number of pairs with detected values	3	4	4	4	4
Number of pairs that overlap with +/- CSU	2	3	2	4	N/A
Minimum RPD	1.8	3.6	4.3	11	0
Average RPD	14	20	14	15	.5
Maximum RPD	24	32	27	18	2.0

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