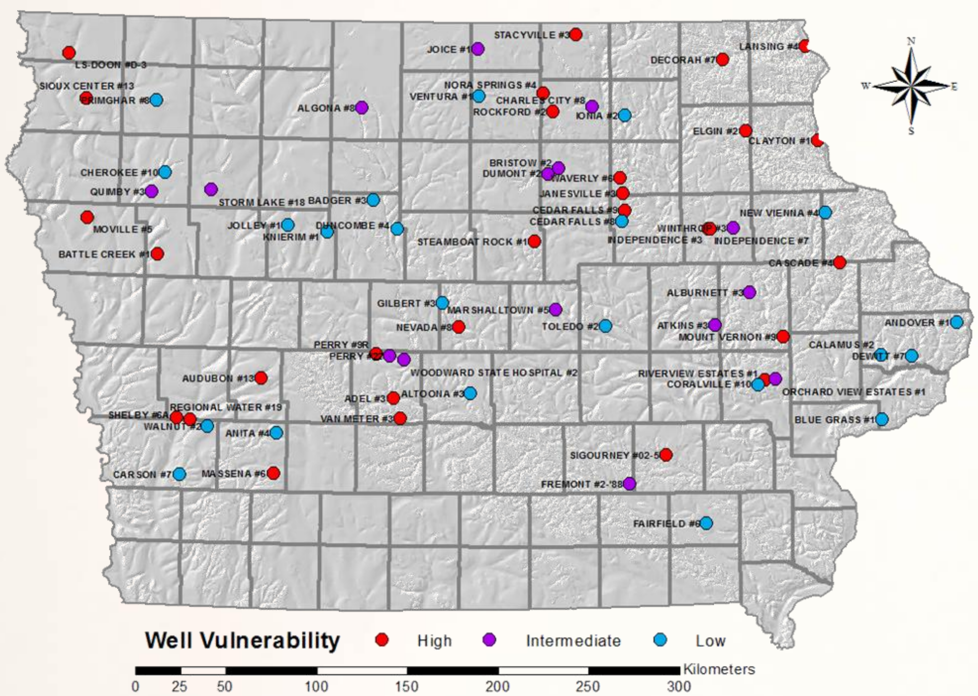
IOWA DEPARTMENT OF NATURAL RESOURCES

2013 SURVEY OF IOWA GROUNDWATER

and Evaluation of Public Well Vulnerability Classifications for Contaminants of Emerging Concern



Iowa Geological and Water Survey
Technical Information Series 57

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2013 Survey of Iowa Groundwater and Evaluation of Public Well Vulnerability Classifications for Contaminants of Emerging Concern

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ABSTRACT

Studies in Iowa have long documented the vulnerability of wells with less than 50 feet (15 meters) of confining materials above the source aquifer to contamination from nitrate and various pesticides. Recent studies in Wisconsin have documented the occurrence of viruses in untreated groundwater, even in wells considered to have little vulnerability to contamination from near-surface activities. In addition, sensitive methods have become available for analyses of pharmaceuticals and pesticides. This study represents the first comprehensive examination of contaminants of emerging concern in Iowa's groundwater conducted to date, and one of the first conducted in the United States.

Raw groundwater samples were collected from 66 public supply wells during the spring of 2013, when the state was recovering from drought conditions. Samples were analyzed for 206 chemical and biological parameters; including 20 general water-quality parameters and major ions, 19 metals, 5 nutrients, 10 virus groups, 3 species of pathogenic bacteria, 5 microbial indicators, 108 pharmaceuticals, 35 pesticides and pesticide degradates, and tritium. The wells chosen for this study represent a diverse range of ages, depths, confining material thicknesses, pumping rates, and land use settings.

The most commonly detected contaminant group was pesticide compounds, which were present in 41% of the samples. As many as 6 pesticide compounds were found together in a sample, most of which were chloroacetanilide degradates. While none of the measured concentrations of pesticide compounds exceeded current benchmark levels, several of these compounds are listed on the U.S. Environmental Protection Agency's Contaminant Candidate List and could be subject to drinking water standards in the future. Despite heavy use in the past decade, glyphosate was not detected, and its metabolite, aminomethylphosphonic acid, was only detected in two of 60 wells tested (3%) at the detection limit of 0.02 μg/L.

Pharmaceutical compounds were detected in 35% of 63 samples. Of the 14 pharmaceuticals detected, six had reported concentrations above the method reporting limit, with the maximum reported concentration of 826 ng/L for acetaminophen. Diphenhydramine was the only pharmaceutical to have two detections above the reporting limit, at 24.5 and 145 ng/L. Eight pharmaceuticals had confirmed detections at concentrations below the method reporting limit. Caffeine was the most frequently detected pharmaceutical compound (25%), followed by the caffeine metabolite, 1,7-dimethylxanthine (16%).

Microorganisms were detected in 21% of the wells using quantitative polymerase chain reaction methodologies. The most frequently detected microorganism was the pepper mild mottle virus (PMMV), a plant pathogen found in human waste. PMMV was detected in 17% of samples at concentrations ranging from 0.4 to 6.38 gene copies per liter. GII norovirus, human polyomavirus, bovine polyomavirus, and *Campylobacter* were also detected, while adenovirus, enterovirus, GI norovirus, swine hepatitis E, *Salmonella*, and enterohemmorhagic *E. coli* were not detected. No correlations were found between viruses or pathogenic bacteria and microbial indicators.

Wells with less than 50 feet (15 meters) of confining material were shown to have greater incidence of surface-related contaminants; however, significant relationships ($p<0.05$) between confining layer thickness and contaminants were only found for nitrate and herbicides.

INTRODUCTION

Groundwater supplies drinking water to about 80% of Iowa's 3 million people, with over 2 million of these people obtaining their drinking water from public water supplies (PWS). Such PWS are required by the United States Environmental Protection Agency (US EPA) to monitor finished water for a variety of chemical, physical, and biological contaminants to protect public health. The remaining 300,000 Iowans rely on groundwater for their drinking water obtained from unregulated private wells.

Pharmaceuticals, viruses, and other contaminants of emerging concern (CECs), which are largely unregulated, are of increasing public interest. CECs have commonly been found in aquatic systems (e.g., Kolpin et al., 2002, 2004), including groundwater (Barnes et al., 2008; Erickson et al., 2014; Schaider et al., 2014). There is mounting evidence that exposures to select CECs can affect aquatic and terrestrial organisms (Brodin et al., 2013; Jonsson et al., 2014; Oaks et al., 2004; Rosi-Marshall et al., 2013). Potential effects to human health have not yet been widely identified (Bruce et al., 2010); however, health-based benchmark values have been assessed for some pesticides and pharmaceuticals (Minnesota Department of Health, 2013; Toccalino et al., 2012; US EPA, 2014b). Increased risk of acute gastrointestinal illness has been associated with viruses found in non-disinfected municipal drinking water (Borchardt et al., 2012).

In addition to the primary and secondary drinking-water contaminants that PWS are required to monitor under the Safe Drinking Water Act, the US EPA continues to evaluate potential contaminants on their "Contaminant Candidate List" (CCL) to determine appropriate standards (US EPA, 2013a). Contaminants needing further assessment are listed under the Unregulated Contaminant Monitoring Rule 3 (UCMR

3), which requires additional monitoring from a subset of PWS for a combination of metals, volatile organic compounds, hormones, viruses, and perfluorinated compounds (US EPA, 2013b). This is the first time the UCMR list included CECs. The CCL was last updated in 2010, and is scheduled to be updated every six years. These lists will likely be revised to include other CECs as new analytical methods become available, detection levels improve, and health effects are studied.

In order to determine whether selected CECs, pesticides, and UCMR 3 contaminants occur in Iowa's aquifers prior to treatment, targeted sampling and analysis of raw groundwater from a strategically selected population of 66 PWS wells was conducted in 2013. A total of 206 unique parameters were measured, including 108 pharmaceutical compounds, 35 pesticide compounds, 19 metals, 5 microbial indicators, 3 bacterial pathogens, and 10 groups of viruses. Concurrent analysis of this untreated groundwater for 20 general water-quality parameters and major ions, 5 nutrients, and tritium provided context for the potential occurrence of CECs. The sampling network represented all major aquifers in Iowa and a broad set of well characteristics. This study represents the first comprehensive examination of CECs in Iowa's groundwater conducted to date, and one of the first conducted in the United States. This project will provide further understanding of CECs in groundwater, help assess future safe drinking water program needs, guide source water protection activities for both public and domestic wells, help evaluate choice of fecal indicators for the Groundwater Rule in Iowa, and serve as a foundation for future epidemiological studies.

Previous Statewide Groundwater-Quality Monitoring

A number of past studies have assessed groundwater quality in Iowa on a state-wide basis, and provided important background information for this study, including the following:

- *Iowa Groundwater Monitoring (IGWM) Network*. Beginning in 1982, the Iowa Geological Survey, U.S. Geological Survey (USGS), and State Hygienic Lab (SHL) collaborated to collect and analyze raw groundwater from public wells. In the 1980s, as it became evident that agricultural practices were affecting groundwater quality, a formal monitoring scheme was developed, and wells in the network tapping vulnerable aquifers were sampled for agricultural chemicals and other surface-related contaminants. Data from the IGWM network have documented the occurrence of herbicides and their metabolites in public wells (Detroy et al., 1988; Kolpin et al., 1997a), allowed for analysis of trends in agrichemical occurrence (Kolpin et al., 1997b), and provided a description of the occurrence and distribution of ammonia-nitrogen (Schilling, 2002) and arsenic (Libra, 2011).

Budgetary constraints resulted in the program stopping annual monitoring in 2006 but the network was sampled again in 2012.

- _Synthetic Organic Compound (SOC) Sampling Survey of Public Water Supplies._ During 1984-85, 128 public wells were sampled for a variety of SOCs. Seventy of these wells were also sampled for commonly-used pesticides. Forty-five percent of the wells contained one or more SOC (Kelley, 1985).

- _The State-Wide Rural Well Water Survey (SWRL)_. SWRL was a statistically designed, population-based sampling of private wells in Iowa, designed to assess the exposure to nitrates, bacteria, and commonly-used herbicides (Kross et al., 1990). SWRL sampled 686 wells during 1988-89, in all counties of the state.

- _Iowa Community Private Well Study._ While SWRL focused on private wells in unincorporated areas, this 2002 study sampled private wells in communities without a public water supply. The study included a random sampling of wells and a component focused on communities with multiple potential contaminant sources. The results of the study indicated these private "in-town" wells exhibit generally similar levels of contamination as rural private wells (Iowa DNR, 2004).

- _The Iowa Statewide Rural Well Water Survey Phase 2 (SWRL2)_. SWRL2 sampled 473 private wells in Iowa, located in 89 of the state's 99 counties. The wells included 116 wells sampled in the original SWRL study (Kross et al., 1990), with the remainder being mainly wells drilled since SWRL. The contaminants analyzed for this study included nitrate, total coliform bacteria, arsenic, atrazine, and herbicides, including chloroacetanilide degradates (CHEEC, 2009).

In addition to these specific projects, raw, public well groundwater has been sampled for a variety of purposes since early in the 20th century by both state and federal agencies, including the Iowa DNR and precursor agencies, the SHL, USGS, and the Iowa Department of Public Health. These wells have been linked, when possible, to well logs and construction records, and those with sufficient documentation have been chosen for a variety of groundwater monitoring studies that have primarily taken place since the 1980s.

Groundwater Vulnerability in Iowa

Investigations into the occurrence of nonpoint source agricultural chemicals in Iowa groundwater during the early 1980s led to the development and testing of a groundwater vulnerability scheme (Hallberg et al., 1983; Hallberg et al., 1984; Libra et al., 1984). This classification provides a general mappable description of the geologic settings where mobile contaminants may reach aquifers. This concept was adapted to produce a groundwater vulnerability map for the state (Hoyer and Hallberg, 1991) and continues to be refined. This classification scheme, shown in Figure 1, guides

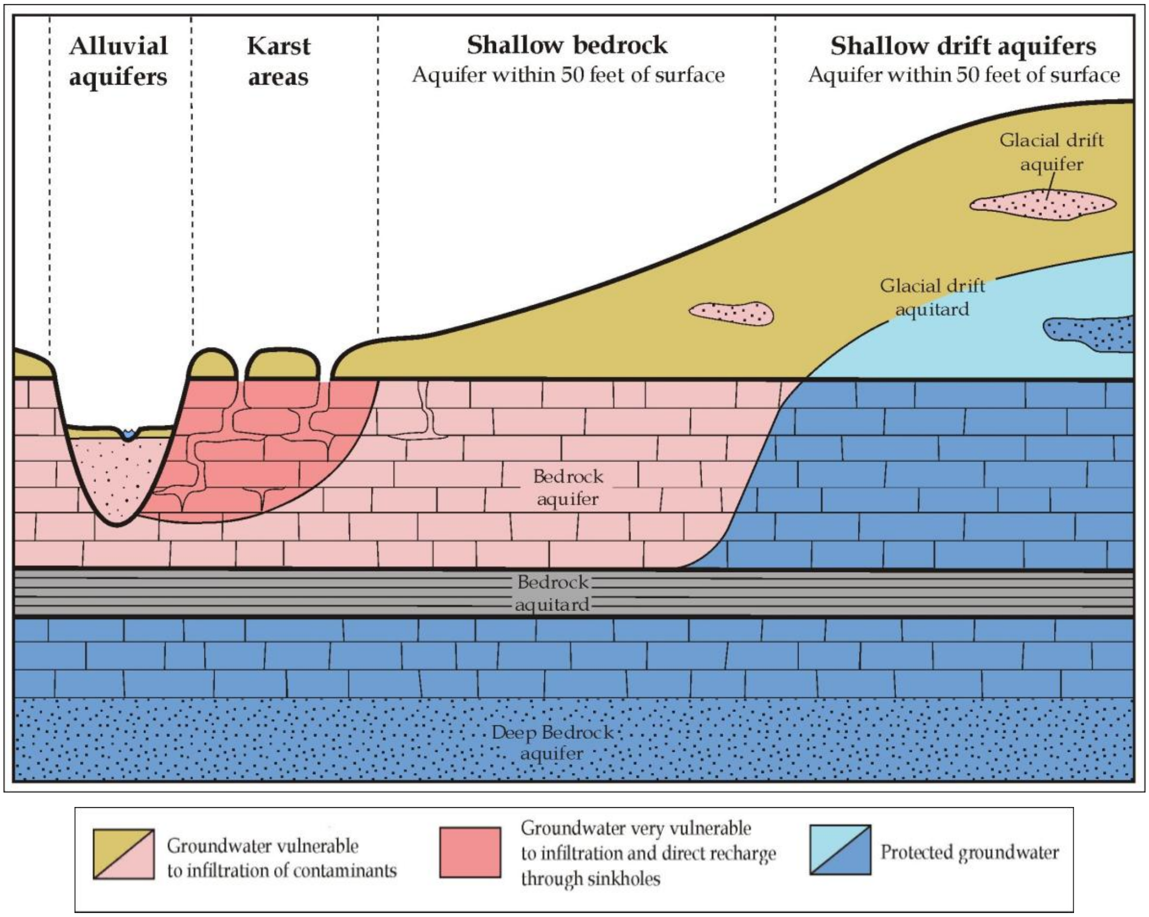

Figure 1. Diagram of the groundwater vulnerability classification used in Iowa (Iowa DNR, 2011).

groundwater-quality monitoring priorities, such as those described above, as well as groundwater and source-water protection activities (Iowa DNR, 2011).

Areas where aquifers are overlain by less than 50 feet (15 meters) of slowly permeable confining beds (typically clayey glacial till or shale bedrock) are vulnerable to contamination, and their groundwater commonly contains mobile contaminants such as nitrate. Shallow bedrock aquifers are most common in the eastern half of the state, while alluvial aquifers occur in river valleys statewide. In northeast Iowa, karst areas with sinkholes and losing streams occur in some shallow bedrock settings and add to the overall vulnerability of the underlying groundwater. In contrast, areas where aquifers are covered by more than 50 feet (15 meters) of confining bed material have a significant degree of natural protection from surficial contamination. Contamination can reach these relatively protected aquifers via direct conduits such as abandoned or inadequately constructed wells, or preferential flow pathways such as fractures, but the geologic setting generally limits contaminant inputs from the surface.

This vulnerability classification was largely derived using nitrate results from private wells. When applied to public wells, several factors alter this approach. First, public wells typically pump significantly larger quantities of water than private wells, resulting in steep downward gradients and the potential to move contaminants to greater depth if pathways exist. Second, these drawdowns result in larger capture zones for pubic wells, relative to private wells. This increases the potential variability in the confining bed thickness across the capture zone, and the potential for windows of less protected aquifer within the zone. Existing geologic data may be inadequate in terms of density to map this variability. Given this uncertainty and much higher pumping rates (often for many decades) the application of the vulnerability concept to public wells errs on the conservative side, and requires a greater confining bed thickness to be considered naturally protected (Iowa DNR, 2011). For this study, wells with less than 50 feet (15 meters) of confining bed thickness were classified as "high vulnerability" wells, wells between 50 – 100 feet (15-30 meters) of confining materials were classified as "intermediate vulnerability," and wells with greater than 100 feet (>30 meters) of confining material were classified as having "low vulnerability."

Background for Selected Analytes

For this study, a comprehensive analysis of the water samples was conducted, with a total of 206 water quality parameters measured, including tritium, 20 general water-quality parameters and major ions, 5 nutrients, 19 metals, 5 microbial indicators, 35 pesticide compounds, 108 pharmaceutical compounds, 10 viruses, and 3 bacterial pathogens. The measurements of commonly assessed water constituents were included to provide context and to evaluate their value as predictors of CECs occurrence.

Twenty-eight contaminants analyzed for this study are currently regulated by the Safe Drinking Water Act. It should be noted; however, that the standards for drinking water only apply to finished water. In addition, multiple treatment methods are used in Iowa and many systems blend water from multiple wells and/or surface sources. Therefore, conclusions about the quality of finished drinking water cannot be drawn from this study of raw groundwater sampling.

Tritium

To complement vulnerability rankings, knowledge of the relative age of groundwater can help determine whether groundwaters are vulnerable to surface-related contamination. Groundwater recharged in the past 50 years is more likely to contain contaminants associated with wastewater and agricultural activities. Tritium (^{3}H) is a radioactive isotope of hydrogen, naturally formed by the interaction of incoming cosmic rays with the upper atmosphere. Human nuclear activities add to the concentrations of tritium in the atmosphere and hydrologic cycle. In particular, atmospheric testing of nuclear weapons during the 1950s and 1960s resulted in precipitation containing several thousand tritium units (TU) in the upper Midwest, whereas natural processes previously are estimated to have resulted in concentrations around 10 TU (Michel, 2004). Tritium has a half-life of approximately 12.4 years; therefore, the concentration of tritium in the atmosphere continues to decline, but it remains a useful indicator of recent groundwater recharge.

General Water-Quality, Major Ions, and Nutrients

Among the groundwater constituents examined for this study were a number of commonly measured parameters that provide insights into the groundwater's history, and were relevant to predicting the probability of the occurrence of surface-derived contaminants. Some of these parameters are also useful for distinguishing between surface-related and naturally derived contamination. It is possible; however, for there to be multiple sources of these constituents. Additionally, subsurface processes can affect these parameters, thus is it best to look at multiple parameters before drawing conclusions about potential sources of contamination. In Iowa for example, nitrate is commonly derived from a combination of inorganic fertilizer application, mineralization/nitrification of soil organic matter, human and animal waste, legume fixation, and atmospheric deposition (Schilling and Wolter, 2008). Because nitrate is regulated for drinking-water use (US EPA, 2013c), it is widely monitored in groundwater. However, one drawback to using nitrate as a tracer of surface contamination is that microbes can transform nitrate to other forms of nitrogen (denitrification) under anoxic subsurface conditions when organic matter is present.

Chloride, which can be introduced into groundwater from human and animal waste and road salts, can also be used as a tracer of surface activities. The benefit of using chloride as a tracer is that, unlike nitrate, it is not removed by chemical or biological processes in the subsurface. However, chloride is contained in certain rock formations, and thus, can be found in some deep protected aquifers. While some correlation between chloride and nitrate are seen in IGWM data, the highest chloride values (1,000 mg/L or more) occur in samples from deep wells drawing water from Cambrian-Ordovician bedrock aquifers (IDNR, 2013).

Dissolved oxygen (DO) is derived from the atmosphere and higher concentrations are generally indicative of shorter duration flow paths and relatively recent recharge. The presence of DO affects many natural and anthropogenic contaminants (Stumm and Morgan, 1981). Water containing greater than 0.5 mg/L DO is defined as oxic. As groundwater moves, DO reacts with organic matter and reduced mineral species, resulting in declining concentrations along its flow path (Rose and Long, 1988); thus, DO can provide a general indication of groundwater age. However, the rate of these reactions is a function of the organic carbon and mineral species the groundwater encounters, and relatively deep and old groundwater may contain substantial DO (Winogrand and Robertson, 1982).

Unlike nitrate, ammonia is a form of nitrogen found in groundwater that is predominantly derived from natural sources at some depth in Iowa (Schilling, 2002); however, it can also be derived from surface activities and persist in groundwater under reducing conditions. Ammonia concentrations above 1 mg/L are a concern for public water supplies, as nitrification of ammonia during treatment processes can generate nitrite. Nitrite as nitrogen (N) has a maximum contaminant level (MCL) of 1 mg/L, and nitrification of more than 1 mg/L ammonia-N may generate nitrite-N concentrations above the MCL (US EPA, 2013c).

Total dissolved solids (TDS) is another frequently measured water-quality parameter that is often associated with dissolution of aquifer material over time, but it can also come from human activities, such as the application of manure on fields, or road salt use during the winter. Common inorganic salts that contribute to TDS concentrations in Iowa groundwater include calcium, magnesium, potassium, and sodium (cations), bicarbonates, and chlorides and sulfates (anions).

Water-quality monitoring also often includes turbidity, a measure of the cloudiness of water. While turbidity does not have direct health effects, it has been associated with the presence of disease-causing microorganisms (US EPA, 2014a). Water systems are required to remove turbidity, usually by filtration or settling.

Metals

Arsenic is a metalloid that can be dissolved into groundwater from minerals in the subsurface. Like ammonia, arsenic is more often found in deep aquifers, protected from surface activities (IDNR, 2013). Most detections of arsenic in Iowa's groundwater occur in the Des Moines Lobe landform region of the state (IDNR, 2013); however, a localized hotspot has been documented near Clear Lake in Cerro Gordo County (Schnoebelen and Walsh, 2014). Arsenic is regulated in drinking water because it has been shown to be associated with health effects such as skin damage, problems with circulatory systems, and the potential increased risk of cancer (US EPA, 2013c). The SWRL2 study conducted in Iowa found 8% of samples exceeding the MCL for arsenic in drinking-water of 0.010 mg/L arsenic (CHEEC, 2009).

Chromium, cobalt, strontium, and vanadium are metals listed on the UCMR 3 (US EPA, 2013b). These metals may be derived from dissolution of naturally occurring minerals or from pipes and industrial processes. Concerns over exposure to these metals have been raised due to potential for reproductive and developmental effects, carcinogenicity, and other human health impacts. For this study, samples were only analyzed for dissolved chromium; however, the UCMR 3 requires drinking-water systems to be tested for total choromium and hexavalent chromium.

Pesticides and Pesticide Degradates

Atrazine is one of the most commonly used herbicides in the US, with annual use of over 60 million pounds for the past two decades (USGS, 2013a). Both atrazine and its degradates, desethyl atrazine and deisopropyl atrazine, have been detected in Iowa's groundwater since the 1980s (Detroy et al., 1998; IDNR, 2013; Kolpin et al., 1997a; 1997b; CHEEC, 2009). The MCL established by the US EPA for drinking-water is 3 μg/L for long-term exposure, and concentrations below 298 μg/L atrazine are considered safe for short-term exposures. Atrazine was detected in 19.5% of groundwater samples collected between 1982 - 1995 in Iowa, with a maximum concentration measured at 21 μg/L, and less than 1% of the samples exceeding the MCL (Kolpin et al., 1997a). Although atrazine was detected in 8% of private wells sampled between 2006 - 2007 in Iowa, none of the measured concentrations exceeded the MCL (CHEEC, 2009).

Chloroacetanilide herbicides, including acetochlor, alachlor, and metolachlor, have been widely used for pre-emergent control of annual grasses in Iowa and throughout the US, primarily for corn production. Metolachlor use has dropped considerably since the 1990s, while alachlor use has remained consistent since it replaced acetochlor in 1994 (USGS, 2013a). These herbicides, and their ethanesulfonic acid (ESA) and oxanilic acid (OXA) degradates, have been documented widely in groundwater in Iowa, with greater concentrations and higher detection frequencies in unconfined aquifers with younger water, and more frequent detections of degradates than their parent compounds (Detroy et al., 1988; IDNR, 2013; Kolpin et al., 1997a; 1997b; CHEEC, 2009). The primary mechanism for degradation of the parent compounds is microbial activity in the soil (Potter and Carpenter, 1995), and, in general, the chloroacetanilide degradates are more soluble than their parent compounds, increasing their potential for leaching (Thurman et al., 1996). Of these compounds, only alachlor has a drinking water standard established by the US EPA of 2 μg/L. Chloroacetanilides and their degradates that are included on US EPA's CCL include acetochlor, acetochlor ESA, acetochlor OXA, alachor ESA, alachlor OXA, metolachlor, metolachor ESA, and metolachlor OXA.

Glyphosate is a non-selective, broad spectrum herbicide that is the most widely used herbicide in the United States having both substantial agricultural and urban uses (Baylis, 2000). Dramatic increases in the agricultural use of glyphosate occurred in 1997 corresponding to the introduction of genetically altered glyphosate-resistant crops through a glyphosate-resistant protein product isolated from a naturally occurring gene that was cloned and expressed in the target crops (e.g., Pline et al., 2001). Sales of products containing glyphosate in Iowa have increased from 33.6 million dollars in 1997 to 237.4 million dollars in 2009 (Iowa Department of Agriculture and Land Stewardship, 2014). National data indicate a significant increase in use of glyphosate since 1992, reaching just under 250 million pounds in 2011 (USGS, 2013a). Dill et al. (2008) estimated that 80% of genetically modified crops worldwide are glyphosate resistant. Microbial degradation of glyphosate produces aminomethylphosphonic acid (AMPA), the primary glyphosate transformation product (Forlani et al., 1999). AMPA is also formed by the degradation of phosphonic acids in detergents (Skark et al., 1998). Concerns over the development of glyphosate resistance, and problems with control of volunteer corn in corn-soybean rotations, has led to incorporation of the herbicide glufosinate into weed management regiments (Shaner, 2000).

The high polarity and water solubility of glyphosate, AMPA, and glufosinate make their analysis in water samples problematic. Thus, compared to other heavily used pesticides (e.g., atrazine), there are relatively few studies on the environmental occurrence of glyphosate and AMPA. In one study, losses of these compounds in runoff from crop fields was shown to be smaller than from the herbicides that these compounds commonly replace, such as atrazine, metribuzin, and alachlor (Shipitalo et al., 2008). The potential human and ecological impacts of these newer compounds are not well understood, although research has suggested a potential link between the exposure to glyphosate and human placenta cell damage, especially in the presence of adjuvants (Richard et al., 2005). Recent research has documented the frequent occurrence of glyphosate and AMPA in streams and the atmosphere from samples collected in Iowa (Battaglin et al., 2005; Chang et al., 2011), and the less frequent occurrence of glufosinate (Battaglin et al., 2005). Less is known about such occurrences in Iowa groundwater. No detections of glyphosate or AMPA were observed in 86 Iowa PWS wells sampled in 2001 (Kolpin et al., 2004). Glyphosate was detected in 5.8% and AMPA in 14.3% of the 1,171 groundwater sampled across 23 U.S. states (Battaglin et al., 2014). With an additional decade of widespread application of glyphosate across Iowa, it was decided a resampling for glyphosate and AMPA in Iowa's groundwater was an important addition to this study, along with the addition of glufosinate analyses.

Pharmaceuticals

The occurrence of pharmaceuticals in the environment has become an increasing public concern worldwide. As used in this report, these compounds include over-the-counter and prescription drugs, narcotics, and common stimulants such as caffeine and nicotine. Such compounds have been frequently detected in streams (Kolpin et al., 2002), groundwater (Barnes et al., 2008), and drinking water sources (Focazio et al., 2008) across the United States. Because conventional treatment is insufficient to completely remove pharmaceuticals, these compounds have also been documented in finished drinking water (Benotti et al., 2009; Stackelberg et al., 2004). Pharmaceuticals can be introduced into the environment through a variety of pathways including discharge of treated wastewater, land application of human and animal waste, septic systems, sewer lines, and landfills (Kummerer, 2008). In general, less research on pharmaceutical occurrence has been conducted in groundwater compared to surface water (Schaider et al., 2014). An intensive groundwater monitoring effort was conducted in California (Fram and Belitz, 2011); however, only 14 pharmaceuticals were analyzed. A recent statewide groundwater CEC study in Minnesota analyzed 127 chemicals (Erickson et al., 2014).

Microbial Indicators

Five microbial indicators were chosen for this study: total coliform bacteria, *Escherichia coli* (*E. coli)*, enterococci, male-specific coliphages, and somatic coliphages. Total coliform bacteria and *E. coli* are currently primary drinking water contaminants under the Safe Drinking Water Act and are routinely monitored in PWS finished drinking water in Iowa. These bacteria are used to indicate whether a sanitary defect exists in the water system (total coliform presence) and whether contamination could be from a sewage source (*E. coli* presence), which is an acute health hazard. Another fecal bacteria indicator tested in this study was the enterococci group. This group of bacteria is thought to persist longer in freshwater environment, especially soils, than fecal coliform bacteria (Anderson et al., 2005).

Coliphages are viruses that infect the bacterium, *E. coli,* and are associated with recent fecal contamination. Because they are viruses and from a sewage source, the fate and transport of coliphages are expected to be similar to that of pathogenic viruses; thus, coliphages have been suggested as a possible indicator for enteric viral contamination (Gerba, 1987).

US EPA's Groundwater Rule calls for source water monitoring using one or all three of the aforementioned fecal indicators: *E. coli*, enterococci, and coliphage. Because virus and pathogenic bacteria sampling and analyses are still very expensive and generally low recovery, this study will evaluate whether any of these indicators will be associated with the occurrence of viruses or pathogenic bacteria.

Viruses and Pathogenic Bacteria

Viruses can occur in high concentrations (up to 10^8 copies per liter) in human and animal wastewaters (Hamza et al., 2011; Hundesa et al., 2009; Kitajima et al., 2014; Wong and Xagoraraki, 2011). Recent studies have also shown that viruses are not completely inactivated by common treatment methods (Gerba et al., 2013) and can survive for months to over a year in groundwater (Nevecherya et al., 2005; Charles et al., 2009). In addition, viruses are small enough (10-300 nm) to fit though fine pores, compared to larger bacteria (200-5000 nm) and pathogenic protozoans such as *Cryptosporidium* (5,000-7,000 nm). Enteric viruses have been reported to migrate in the subsurface as far as 400 meters (1300 feet) in glacial till and 2.5 kilometers (~1.5 miles) in fractured limestone (Keswick and Gerba, 1980). More recent research in Iowa indicates that viruses originating in surface waters can migrate over 1 km through an alluvial aquifer to city wells (Davison et al., 2013). Sampling methods that concentrate viruses from large volumes of water onto glass filters (Lambertini et al., 2008) combined with the use of quantitative polymerase chain reaction (qPCR) analyses, now make it possible to study the occurrence of viruses in groundwater at low concentrations (<10 copies per liter).

Recent studies have demonstrated relatively widespread occurrence of viruses in domestic and municipal wells in the United States (Abbaszadegan et al., 2003; Borchardt et al., 2003; Fout et al., 2003; Hunt et al., 2010). In addition, several studies have described the association of virus occurrence in groundwater supplies with disease outbreaks, and sporadic and endemic illnesses (Keswick and Gerba, 1980; Azadpour-Keeley et al., 2003; Borchardt et al., 2012; Wallender et al., 2013). Investigations in Wisconsin, in locales with generally similar geology to Iowa, including aquifers considered protected from surface contamination, have shown the common and frequent presence of human enteric viruses in PWS well source water commonly and frequently enough to prompt a regulatory response at the state level (Borchardt et al. 2003; 2004; 2007; and Bradbury et al.. 2013). An investigation of virus occurrence in groundwater in La Crosse, Wisconsin, implicated leaking sanitary sewer lines as a probable source, whereas septic systems, application of human waste, waste lagoons, and transport from surface waters have also been indicated as potential sources of these virus detections (Hunt et al., 2010; Azadpour-Keeley et al., 2003). Given the widespread occurrence of viruses in water supplies, the US EPA has placed four virus species on its CCL.

This study is unique because of the inclusion of analysis for the pepper mild mottle virus (PMMV). PMMV is a plant virus that occurs at high levels in human wastewater and has been shown to be a useful indicator of the presence of other viruses in surface waters (Hamza et al., 2011; Kitijama et al., 2014; Rosario et al., 2009). This is the first state-wide survey for PMMV in groundwater.

Enterohemmorhagic *E. coli*, *Salmonella*, and *Campylobacter jejeuni* are bacterial species known to cause gastroenteritis and other serious illnesses in humans. *Salmonella* and *Campylobacter* are listed on the US EPA's CCL. While transport of these bacteria through soils, from human and animal wastes, has been documented, transport to all but the most vulnerable aquifers should be limited due to the size of these organisms. A recent pilot study in the karst-dominated Kewaunee County in Wisconsin showed detectable levels of both *Salmonella* and *Campylobacter* (Borchardt et al., 2014). It should be noted that the quantitative polymerase chain reaction (qPCR) method used to detect these pathogens in groundwater does not differentiate between genetic material from living or dead cells.

METHODS

Well Selection

For this study, a total of 66 public water supply wells were strategically selected for sampling. This network represents 2% of the approximately 3,268 active or stand-by public wells in Iowa. The sampling network represented all major aquifers in Iowa and captured a range of confining layer thickness, construction methods, well ages, pumping rates, and dominant land uses in the capture zones. In addition, this study was a test of the long-term groundwater vulnerability classification scheme used in Iowa, and represents the first time this scheme has been related to CECs. Minimum selection criteria required that wells were drilled in the last 60 years; had adequate location, geologic, and construction information housed within Iowa Department of Natural Resource databases; and could be pumped for 4 hours during the sample collection process. Most wells had previously been sampled for conventional water quality at least once, or were near wells in the same aquifer where such samples had been collected. The selected network of wells sampled for this study is shown in Figure 2 and well characteristics are summarized in Table 1. A complete list of wells and associated characteristics can be found in Appendix A.

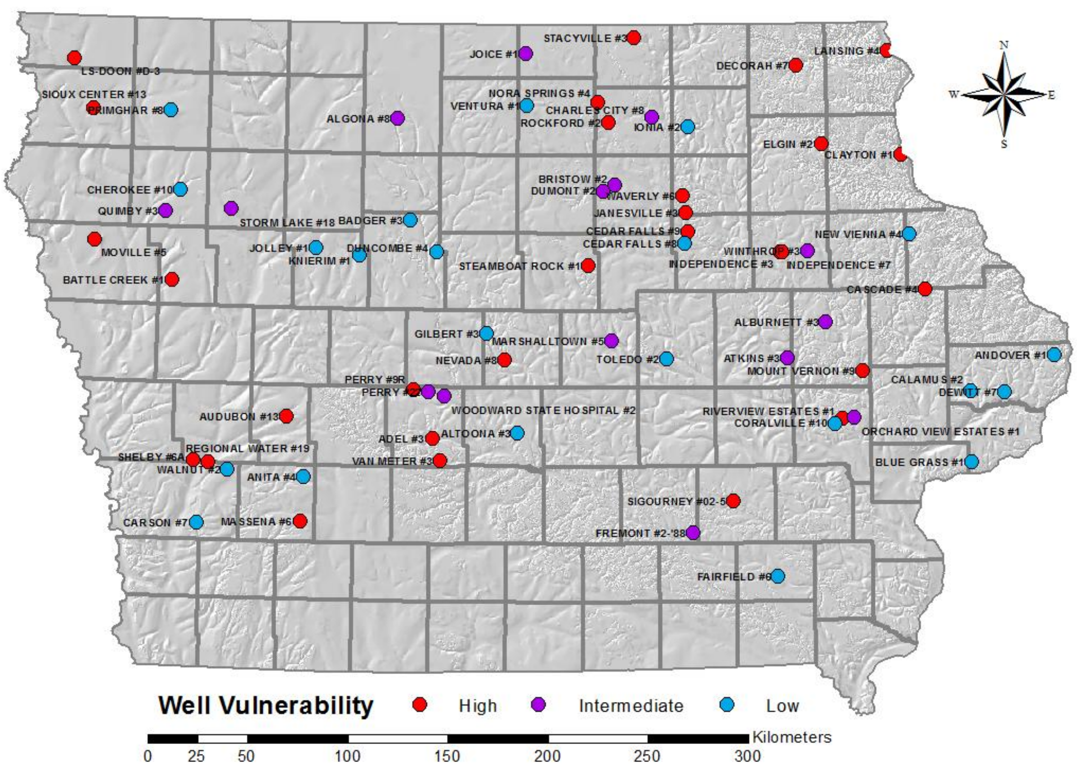

Figure 2. Map of the public water supply wells sampled for this study by vulnerability class.

Table 1. Characteristics of wells used in this study.

Well Characteristic	Number of Wells	Percent	Well Characteristic	Number of Wells	Percent
Aquifer Group			**Pumping Rate**		
Alluvial	12	18%	< 151,000 L/day (< 40,000 gpd)	28	42%
Buried Sand and Gravel	7	11%	> 151,000 L/day (> 40,000 gpd)	38	58%
Cretaceous (Dakota)	7	11%	**Age (Year Drilled)**		
Silurian-Devonian	23	35%	1943-1979	24	36%
Mississippian	5	8%	1980-1999	21	32%
Cambrian-Ordovician	12	18%	2000-2010	21	32%
Vulnerability Class			**Confining Layer Thickness**		
Low	22	33%	> 30 m (> 100 ft)	22	33%
Intermediate	13	20%	15 - 30 m (50-100 ft)	13	20%
High	31	47%	< 15 m (< 50 ft)	31	47%
Well Depth			**Dominant Land Use within 1000 feet**		
< 30 m (< 100 ft)	15	23%	Row Crop	17	26%
30 - 76 m (100-250 ft)	20	30%	Grasses	19	29%
> 76 m (> 250 ft)	31	47%	Developed	30	45%

Sampling and Analyses

Samples were collected with cooperation from municipal well operators. Sampling began on March 4, 2013, and was completed by June 18, 2013. Samples were collected by staff from the SHL of Iowa and the USGS following standard collection protocols for pharmaceuticals, including the "clean hands/dirty hands" technique, wearing latex gloves, and other precautionary measures (USGS, 2006). In addition, staff attended training for virus sampling conducted by Dr. Mark Borchardt. Specific bottle requirements, handling, analytical procedures, and quality assurance/quality control procedures for each group of analytes are summarized, below.

Tritium

Samples for tritium analysis were collected in 500-milliliter (mL) plastic bottles, sealed with plastic wrap, and refrigerated until transported to the laboratory for analysis. Tritium concentrations were quantified by the Environmental Isotope Laboratory at the University of Waterloo, Ontario, using liquid scintillation counting (LSC) (e.g., Hoffman and Stewart, 1966). Tritium concentrations are typically reported as tritium units (TU), where a TU equals 1 atom of tritium per 10^{18} atoms of hydrogen, or 3.2 pCi/L. Direct tritium measurements have a detection limit at about 6 TU. Samples with tritium content near this level were enriched 15 times by electrolysis (Taylor, 1977) and then counted. The detection limit for enriched samples is 0.8 +/-0.8 TU. Each batch of samples includes three background samples: water from a well near Newmarket, Ontario with no detectable tritium and radiocarbon age dated to >6000 BP, a long term monitor (lab deionized water), and a National Institute of Standards and Technology (NIST) standard (NIST-4926-E) which has been calibrated with NIST-SRM-4361B-21. Repeated analyses were performed within each batch and samples from each batch were repeated in a subsequent batch.

General Water-Quality, Major Ions, Nutrients, and Metals

Sampling and analysis of general water-quality characteristics, major ions, nutrients, and metals were determined according to standard operating procedures based on approved US EPA drinking water methods for regulated drinking water analytes (US EPA, 2013d) at SHL. For those parameters/analytes that are not regulated drinking water analytes (e.g., total organic carbon), all analyses were also performed according to US EPA approved methods. Analytes and their corresponding quantitation limits and method numbers are listed in Table 2. Four field blanks and five field replicate samples were collected and analyzed for these parameters during the course of the investigation.

Table 2. Quantitation limits and methods used by the State Hygienic Laboratory to analyze water samples for general water-quality parameters, major ions, nutrients, and metals.

	Analyte	Quantitation Limit(s)	Units	Method Number*
General Water Quality	pH			SM 4500 H+ B
General Water Quality	Conductivity	1	umho/cm	ISO 7888-1985
General Water Quality	Total Hardness	1	mg/L	SM 2340 C
General Water Quality	Total Alkalinity	1	mg/L	SM 2320 B
General Water Quality	Dissolved Oxygen	0.1	mg/L	ASTM D 888-05 C
General Water Quality	Total Organic Carbon	0.05	mg/L	SM 5310 B
General Water Quality	Total Dissolved Solids	1	mg/L	SM 2540 C 18th
General Water Quality	Total Suspended Solids	1	mg/L	USGS I-3765-85
General Water Quality	Turbidity	1.0	NTU	SM 2130 B 18th
Major Ions	Bromide	0.25/0.5	mg/L	EPA 300.0
Major Ions	Chloride	1.0	mg/L	EPA 300.0
Major Ions	Fluoride	0.1	mg/L	SM 4500-F C
Major Ions	Sulfate	1.0	mg/L	EPA 300.0
Major Ions	Silica as SiO2	1.0	mg/L	SM 4500-SI D
Major Ions	Carbonate Alkalinity	1.0	mg/L	SM 2320 B
Major Ions	Bicarbonate Alkalinity	1.0	mg/L	SM 2320 B
Major Ions	Calcium (dissolved)	1.0	mg/L	EPA 200.7
Major Ions	Magnesium (dissolved)	0.5	mg/L	EPA 200.7
Major Ions	Potassium (dissolved)	1.0	mg/L	EPA 200.7
Major Ions	Sodium (dissolved)	0.5	mg/L	EPA 200.7
Nutrients	Ammonia as N	0.05	mg/L	LAC 10-107-06-1J (based on EPA 350.1)
Nutrients	Nitrate + Nitrite as N	0.1	mg/L	LAC 10-107-04-1J (based on EPA 353.2)
Nutrients	Total Kjeldahl Nitrogen as N	0.1	mg/L	LAC 10-107-06-2E (based on SM $4500N_{ORG}$ D (1997))
Nutrients	Ortho-Phosphate as P	0.02	mg/L	LAC 10-115-01-1A (based on EPA 365.1)
Nutrients	Total Phosphorus as P	0.02	mg/L	LAC 10-115-01-1C OR -1D (based on SM 4500 P HN (1999))
Metals (dissolved)	Aluminum	0.1	mg/L	EPA 200.8
Metals (dissolved)	Antimony	0.005	mg/L	EPA 200.8
Metals (dissolved)	Arsenic	0.001	mg/L	EPA 200.8
Metals (dissolved)	Barium	0.05	mg/L	EPA 200.8
Metals (dissolved)	Beryllium	0.002	mg/L	EPA 200.8
Metals (dissolved)	Chromium	0.01	mg/L	EPA 200.8
Metals (dissolved)	Cobalt	0.05	mg/L	EPA 200.8
Metals (dissolved)	Copper	0.01	mg/L	EPA 200.8
Metals (dissolved)	Iron	0.02	mg/L	EPA 200.7
Metals (dissolved)	Lead	0.001	mg/L	EPA 200.8
Metals (dissolved)	Manganese	0.02	mg/L	EPA 200.8
Metals (dissolved)	Nickel	0.05	mg/L	EPA 200.8
Metals (dissolved)	Selenium	0.01	mg/L	EPA 200.8
Metals (dissolved)	Strontium	0.02	mg/L	EPA 200.8
Metals (dissolved)	Thallium	0.001	mg/L	EPA 200.8
Metals (dissolved)	Titanium	0.05	mg/L	EPA 200.8
Metals (dissolved)	Uranium	0.001	mg/L	EPA 200.8
Metals (dissolved)	Vanadium	0.05	mg/L	EPA 200.8
Metals (dissolved)	Zinc	0.02	mg/L	EPA 200.8

*Acronyms reference standard method sources as follows: ISO = International Organization for Standardization (ISO, 1985), EPA = US EPA Approved General Purpose Methods (US EPA, 2013d), LAC = 21st edition of Lachat Standard Methods (Lachat, 2008), SM = Standard Methods for the Examination of Water and Wastewater - 18th edition (Greenberg, 1992), ATSM = American Society for Testing Materials (ASTM Standard D888, 2012) and USGS = United States Geological Survey (USGS, 1989).

Pesticides and Pesticide Degradates

For the determination of pesticides and chloroacetanilide herbicides and their degradates, samples were collected in unpreserved amber glass bottles (1 L) with Teflon-lined lids, and stored at < 4° C prior to analysis. Two bottles were collected; one for the analysis for the EPA Method 8270 pesticides and a second bottle was used to test for the chloroacetanilides and their degradates. Samples were shipped on ice packs and stored at 4 degrees C until time of sample preparation. Extraction of samples for the

EPA method 8270 pesticides was within seven days of collection and analysis of the sample extracts was within 40 days of preparation. Sample preparation for the chloroacetanilides and their degradates was within 14 days of collection and the analysis of the extracts was within 28 days of extraction.

All study pesticides with the exception of the chloroacetanilides were measured at SHL and determined by EPA Method 8270 (US EPA, 2013e) with reporting limits of 0.1 μg/L for all compounds. Chloroacetanilide herbicides (acetochlor, alachlor, dimethenamid, and metolachlor) and their ethanesulfonic- and oxanilic acid-environmental degradates were determined according to SHL SOP UHL-H-016 LC/MS/MS which is based on EPA Method 535 (US EPA, 2013e). Reporting limits for all the chloroacetanilide compounds , including the degradates, were 0.025 μg/L. Four field blanks and five field replicate samples were collected and analyzed for these parameters during the study period.

For the determination of glyphosate, glufosinate, and AMPA, whole water samples were collected in a 125-mL baked, amber glass bottle and shipped on ice to the USGS Organics Geochemistry Research Laboratory in Lawrence, KS. Upon receipt at the laboratory, samples were filtered through a 0.7-μm pore sized baked glass-fiber filter. Samples were separated on a liquid chromatograph using a gradient separation and analyzed by liquid chromatography/tandem mass spectrometery (LC/MS/MS) with electrospray ionization in negative-ion mode using multiple reaction monitoring (MRM) (Meyer et al., 2009). Sample aliquots of 10 mL were derivatized. A 5-mL aliquot of the derivatized sample and 5.5 mL of deionized water are added to the autosampler vials, loaded into the cartridge, and placed in the liquid chromatography mobile-phase stream using solid-phase extraction. Comparing the retention times to the internal standards in each sample and comparing the ratio of the quantitation MRM daughter-ion to the confirming MRM daughter-ion allows for the identification of the compounds. The ratio of the area response produced by the quantitation daughter-ion of the analyte to the area response produced by the quantitation daughter-ion of the corresponding internal standard calculates the concentration of each identified compound. Two blanks (pesticide grade organic blank water) and four replicate samples were collected and analyzed alongside environmental samples in the field for quality assurance. Laboratory quality assurance protocols included duplicates, carryover blanks, and check standards for every analytical run. A duplicate sample, matrix spiked sample, and carryover blank were analyzed after every tenth sample. Two check standards and a carryover blank were also inserted at the beginning, middle, and end of each analytical run. Two blank samples were also interspersed between each set of five environmental samples. All standard solutions, blanks, and matrix spikes were treated the same as the environmental water samples.

Pharmaceuticals

Roughly 30 mL of unfiltered water for pharmaceutical analysis was collected in a 40-mL amber glass vial and shipped within seven days to the USGS National Water Quality Laboratory in Denver, CO, for analysis. Upon receipt at the laboratory, 10 to 30 mL of the leachate sample was filtered through a 0.7-µm nominal pore size glass-fiber filter (Whatman GF/F). A 100-µL aliquot of the filtered water sample was injected into a high-performance liquid chromatograph (HPLC) coupled to a triple quadrupole mass spectrometer (MS/MS) by using an electrospray ionization source operated in the positive ion mode. The 109 compounds were separated using a reversed-phase gradient of formic acid/ammonium formate-modified water and methanol. Multiple reaction-monitoring (MRM) of two fragmentations of the protonated molecular ion of each analyte to two unique product ions was used to specifically and sensitively identify each compound. The primary MRM precursor-product ion transition was quantified for each compound relative to the primary MRM precursor-product transition of the specific isotope-dilution standard chosen for that compound. The secondary MRM precursor-product ion transition was used to qualitatively confirm compound identity. The use of direct analysis without prior sample preconcentration and cleanup steps, combined with the separation provided by the HPLC and the selectivity and specificity of the MRM-MS/MS technique, resulted in method detection limits (MDLs; determined in reagent water) that range between 0.45 and 94.1 ng/L; the median MDL for all pharmaceuticals was 5.2 ng/L. The majority of MDLs for this method, as defined by the 25th and 75th percentiles of MDL distribution, were between 2.8 and 18 ng/L. Laboratory reagent spike and laboratory reagent blank samples were included with every 17 environmental samples. This method and the associated validation results and performance characteristics are described in detail elsewhere (Furlong et al., 2014). Two field blanks (pesticide grade organic blank water) and five field replicate samples were collected and analyzed for pharmaceuticals during the study period.

Original pharmaceutical results from the laboratory were given an additional screening using three main steps. First, a technique (similar to the algorithm technique now used with schedule 2440) was used to screen detection values less than the method detection limit and list them as non-detections. Second, all detections less than 1 ng/L were treated as non-detections. Third, all value qualifier codes from the laboratory were closely examined. The following are examples of how these qualifier codes were used for decision-making purposes.

- Example 1. Detection was below the laboratory reporting limit but above the long term method detection limit, the compound was considered present in the sample but cannot be quantified ("detection").

- Example 2. The value was below the long term method detection limit, the value was treated as a non-detection.
- Example 3. The analyte was detected in the laboratory blank, the blank detection value was compared to the environmental sample value; if the environmental sample detection was >3× the blank detection value then the concentration was reported; if sample detection was <3× the blank detection value then the concentration was treated as a non-detection.

One of the organic compounds analyzed was atrazine, which was also analyzed at a higher detection limit using EPA method 8270 as described on the previous page. Results for atrazine are reported along with the pesticides and pesticide degradates in this report. The remaining 108 compounds are grouped as "pharmaceuticals" in this report.

Microbial Indicators

Samples for microbial indicators were collected in sterile 100-mL bottles supplied by SHL. Sterile, 4-ounce sampling containers were used for all microbial indicator samples; one bottle for each analyte. Samples were kept on ice packs and shipped daily to SHL to allow for analysis within 24 hours of sample collection.

The method performed by SHL for the total coliform and *E. coli* analyses was Standard Method 9223 using the IDEXX Colilert® product. Enterococci analysis was performed using IDEXX Enterolert® reagent. All analyses were reported in most-probable-number (MPN) per 100 milliliters. SHL used EPA Method 1602, a single agar layer procedure, to detect male-specific and somatic coliphages. The quantity of coliphages is expressed in plaque-forming units per 100mL (PFU/100mL). For quality control purposes, both coliphage positive and negative reagent water were analyzed for each type of coliphage with each sample batch. Four field blanks and five field replicate samples were collected and analyzed for microbial indicators during the March – May sampling period.

Viruses and Pathogenic Bacteria

Samples were obtained directly from the wellhead prior to any water treatment following the method of concentration on glass-wool filters of Lambertini et al. (2008). 1000 liters (L) of well water were sampled (with a few exceptions when flow through the filters was unusually slow) using a sampling apparatus as shown in Figure 3. The filtered volume was measured using an in-line flowmeter. For wells with pH levels greater than 7.5, a constant pH of 6.5 – 7.0 was maintained during sampling by using an in-line acid pump supplied with an acid buffer. Field blanks were collected by pumping 19 L of autoclaved tap water through a glass wool filter using decontaminated field equipment. Glass wool filters were shipped overnight to the USGS-ARS laboratory (Marshfield, WI) on ice and processed the day after sampling. Upon receipt at the laboratory, elution of the glass wool filters, extraction of RNA and DNA, and analyses by quantitative polymerase chain reaction (qPCR) proceeded as described in Borchardt et al. (2012). Primers and probes used to quantify specific organisms are listed in Table 3 along with corresponding references.

Sampling equipment blanks were conducted in the field three times during the March-May sampling period. Filter recovery controls were conducted with water from four sampling sites (Appendix C). Inhibition to the PCR assays was measured on every sample and mitigated following the methods described in Borchardt et al. (2012) and Gibson et al. (2012). Negative controls were performed for every batch of PCR analyses including nucleic acid extraction, PCR master mix, and reverse transcription master mix (for RNA viruses). Positive controls for each target also were performed for every batch of analyses. Standard curve efficiencies (equal to $10^{-1/slope}$) and error values indicate highly efficient amplification reactions (perfect amplification would have an efficiency of 2) and accurate quantification (<0.2) as reported in Table 3.

Using the theoretical detection limit of 3 genomic copies per PCR reaction (Wittwer and Kusawaka, 2004), and assuming a 1000-L sample, the calculated limit of detection (LOD) for RNA viruses is 3.1 genomic copies/L, and for DNA targets it is 0.54 genomic copies/L. LOD is defined here as 95% probability of detection. Measured concentrations below the LOD are reported, though the probability of detection is lower.

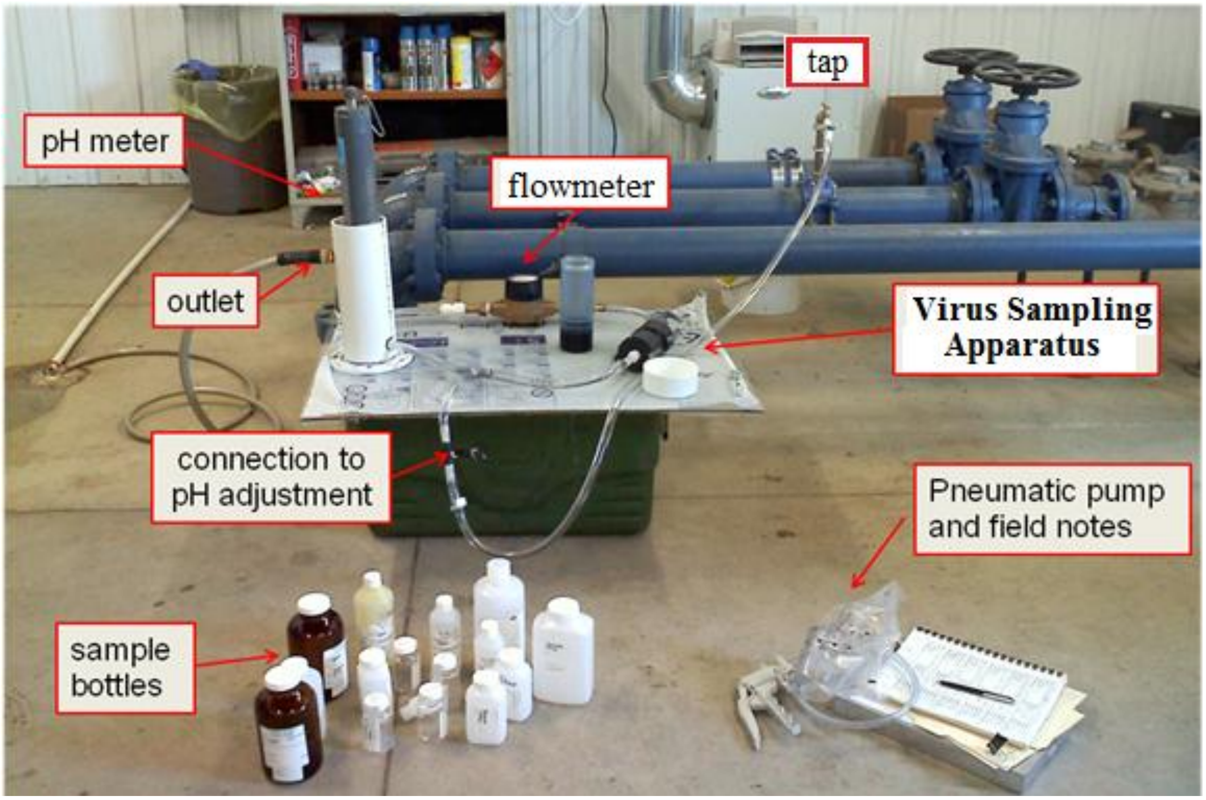

Figure 3. Virus sampling apparatus at one of the study locations (pH adjustment not shown).

Table 3. Targets, citations, and amplicon size in base pairs (bp) for microorganisms quantified by quantitative polymerase chain reaction.

Microorganism	Target	Primer & Probe Citations	Amplicon Size (bp)	Standard Curve Efficiency	Standard Curve Error
Adenovirus Group A	Hexon gene	Kuo et al., 2009	290	1.914	0.0134
Adenovirus Group B	Hexon gene	Kuo et al .,2009	255	1.965	0.0187
Adenovirus Groups C, D, & F	Hexon gene	Kuo et al .,2009	263	1.896	0.118
Enterovirus	UTR region	De Leon et al., 1990; Monpoeho et al., 2000	196	1.912	0.0407
Norovirus Genogroup I	ORF1-ORF2 junction	Jothikumar et al., 2005	95	1.913	0.0225
Norovirus Genogroup II	ORF1-ORF2 junction	Kageyama et al., 2003	97	1.961	0.0279
Human polyomavirus	T antigen	McQuaig et al., 2009	173	1.927	0.0228
Bovine polyomavirus	VP1 gene	Wong and Xagoraraki, 2011	79	1.888	0.00997
Swine hepatitis E	ORF 3 region	Jothikumar et al., 2006; Garson et al., 2012	69	1.95	0.00273
Pepper mild mottle virus	PPMV replication-associated protein	Zhang et al ., 2006	68	1.979	0.0237
Enterohemorrhagic *E. coli*	eae gene	Ibekwe et al., 2004	106	1.926	0.0559
Campylobacter jejuni	mapA gene	Best et al., 2003	95	1.956	0.00686
Salmonella spp.	invA gene	Hoofar et al., 2000	119	1.972	0.0232

Statistical Analyses

Spearman's rank correlation analyses using JMP software (SAS Institute, Cary, NC) were performed to evaluate whether commonly measured analytes could be used as indicators of less frequently assessed contaminants, and to determine whether numerical well characteristics correlated to analyte concentrations. This nonparametric statistical method was chosen because analyte concentrations were rarely normally distributed and often heavily left-censored. This method assumes a monotonic relationship between variables. The closer the absolute values of the resulting Spearman's rho (ρ) coefficients are to 1, the higher degree of correlation. Negative values of ρ denote negative correlations. Results of these analyses were considered significant at $\alpha = 0.05$. Numerical well characteristics included well age (by year constructed), confining layer thickness, well depth, pumping rates, and recent precipitation totals. Given the sample size and the total population of wells in the state, measured concentrations from at least 12 wells (33% of samples) were needed to meet a 95% confidence level standard with a confidence interval of 12%. Four of the analytes selected for correlation analyses were not detected frequently enough to meet this standard (uranium, alachlor ESA, atrazine, and metolachlor OXA); therefore, caution should be used when interpreting those results. For these analyses, concentrations reported as non-detections were assigned values of half the limit of quantitation (Helsel and Hirsch, 2002). Occurrence of individual pharmaceuticals was not sufficient to support correlation analyses, and the more frequently detected pharmaceuticals often were reported only as "detects;" therefore, correlation analyses were done for the number of pharmaceuticals detected per well and for the sum of all pharmaceutical detections. This method has been used previously by Schaider and others (2014). Correlation analyses were also performed for the number of microbial indicators and the number of microorganisms detected by qPCR.

To assist the IDNR's Source Water program with evaluation of risks to wells, relationships between individual contaminant concentrations and occurrence of groups of contaminants were investigated. To determine whether distributions of concentrations of selected parameters differed between pairs of vulnerability classes, Wilcoxon rank sum analyses were performed using JMP software (SAS, NC). For these analyses, non-detections were assigned the value of the limit of detection, with the exception of the pharmaceuticals and atrazine, for which, non-detections were assigned half the method reporting limit, and the value of the method reporting limit was assigned to those samples with confirmed detections below the method reporting limit.

Given the low detection rates for some contaminant groups, the effectiveness of current well vulnerability classification scheme was also evaluated for predicting the presence/absence of groups of contaminants. These analyses were completed using the chi-squared (χ^2) statistic, or the "Fisher Exact Probability" test, when detection frequencies were below five percent. These contingency analyses were completed using the R software package (R Foundation for Statistical Computing, Vienna, Austria). Contaminant groups included nitrate + nitrite, pesticides and pesticide degradates, pharmaceuticals, microbial indicators, and viruses and pathogens by qPCR. As with the numerical correlation analyses, these categorical analyses were considered significant at $\alpha = 0.05$. Wilcoxon rank sum analyses were also performed to determine whether differences between concentrations of surface-derived contaminants could be associated with primary land use around wells classified as highly vulnerable. Land use around a well can have a strong influence on water quality, with both urban and rural settings providing the potential for contaminants to reach groundwater. For this study, primary land use within 1000 ft (305 m) of the well was determined from 2012 satellite imagery (USDA, 2013) and grouped into three categories: developed (urban), grasses, and row crop. These analyses were performed both with non-detections excluded and with non-detections assigned the value of the reporting limit.

HYDROLOGIC CONDITIONS

Numerous studies in Iowa have shown the presence and concentration of contaminants in relatively shallow, vulnerable aquifers often varies with recent recharge conditions (Hallberg et al., 1983; 1984; Libra et al., 1984; 1987; Seigley and Hallberg, 1991). Periods with significant recharge deliver contaminants to groundwater, resulting in generally greater rates of occurrence and/or concentrations. While this is a generality that depends upon the geologic setting and the contaminant type and source (i.e., point vs. nonpoint), the timing and magnitude of recharge events often impact groundwater quality. The Wisconsin virus studies, which included temporal sampling, suggest that this is true for virus occurrence in groundwater as well (Bradbury et al., 2013, Hunt et al., 2010).

Initial planning for this study targeted October-November 2012 for sample collection. However, by late summer severe drought conditions had developed across much of the state and continued into the fall. Figure 4 shows departure from normal precipitation estimates by county for calendar-year 2012. Much of the state was substantially below normal, and in addition, the summer of 2012 was marked by significantly above-average temperatures. In particular, July was the driest and second hottest month on record in Iowa (Iowa State Climatologist, 2013). Soil moisture and hydrologic conditions responded accordingly. Figure 5a shows Iowa's drought status at the beginning of October (Drought Monitor, 2013). As a result of prolonged statewide drought conditions, the sample collection window was moved to March and April of 2013. Conditions improved in late fall and winter, with the greatest improvement in the east. In early March, roughly the northwest half of the state remained in severe to extreme drought, and the southeast half was classified as moderate drought to abnormally dry (Figure 5b). Average precipitation fell in March across much of the state, and April was the wettest April on record, at almost 200% of normal; May continued this trend, and was also the wettest on record (Iowa State Climatologist, 2013). By early May, about 60% of the state was considered to have returned to normal conditions, with only a few of the northwest counties still in severe drought (Figure 5c). The transition from drought to wetter-than-average conditions prompted the re-sampling of five wells for a subset of analytes, including viruses, in June of 2013. The five wells chosen for the resampling were high-vulnerability wells and were selected to provide a wide spatial distribution while accommodating limited staff time and resources.

The wetter conditions during the spring of 2013 generated groundwater recharge. Water levels are monitored continuously in nine shallow wells distributed across the state, as part of a joint Iowa DNR – USGS Iowa Water Science Center monitoring effort. Figure 6 shows the well locations and Figure 7 shows hydrographs for eight of the nine wells from March 1, 2013, through June 20, 2013, based on data extracted from USGS (2013c). Wells in eastern Iowa, such those in Fayette and Hancock counties, show recharge occurred during the sampling period. In contrast, wells in western Iowa (Crawford and O'Brien counties) show little water table response until late in or after the sampling period.

Precipitation estimates for each sampled well location were obtained from the Iowa Mesonet, which utilizes Stage 4 analysis (Iowa Mesonet, 2013). Early in March, snow was present in parts of the state, and snowmelt was not factored into precipitation estimates. Estimated 7-day, 30-day, and 60-day antecedent precipitation totals are included in Appendix A. The 7-day totals varied from 0 to 10.5 centimeters (4.1 in), 30-day totals ranged from 1.75 to 20.2 cm (0.69 to 7.95 in), and 60-day totals ranged from 3.20 to 41.91 cm (1.26 to 16.50 in).

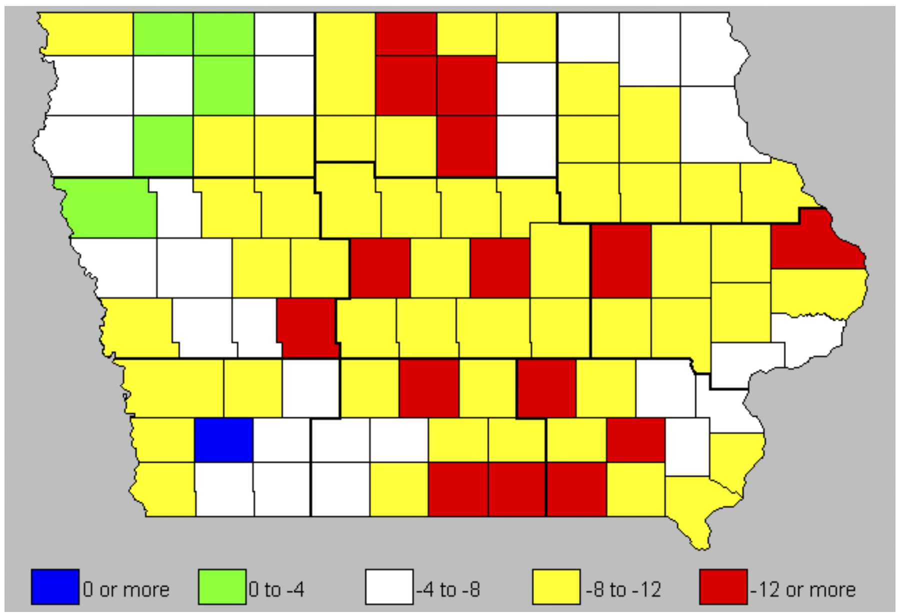

Figure 4. Estimated departure from normal precipitation by county (in inches) for 2012 (Iowa State Climatologist, 2013).

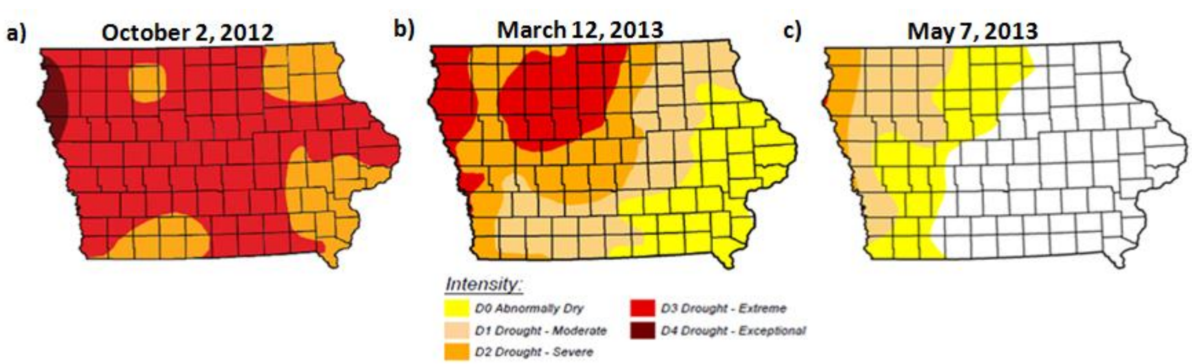

Figure 5. Drought conditions for a) October 2, 2012; b) March 12, 2013; and c) May 7, 2013 (Drought Monitor, 2013).

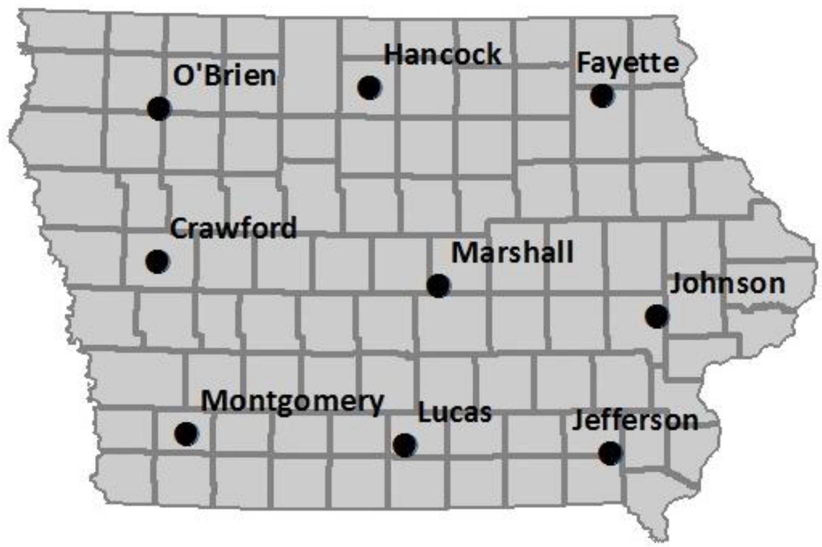

Figure 6. Locations of wells with continuous water-level monitoring as part of joint Iowa DNR – USGS efforts.

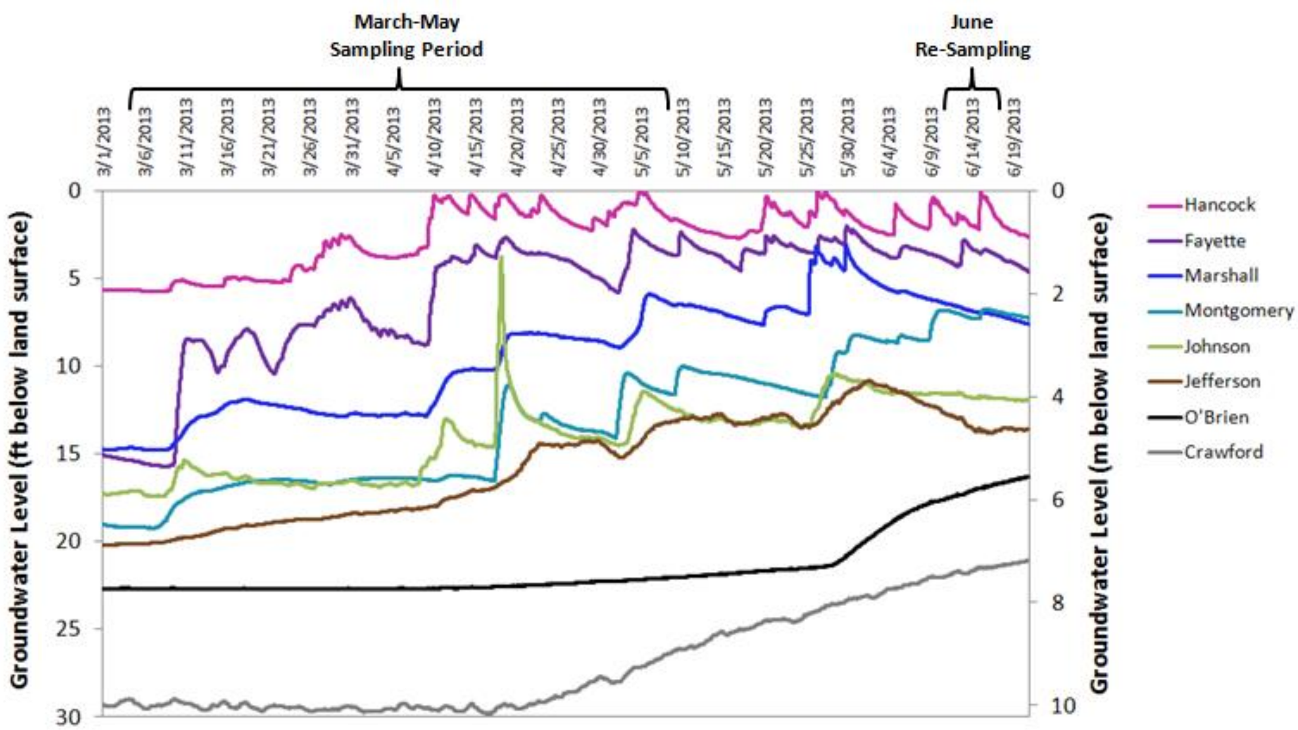

Figure 7. Hydrographs for eight shallow groundwater level monitoring wells across Iowa during the March-May and June 2013 sampling periods (from USGS, 2013c). Water table depths are displayed in feet below the surface on the left axis and meters below the surface on the right.

RESULTS

Results are summarized below by groups of parameters. For a listing of individual sample results, including quality assurance samples, refer to Appendix B.

Tritium, General Water-Quality, Major Ions, and Nutrients

Table 4 summarizes the results of tritium, general water-quality parameters, major ions, and nutrients, with basic statistical parameters and water-quality standards where applicable.

Twenty-three (46%) of 50 samples contained tritium above the 0.8 TU detection limit, with a maximum concentration of 5.5 TU and a median of detections at 4.4 TU. Standard deviations resulting from repeated analyses were reported for each sample and ranged from 0.3 to 0.6 TU. No differences in reported tritium concentrations were shown between laboratory duplicate samples as all of these analyses resulted in non-detections (< 0.8 TU).

Several of the general water quality parameters were detected at low concentrations (close to or at the quantitation limit) in the four field blanks. Total hardness was detected at a concentration of 1 mg/L in one of the four samples. Total alkalinity was detected in two of the four field blanks at concentrations of 2 and 3 mg/L. Total organic carbon was detected at 0.8 mg/L in two of the blanks. One of the blank samples contained 4 mg/L total dissolved solids, and one sample contained 1 mg/L total suspended solids. Of the major ions, only silica and bicarbonate alkalinity were detected in field blanks at 0.12 mg/L and 2 mg/L, respectively. Of the five nutrients, only total phosphorus was detected in the field blanks at a maximum concentration of 0.08 mg/L.

Results of field replicate analyses were generally consistent with those of their counterparts. The largest differences were seen for turbidity (up to 13 NTU), total Kjeldahl nitrogen as N (up to 1.8 mg/L), and orthophosphate as P with a maximum difference of 0.37 mg/L.

General water-quality characteristics of samples are illustrated using a Piper diagram (Figure 8). In general, samples from the Cambrian-Ordovician had higher proportion of sodium (Na) and potassium (K) relative to other aquifers, which contain more calcium (Ca) and magnesium (Mg). Samples from Silurian/Devonian wells generally have more bicarbonate (HCO_3), while Mississippian and Cretaceous (Dakota) wells have higher proportion of sulfate. Samples from both Cambrian-Ordovician and alluvial wells had relatively higher proportions of chloride (Cl) than samples from other aquifers. The chemistry of water drawn from buried sand and gravel aquifers varied widely.

Ammonia was detected in 74% of the wells, while nitrate + nitrite was detected in 26% of the wells. The maximum concentration of ammonia was 6.1 mg/L, which was found in a 170 m (558 ft) deep Silurian-Devonian well with 18 m (60 ft) of confining material. The maximum concentration of nitrate + nitrite (12.0 mg/L) was found in a 32 m (105 ft) deep Silurian well with no confining materials above the aquifer. Nitrate + nitrite concentrations exceeded the drinking-water MCL for nitrate in two of 66 (3%) wells.

Metals

Table 5 summarizes the results of analyses for 19 metals, along with applicable water-quality standards and action levels. Samples were analyzed for four metals that are on the US EPA's CCL and UCMR 3 lists: chromium, cobalt, strontium, and vanadium. Of these, only strontium was detected. While all but one of the samples had detectable levels of strontium, only two of 66 (3%) exceeded the health based screening level of 4 mg/L. Of the 16 metals with current drinking water standards, eight were detected, but only three (arsenic, iron, and manganese) ever exceeded the current standards. As mentioned previously, exceedances of these standards in the sampled wells do not indicate that drinking-water standards were violated in the finished drinking water. No metals were detected in the four field blanks, and results of field replicates were consistent with their counterpart samples.

Table 4. Summary of results for tritium, general water-quality, major ions, and nutrients. Maximum contaminant levels (MCL) and secondary drinking-water standards (2nd Std) are set by the EPA (US EPA, 2013c).

	Analyte	N	% Detect-ions	Quantitation Limit	Units	Minimum	Maximum	Median of Detections	Benchmark Value	Benchmark Type	% Exceed-ances
Age	Tritium	50	46%	0.8	TU	<0.8	5.5	4.4			
General Water Quality	pH	66				6.9	7.7	7.2	6.5 - 8.5	2nd Std	0%
	Conductivity	66	100%	1.0	umho/cm	420	2300	670			
	Total Hardness	64	100%	1.0	mg/L	170	1100	320			
	Total Alkalinity	66	100%	1.0	mg/L	91	1100	280			
	Dissolved Oxygen	66	59%	0.1	mg/L	<0.1	7.4	0.5			
	Total Organic Carbon	66	94%	0.1	mg/L	<0.5	5.0	1.2			
	Total Dissolved Solids	66	100%	1.0	mg/L	250	1970	420	500	2nd Std	33%
	Total Suspended Solids	66	33%	1.0	mg/L	<1.0	46.0	3.5			
	Turbidity	66	61%	1.0	NTU	<1.0	190.0	12.5			
Major Ions	Bromide	66	2%	0.25/0.5	mg/L	<0.25	0.59	0.47			
	Chloride	66	91%	1.0	mg/L	<1.0	230	12.0	250	2nd Std	0%
	Fluoride	66	100%	0.1	mg/L	0.12	3.0	0.43	4.0 2.0	MCL 2nd Std	0% 5%
	Sulfate	66	97%	1.0	mg/L	1.0	970.0	51.5	250	2nd Std	15%
	Silica as SiO2	66	100%	1.0	mg/L	7.4	37.0	15.5			
	Carbonate Alkalinity	66	0%	1.0	mg/L	<1.0	<1.0				
	Bicarbonate Alkalinity	66	100%	1.0	mg/L	91.0	480.0	280.0			
	Calcium (dissolved)	66	100%	1.0	mg/L	34.0	310.0	87.5			
	Magnesium (dissolved)	66	100%	0.5	mg/L	13.0	100.0	28.5			
	Potassium (dissolved)	66	97%	1.0	mg/L	<1.0	36.0	2.8			
	Sodium (dissolved)	66	100%	0.5	mg/L	2.7	280.0	16.5			
Nutrients	Ammonia as N	66	74%	0.05	mg/L	<0.05	6.1	0.64			
	Nitrate + Nitrite as N	65	26%	0.1	mg/L	<0.1	12	5.4	10	MCL*	3%
	Total Kjeldahl Nitrogen as N	66	71%	0.1	mg/L	<0.1	6.4	0.7			
	Orthophosphate as P	66	48%	0.02	mg/L	<0.02	0.78	0.05			
	Total Phosphorus as P	66	85%	0.02	mg/L	<0.02	1.6	0.06			

*Maximum contaminant level (MCL) is for Nitrate as Nitrogen.

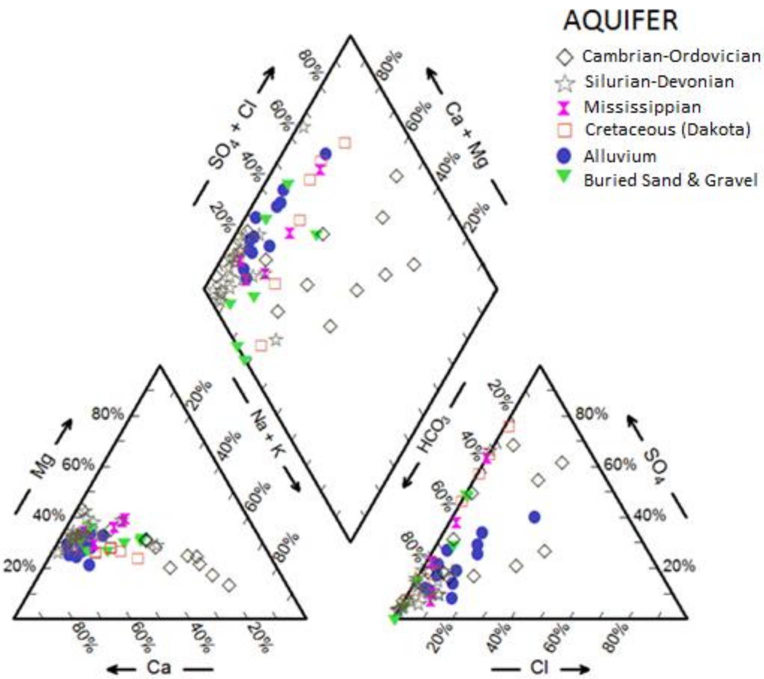

Figure 8. Basic water-quality parameters plotted on a Piper diagram by aquifer.

Table 5. Summary of the results for metal analyses, maximum contaminant levels (MCL), secondary drinking water standards (2nd Std), and action levels (US EPA, 2013c), and health-based screening levels (HBSL) (USGS, 2013b).

				mg/L						
	Analyte	**N**	**% Detect-ions**	**Detection Limit**	**Minimum**	**Maximum**	**Median of Detections**	**Benchmark Value**	**Benchmark Type**	**% Exceed-ances**
Metals (dissolved)	Aluminum	66	0%	0.1	<0.1	<0.1		0.05-0.2	2nd Std	0%
	Antimony	66	0%	0.005	<0.005	<0.005		0.006	MCL	0%
	Arsenic	66	36%	0.001	<0.001	0.033	0.004	0.010	MCL	8%
	Barium	66	67%	0.05	<0.05	1.60	0.14	2	MCL	0%
	Beryllium	66	0%	0.002	<0.002	<0.002		0.004	MCL	0%
	Chromium*†	66	0%	0.01	<0.01	<0.01		0.1	MCL	0%
	Cobalt*†	66	0%	0.05	<0.05	<0.05				
	Copper	66	0%	0.01	<0.01	<0.01		1.3	Action Level	0%
	Iron	66	80%	0.02	<0.02	16.00	0.50	0.3	2nd Std	47%
	Lead	66	3%	0.001	<0.001	0.011	0.007	0.015	MCL	0%
	Manganese	66	50%	0.02	<0.02	1.20	0.09	0.05	2nd Std	0%
	Nickel	66	0%	0.05	<0.05	<0.05		0.1	HBSL	0%
	Selenium	66	5%	0.01	<0.01	0.01	0.01	0.05	MCL	0%
	Strontium*†	66	98%	0.02	<0.02	8.50	0.42	4	HBSL	3%
	Thallium	66	0%	0.001	<0.001	<0.001		0.002	MCL	0%
	Titanium	66	0%	0.05	<0.05	<0.05				
	Uranium	66	21%	0.001	<0.001	0.016	0.003	0.03	MCL	0%
	Vanadium*†	66	0%	0.05	<0.05	<0.05				
	Zinc	66	9%	0.02	<0.02	0.07	0.03	5	2nd Std	0%

Analytes with one or more detections are listed in **bold**
* = analyte on Contaminant Candidate List (US EPA, 2013a)
† = analyte on Unregulated Contaminant Monitoring Rule 3 List (US EPA, 2013b)

Pesticides and Pesticide Degradates

Samples were analyzed for 24 pesticides (herbicides and insecticides), and 11 pesticide degradates as summarized in Table 6. Pesticide compounds were present in 41% of the samples. Of the 24 parent compounds, only atrazine and dimethanamid were detected. Atrazine was not detected above the 0.1 µg/L detection limit reported by SHL, whereas analyses at a detection limit of 0.0194 µg/L, included in the suite of chemicals analyzed by the USGS laboratory in Denver, CO, produced 13% detections. Glyphosate, AMPA, and glufosinate were analyzed in 63 of the 66 wells by USGS using a method with a detection limit of 0.02 µg/L (Meyer et al., 2009). Glyphosate and glufosinate were not present in any samples at or above that concentration, and AMPA was present at the quantitation limit (0.02 µg/L) in two of 63 samples (3%). None of the pesticide compounds were detected in field blanks, and differences between original samples and field replicates were always smaller than the applicable method detection limit.

Pesticide degradate occurrence was higher than that of the parent compounds for pesticides with comparable detection limits. Acetanilide degradate detections included acetochlor ESA (20%), acetochlor OXA (8%), alachlor ESA (29%), alachlor OXA (5%), dimethenamid ESA (2%), metolachlor ESA (41%), and metolachlor OXA (14%). OXA degradates of these acetanilide herbicides generally occurred less frequently than the ESA degradates. None of the pesticides or pesticide degradates exceeded the health based screening levels (HBSLs) (USGS, 2013b), or the maximum contaminant levels (MCLs) or human health benchmarks for pesticides (HHBPs) set by the US EPA (US EPA, 2013c; US EPA, 2014b). Figure 9 illustrates the occurrence and distribution of concentrations for pesticide detections. Metolachlor ESA was both the most frequently detected pesticide and also the pesticide with the highest measured concentrations. All but two samples had pesticide concentrations below 1 μg/L, and medians of the concentrations of positive detections were below 0.1 μg/L, except for metolachlor ESA (0.23 μg/L) and alachlor ESA (0.12 μg/L). Co-occurrence of pesticide compounds (i.e., mixtures of pesticide degradates and parent compounds) was common. Twenty-three of the 27 samples with a pesticide detection had more than one pesticide compound present and as many as 6 chemicals measured in a single sample (Figure 10). Metolachlor ESA was present in all samples with pesticide detections.

Table 6. Summary of results for pesticides and their degradates along with benchmark values where available. Detected compounds are highlighted in bold, and degradates are indented below their parent compound. Health-based screening levels (HBSL) are listed by the U.S. Environmental Protection Agency (US EPA, 2013c; US EPA, 2014b).

				μg/L						
	Analyte	N	% Detections	Detection Limit	Minimum	Maximum	Median of Detections	Benchmark Value	Benchmark Type	% Exceedances
Pesticides and Pesticide Degradates	Acetochlor*	66	0%	0.025	<0.025	<0.025		1	HBSL	0%
	Acetochlor ESA*	66	20%	0.025	<0.025	0.240	0.058	600	HBSL	0%
	Acetochlor OXA*	66	8%	0.025	<0.025	0.290	0.082	200	HBSL	0%
	Alachlor	66	0%	0.025	<0.025	<0.025		2	MCL	0%
	Alachlor ESA*	66	29%	0.025	<0.025	0.780	0.120	100	HBSL	0%
	Alachlor OXA*	66	5%	0.025	<0.025	0.110	0.046	100	HBSL	0%
	Ametryn	66	0%	0.1	<0.1	<0.1				
	Atrazine	66	0%	0.1	<0.1	<0.1		3	MCL	0%
	Atrazine‡	60	13%	0.02	<0.02	0.13	0.04	3	MCL	0%
	Desethyl Atrazine	66	0%	0.1	<0.1	<0.1				
	Deisopropyl Atrazine	66	0%	0.1	<0.1	<0.1				
	Bromacil	66	0%	0.1	<0.1	<0.1				
	Butachlor	66	0%	0.1	<0.1	<0.1				
	Butylate	66	0%	0.1	<0.1	<0.1				
	Carbaryl	66	0%	0.1	<0.1	<0.1		40	HBSL	0%
	Carbofuran	66	0%	0.1	<0.1	<0.1		40	MCL	0%
	Clomazone	66	0%	0.1	<0.1	<0.1		5880	HHBP	0%
	Cyanazine	66	0%	0.1	<0.1	<0.1		1	HBSL	0%
	Dimethenamid	66	2%	0.025	<0.025	0.03	0.03	350	HHBP	0%
	Dimethenamid ESA	66	2%	0.025	<0.025	0.035	0.035			
	Dimethenamid OXA	66	0%	0.025	<0.025	<0.025				
	EPTC	66	0%	0.1	<0.1	<0.1		350	HHBP	0%
	Glyphosate‡	63	0%	0.02	<0.02	<0.02		700	MCL	0%
	Aminomethylphosphonic acid (AMPA)‡	63	3%	0.02	<0.02	0.02	0.02			
	Glufosinate‡	63	0%	0.02	<0.02	<0.02				
	Metolachlor*	66	0%	0.025	<0.025	<0.025		700	HBSL	0%
	Metolachlor ESA*	66	41%	0.025	<0.025	1.200	0.230			
	Metolachlor OXA*	66	14%	0.025	<0.025	0.190	0.059			
	Metribuzin	66	0%	0.1	<0.1	<0.1		90	HBSL	0%
	Pendimethalin	66	0%	0.1	<0.1	<0.1		210	HHBP	0%
	Prometon	66	0%	0.1	<0.1	<0.1		400	HBSL	0%
	Propachlor	66	0%	0.1	<0.1	<0.1				
	Propazine	66	0%	0.1	<0.1	<0.1				
	Simazine	66	0%	0.1	<0.1	<0.1		4	MCL	0%
	Triallate	66	0%	0.1	<0.1	<0.1		175	HHBP	0%
	Trifluralin	66	0%	0.1	<0.1	<0.1				

Analytes with one or more detections are listed in **bold**

* Listed on the US EPA's Contaminant Candidate List (US EPA, 2013a)

‡ Analyzed by the U.S. Geological Survey (all other pesticides analyzed by the State Hygienic Laboratory of Iowa)

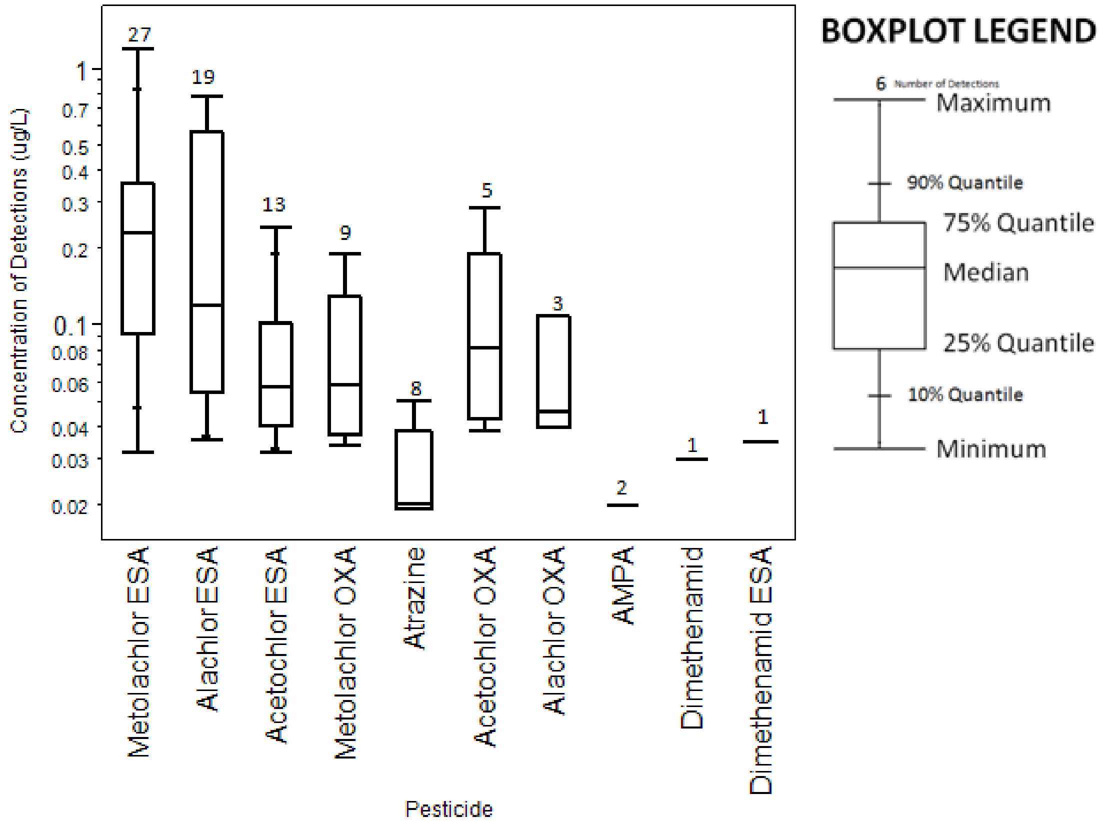

Figure 9. Boxplots representing distributions of concentration for pesticides and pesticide degradates with non-detections excluded. As the legend illustrates, the line inside the box represents the median of the detections, 50% of the data lie within the box, short lines on the whiskers indicate the bounds of 90% of the data, and the numbers of detections are displayed above.

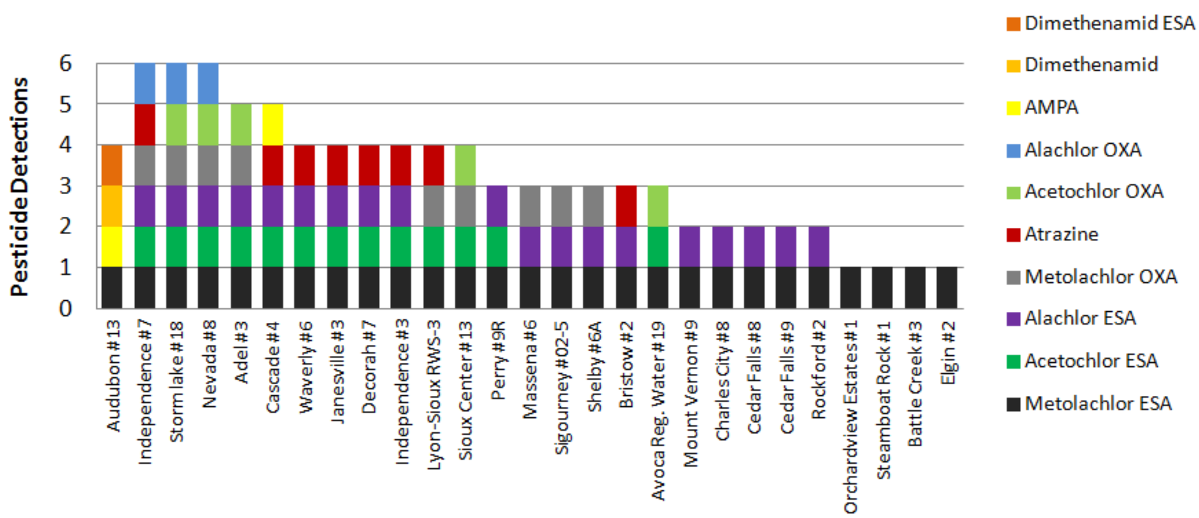

Figure 10. Co-occurrence of pesticide detections by location.

Pharmaceuticals

Samples for pharmaceutical analyses were taken from 60 of the 66 wells during the March-May sampling period. Of the five wells sampled in June, two were obtained for the first time, and three were resampled from wells sampled during the March-May period. A total of 63 samples were collected from 60 wells. Samples were analyzed for 109 individual pharmaceutical compounds. Pharmaceuticals were detected in 22 (35%) of 63 samples, including two wells that had no detections of pharmaceuticals during the March-May sampling, but did have detections during the June sampling period. Table 7 summarizes the results of detected pharmaceuticals and lists their common name or use. A full list of pharmaceutical results can be found in Appendix B.

Table 7. Summary of results for detected pharmaceuticals. Confirmed detections below the method reporting limit are designated by "det." Metabolites are indented under their parent compounds.

	Analyte	N	% Detections	Method Reporting Limit (ng/L)	Minimum (ng/L)	Maximum (ng/L)	Use/Common Name
Pharmaceuticals	acetaminophen	63	2%	7.13	< 7.13	826	analgiesic
	atenolol*	63	2%	13.3	< 13.3	det	hypertension
	caffeine	63	25%	90.7	< 90.7	173	stimulant
	1,7-dimethylxanthine	63	16%	87.7	< 87.7	det	caffeine metabolite
	carisoprodol	63	2%	12.5	< 12.5	det	muscle relaxant
	chlorpheniramine	63	2%	4.68	< 4.68	det	antihistamine
	diphenhydramine	63	3%	5.79	< 5.79	145	antihistamine
	lidocaine	63	8%	15.2	< 15.2	48.6	anesthetic
	nicotine	63	2%	57.8	< 57.8	det	stimulant
	cotinine	63	2%	6.37	< 6.37	det	nicotine metabolite
	sulfamethoxazole	63	2%	26.1	< 26.1	det	antibiotic
	thiabendazole	63	2%	4.1	< 4.1	127	fungicide/parasiticide
	tramadol*	63	2%	15.1	< 15.1	det	narcotic
	warfarin	63	2%	6.03	< 6.03	7.78	anticoagulant

* Atenolol and tramadol were detected during the June resampling period, but not during the March-May sampling period.

Of the 14 pharmaceuticals detected, six had reported concentrations above the method reporting limit, with the maximum reported concentration of any pharmaceutical at 826 ng/L (acetaminophen). Diphenhydramine was the only pharmaceutical to have two detections above the reporting limit, at 24.5 and 145 ng/L. Eight pharmaceuticals had confirmed detections at concentrations below the method reporting limit (reported as "det" in Table 7). Caffeine was the most frequently detected compound (25% detection frequency; maximum concentration 173 ng/L), followed by the caffeine metabolite, 1,7-dimethylxanthine (16% detection frequency) (Figure 11).

Most of the pharmaceuticals detected have specific human uses (1,7-dimethylxanthine, acetaminophen, atenolol, caffeine, carisoprodol, chlorpheniramine, cotinine, diphenhydramine, nicotine, sulfamethoxazole, and tramadol). Some, however, have multiple uses. Thiabendazole has both human pharmaceutical uses (used to treat parasitic worms; Kappagoda et al., 2011) and human commercial uses as a preservative, but it is also commonly used as fungicide, and is increasingly used as a seed coating on soybeans (US EPA, 2002). Warfarin is used as both a rodenticide and as an anticoagulant used in heart medication (US EPA, 1991). Lidocaine is an anesthetic commonly used in anti-itch creams, and there are reports of lidocaine use in cattle operations (Duffield et al., 2010). Multiple pharmaceuticals were detected in 13 (21%) of the 63 samples (Figure 12), with up to four pharmaceuticals present in a single sample. Nine samples had one pharmaceutical detection, including two wells that had detections during the June sampling period, but not the March-May sampling period.

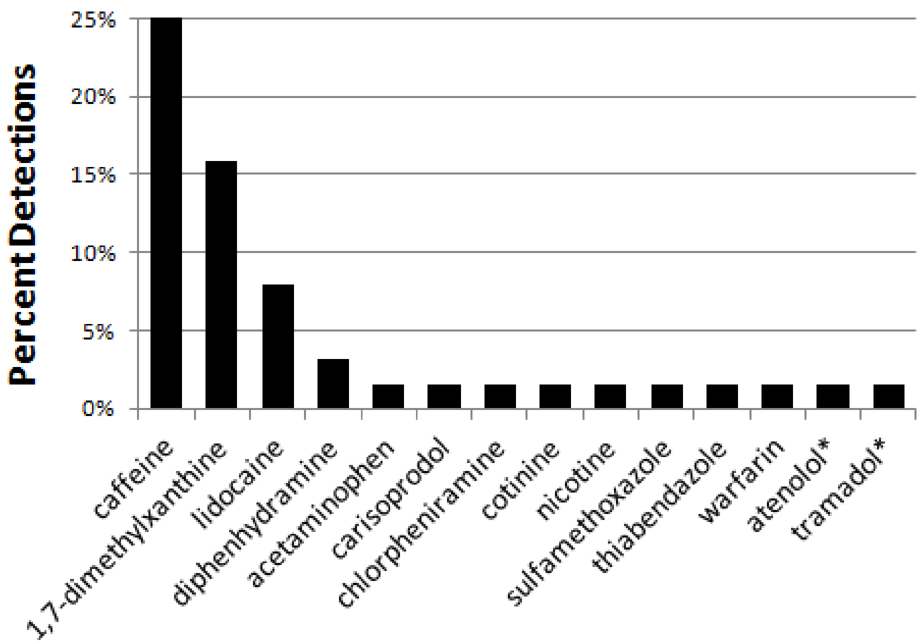

Figure 11. Occurrence of pharmaceuticals detected in study wells. *Atenolol and tramadol were detected during the June resampling period, but not during the March-May sampling period.

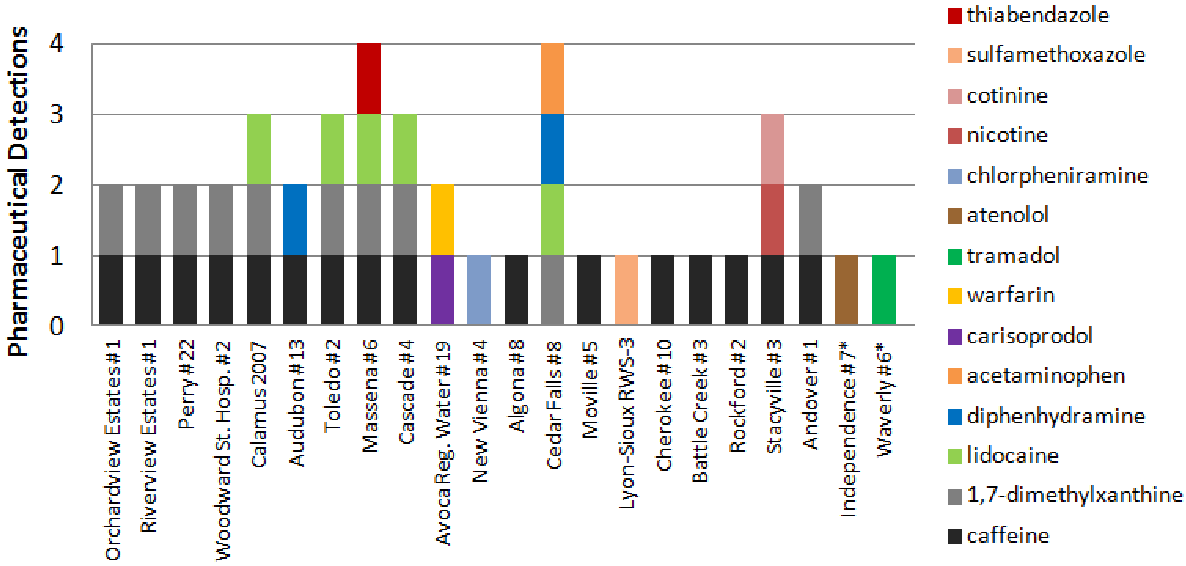

Figure 12. Pharmaceutical occurrence by well in chronological order of sampling. *Indicates communities where the pharmaceuticals were detected during the June resampling period.

Microbial Indicators

Five microbial indicators were analyzed in all 66 samples from the initial sampling period (Table 8). Male specific coliphage and enterococci bacteria were each detected once out of 66 samples (2%) and total coliform bacteria were detected in two of 66 samples (3%) during the initial sampling. During the resampling period, samples were only analyzed for *E. coli*, enterococci, and total coliform. Of the five samples from this period, total coliform bacteria were detected in one sample at a concentration of 4.1 MPN/100 ml. Somatic coliphage and *E. coli* were never detected.

Table 8. Summary of results for microbial indicator analyses. Items listed in bold have one or more detections.

	Analyte	N	% Detect-ions	Detection Limit	Units	Minimum	Maximum
Microbial Indicators	**Coliphage Male Specific**	66	2%	1.0	PFU/100mL	< 1.0	3.0
	Coliphage Somatic	66	0%	1.0	PFU/100mL	< 1.0	< 1.0
	E. coli	66	0%	1.0	MPN/100ml	< 1.0	< 1.0
	Enterococci	66	2%	1.0	MPN/100ml	< 1.0	1.0
	Total Coliform Bacteria	66	3%	1.0	MPN/100ml	< 1.0	1.0*

*Total coliform bacteria were measured at 4.1 MPN/100ml in one sample obtained in June.

Viruses and Pathogenic Bacteria

The results of qPCR analyses for ten virus groups and three human pathogenic bacteria are shown in Table 9. Sample volumes ranged from 392 to 1107 L, with a median value of 1003 L, and a mean of 953 L. Volumes less than 1000 L were obtained from wells when the flow rate through the filter dropped below 4 L per minute. Virus concentrations ranged from 0.46 to 6.38 copies/L. None of the wells had detections of more than one microbial species using qPCR. Fourteen of the 66 samples (21%) from the initial sampling period had viral nucleic acid detections, and only one sample (2%) tested positive for bacterial DNA. Adenoviruses, enteroviruses, GI noroviruses, swine hepatitis E, *Salmonella*, and enterohemorrhagic *E. coli* were not detected in any of the samples. Three wells (5% of samples) were positive for human pathogens; two viruses, the GII norovirus (4.23 copies/L) and human polyomavirus (3.07 copies/L), and one species of bacteria, *Campylobacter jejuni* (0.40 genomic copies/L). One sample (2%) was positive for RNA from the animal pathogen, bovine polyomavirus, at a concentration of 0.46 genomic copies/L. All controls were in compliance; negative controls showed no quantification cycle measure (i.e., zero fluorescence increase) and positive controls had Cq (concentration quantification) values ± 0.5 cycles within their reference controls. No viruses or bacterial pathogens were detected in the three field equipment blanks.

Pepper Mild Mottle Virus (PMMV) was the most prevalent virus, detected in 11 of 66 samples (17%), with a maximum concentration of 6.38 copies/L, and a median of positive detections of 4.28 genomic copies/L. No PMMV or the other microbes were detected in samples collected in June. Of the five resampled wells, two were positive for PMMV during the initial sampling period. There was no co-occurrence of microbial indicators and microorganisms detected by qPCR, with the exception of one well (Janesville #3), where male specific coliphage was detected in the same sample as PMMV (Figure 13).

Recovery controls using poliovirus, *Campylobacter* jejuni, and *Giardia lamblia* spiked into water from four wells yielded percent recovery ranges of 13%-102%, 23%-105%, and 22%-72%, respectively. Given that some matrix recovery rates were below 50% and filter recoveries were usually less than 100%, reported concentrations are conservative estimates.

Table 9. Summary of the results for virus and pathogenic bacteria analyses by qPCR. The theoretical limits of detection (LOD) as defined by Wittwer and Kusawaka (2004) were modified using an assumed sample volume of 1000 L and defined by a 95% probability of detection. Concentrations reported below these LODs have lower probabilities of detection.

	Analyte	N	% Detections	Theoretical Limit of Detection (genomic copies/L)	Maximum Reported Value (genomic copies/L)
Viruses & Pathogens by qPCR	Adenovirus C,D,F	66	0%	3.0	ND
	Adenovirus A	66	0%	3.0	ND
	Adenovirus B	66	0%	3.0	ND
	Enterovirus*†	66	0%	3.0	ND
	GI Norovirus*†	66	0%	3.0	ND
	GII Norovirus*†	66	2%	3.0	4.23
	Human Polyomavirus	66	2%	3.0	3.07
	Hepatitis E Virus	66	0%	3.0	ND
	Bovine Polyomavirus	66	2%	3.0	0.46
	PMMV	66	17%	3.0	6.38
	Campylobacter*	66	2%	0.54	0.40
	Salmonella*	66	0%	0.54	ND
	Enterohemorrhagic *E. coli*	66	0%	0.54	ND

Analytes with one or more detections are listed in **bold**
* = analyte on Contaminant Candidate List (US EPA, 2013a)
† = analyte on Unregulated Contaminant Monitoring Rule 3 List (US EPA, 2013b)

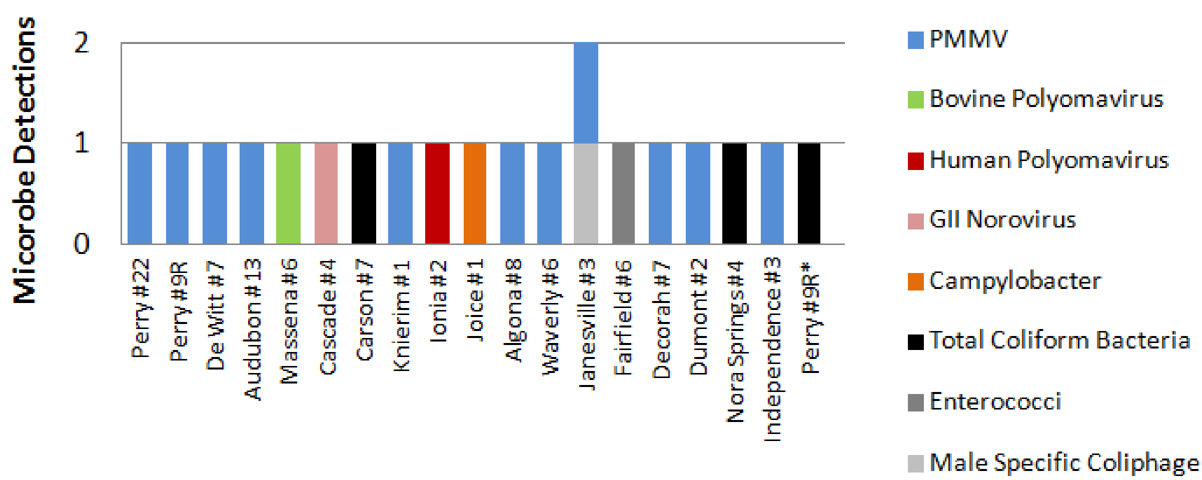

Figure 13. Microbe detections in chronological order of sampling. Well samples and microbes with no detections are not shown. *The asterisk indicates a well sampled during the June resampling period.

Correlations Between Analytes

Spearman's rank correlation analyses between analyte concentrations were performed to determine how commonly measured groundwater-quality parameters relate to each other and to concentrations and/or numbers of CECs. Table 10 displays results of these analyses for selected analytes.

In general, concentrations of surface-derived analytes, including tritium, DO, chloride, nitrate, atrazine, and acetanilide degradates, were positively correlated to each other and negatively correlated to analytes considered to be naturally-derived, such as arsenic and ammonia. All Spearman's rho (ρ) correlation coefficients between tritium concentrations and nitrate + nitrite and pesticides/degradates were greater than 0.05, and significant at $p < 0.001$ or 0.0001. Correlation coefficients between chloride and nitrate + nitrite and pesticides/degradates were less than 0.5, and were generally less significant. None of the commonly measured parameters significantly correlated to CECs with the exception of atrazine, which correlated significantly to concentrations of PMMV and to the number of microbe detections using qPCR.

Strontium was the only metal listed on the UCMR3 list to be detected. Strontium showed a significant positive correlation with TDS, turbidity, fluoride, and ammonia as nitrogen, and significant negative correlations with the surface-indicators: tritium, dissolved oxygen, and nitrate.

Detection frequency of individual microbial indicators was too low to run correlation analyses. Instead, the total number of microbial indicators per sample was used for analysis. No significant correlation was seen between turbidity and the number of microbial indicators tested. The sample with the maximum turbidity value of 190 NTU did have the only reported detection of bovine polyomavirus; however, the reported concentration of this virus was below the theoretical limit of detection.

A closer look at the data confirms the usefulness of certain indicators for predicting whether nitrate and pesticide degradates will be present in raw groundwater. Fifty percent of wells with detectable tritium levels (indicating recent recharge) contained nitrate. Only one well without detectable tritium levels contained nitrate + nitrite (4%). Tritium was an even better predictor of the occurrence of acetanilide degradates, which occurred in 86% of the tritium-positive samples and only 4% of the tritium-negative samples. Combining tritium and DO revealed even stronger prediction of occurrence of these contaminants. One hundred percent of oxic (>0.5 mg/L DO) wells with detectable tritium contained detectable levels of both nitrate + nitrite and pesticide degradates. Only two (17%) of the 12 anoxic tritium-positive samples contained nitrate + nitrite, and these were the only two samples where ammonia and nitrate + nitrite co-occurred.

Redox conditions are also likely to play an important role in determining whether or not dissolved arsenic is present in samples. As shown in Figure 14, the five samples that exceeded the MCL for arsenic occurred in anoxic waters (less than 0.5 mg/L dissolved oxygen).

Table 10. Spearman's rho correlation coefficients resulting from one-to-one correlation analyses between analyte concentrations and detection counts for select contaminant groups.

	Analyte or Analyte Group	Tritium	pH	TOC	TDS	TSS	Turbidity	DO	Cl	F	NH_4-N	NO_x-N	PO_4-P	As	ATZ
General WQ, Ions, & Nutrients	pH	-0.16													
	Total Organic Carbon (TOC)	-0.06	-0.28												
	Total Dissolved Solids (TDS)	-0.26	-0.33*	0.31											
	Total Suspended Solids (TSS)	0.09	-0.29	0.57***	0.29										
	Turbidity	-0.16	-0.20	0.56***	0.27	0.79***									
	Dissolved Oxygen (DO)	0.22	0.05	-0.26	-0.08	-0.44**	-0.59***								
	Chloride (Cl)	0.49**	-0.03	-0.12	0.22	-0.07	-0.15	0.19							
	Fluoride (F)	-0.45*	-0.47	0.23	0.41**	0.07	0.27	-0.27	-0.10						
	Ammonia as N (NH_4-N)	-0.62***	0.03	0.55***	0.45**	0.42**	0.60***	-0.50***	-0.23	0.53***					
	Nitrate + Nitrite as N (NO_x-N)	0.58***	0.05	-0.26	-0.12	-0.29	-0.51***	0.63***	0.27	-0.52***	-0.60***				
	Orthophosphate as P (PO_4-P)	0.14	0.01	0.45**	0.09	0.42**	0.36*	-0.11	0.03	-0.24	0.07	0.15			
Metals	Arsenic (As)	0.07	-0.14	0.45**	0.01	0.66***	0.66***	-0.44**	-0.20	0.12	0.29	-0.34*	0.24		
	Barium	0.24	-0.06	0.21	-0.48***	0.16	0.09	-0.10	-0.21	-0.33*	-0.16	0.11	0.30	0.20	0.20
	Iron	-0.16	-0.12	0.50***	0.22	0.80***	0.92***	-0.64***	-0.11	0.28	0.58***	-0.56***	0.37*	0.65***	0.65***
	Manganese	0.19	-0.40**	0.43**	0.20	0.75***	0.60***	-0.34*	-0.09	-0.08	0.15	-0.17	0.50***	0.58***	0.58***
	Strontium	-0.60***	0.01	0.23	0.56***	0.14	0.32*	-0.38*	-0.06	0.81***	0.69***	-0.50***	-0.13	0.01	0.01
	Uranium	0.39*	-0.42**	0.08	0.22	0.10	-0.13	0.26	0.17	-0.15	0.33*	0.39*	0.19	0.08	0.08
Pesticides & Degs	Atrazine (ATZ)	0.59***	0.14	-0.29	-0.18	-0.24	-0.36*	0.38*	0.30	-0.50***	-0.43**	0.51***	-0.14	-0.23	
	Acetochlor ESA	0.72***	-0.07	0.07	0.00	0.14	-0.06	0.16	0.47***	-0.35*	-0.35*	0.34*	0.09	-0.01	0.60***
	Alachlor ESA	0.70***	0.07	-0.16	-0.39*	0.09	-0.04	0.02	0.26	-0.45**	-0.38*	0.28	-0.05	0.09	0.56***
	Metolachlor ESA	0.86***	-0.02	-0.04	-0.31	0.03	-0.19	0.27	0.43**	-0.45**	-0.53***	0.53***	0.10	-0.02	0.47**
	Metolachlor OXA	0.51**	-0.25	0.27	0.03	0.38*	0.25	-0.21	0.36*	-0.16	-0.03	0.07	0.31	0.24	0.12
	Sum of acetanilide metabolites	0.86***	0.00	-0.07	-0.32*	0.04	-0.19	0.24	0.43**	-0.48***	-0.54***	0.51***	0.08	-0.01	0.51***
	Number of pesticide detections	0.88***	-0.03	-0.07	-0.30	0.05	-0.18	0.23	0.45**	-0.49***	-0.54***	0.51***	0.11	0.00	0.57***
	Number of microbial indicators	-0.13	0.07	0.00	0.01	-0.10	-0.19	0.11	0.12	0.05	0.04	0.03	-0.01	-0.19	0.08
CECs	Pepper mild mottle virus (PMMV)	0.20	0.10	0.03	0.09	0.01	0.01	0.08	0.09	-0.16	-0.11	0.16	0.02	-0.04	0.32
	Number of microbe detections	0.15	0.00	0.09	-0.03	0.04	0.06	0.14	0.03	-0.23	-0.11	0.15	0.03	0.03	0.38*
	Sum of pharmaceuticals	-0.04	-0.05	-0.03	-0.08	-0.10	-0.03	-0.01	-0.01	0.05	-0.02	-0.02	0.01	0.03	-0.09
	Number of pharmaceuticals	0.00	-0.03	-0.01	-0.11	-0.09	-0.02	0.00	0.00	0.07	-0.03	-0.02	0.02	0.04	-0.08

Items in bold and shaded in gray are significant at P<0.05, *P<0.01, **P<0.001, ***P<0.0001

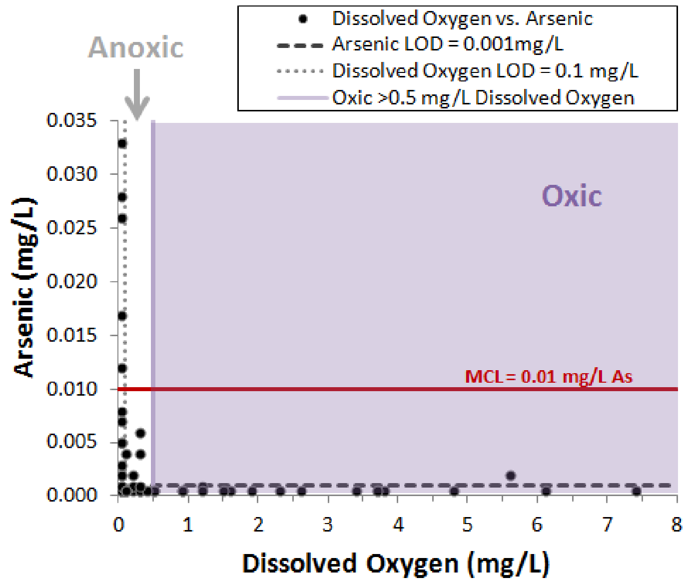

Figure 14. Dissolved oxygen concentrations vs. arsenic concentrations for study wells. Dashed and dotted lines indicate limits of detection (LOD) for dissolved oxygen and arsenic, respectively.

Relationships Between Well Characteristics and Contaminants

Numerical and contingency analyses were performed to determine whether characteristics of each well, or conditions around the well, could be used to predict well water quality. The results of Spearman's rank correlation analyses for numerical well characteristics and measured concentrations of selected analytes are presented in Table 11. Significant negative correlations indicate that as confining layer thickness increases, concentrations of surface-derived analytes, including tritium, nitrate + nitrite, orthophosphate, total phosphorus, atrazine, and the sum of acetanilide degradates, tend to decrease. Conversely, significant positive correlations show that as confining layer thickness increases, concentrations of naturally derived analytes, including ammonia and strontium, tend to increase. Similar results were seen for well depth, although orthophosphate, total phosphorus, barium, and manganese showed stronger negative correlations with well depth than with confining layer thickness. Results indicate that more recently drilled wells had lower concentrations of nitrate + nitrite and atrazine, but higher turbidity, iron, and manganese values. Higher pumping rates were significantly positively correlate to some, but not all indicators of surface influence, including tritium, chloride, and two of the acetanilide degradates. None of the well characteristics showed significant correlation with PMMV concentrations, the number of microbial indicators, the total number of microbes detected by qPCR, the sum of pharmaceutical concentrations, or the number of pharmaceutical detections. Negative correlations were observed between the antecedent precipitation estimates and a variety of both natural and surface-derived water-quality parameters.

Testing the Vulnerability Classification Scheme

A major objective of this study was to test whether the vulnerability classes (low, intermediate, and high), as defined by confining layer thickness, effectively predicted surface-related contamination, including CECs.

Significant differences were seen for concentrations of tritium and nitrate + nitrite in high vulnerability wells compared to low and intermediate vulnerability wells (Figure 15). Statistical differences between vulnerability classes were not seen for DO concentrations; however, the median DO value was higher (1.5 mg/L) for the high vulnerability class compared to the intermediate (0.5 mg/L) and low (0.3 mg/L) vulnerability classes. Ammonia concentrations were significantly higher in low vulnerability wells than in intermediate or high vulnerability wells.

Results of the contingency analysis showed significant differences ($p < 0.001$) in detection frequencies between vulnerability classes for both nitrate + nitrite and the pesticide and degradates group (Figure 16). Differences between vulnerability categories were not significant for microbial indicators, pharmaceuticals, or the viruses and bacterial pathogens group.

Statistical analysis revealed significantly higher concentrations of four of the five most commonly detected pesticides/degradates in high vulnerability wells compared to intermediate and low vulnerability wells, and no differences between low and intermediate vulnerability wells (Figure 17). Metolachlor OXA showed significantly higher concentrations in high vulnerability wells than low vulnerability wells.

Table 11. Spearman's correlation coefficient (rho) for selected water-quality parameters vs. numerical well characteristics and antecedent 7-, 30-, and 60-day precipitation totals.

		Well Characteristics				Antecedent Precipitation		
	Analytes and Analyte Groups	Confining Layer Thickness	Depth	Age (Year Drilled)	Pumping Rate	7-Day	30-Day	60-Day
	Tritium	**-0.69*** **	**-0.72*** **	-0.11	**0.26**	0.04	-0.09	-0.06
General Water Quality	pH	0.03	0.21	-0.20	0.19	0.01	0.23	**0.35***
	Total Hardness	0.19	-0.03	-0.13	-0.08	-0.15	**-0.39***	**-0.39***
	Total Alkalinity	**0.27**	-0.02	-0.03	-0.19	-0.06	**-0.39***	**-0.42***
	Total Organic Carbon	0.11	**-0.28**	0.18	-0.09	**-0.25**	**-0.58*** **	**-0.62*** **
	Turbidity	0.02	-0.14	**0.31**	0.02	0.15	-0.22	-0.21
	Dissolved Oxygen	-0.13	-0.06	-0.18	-0.14	-0.22	-0.03	-0.04
	Chloride	-0.19	-0.11	0.01	**0.29**	-0.09	-0.07	-0.03
Nutrients	Ammonia as N	**0.60*** **	**0.33***	0.15	0.02	0.09	0.01	-0.05
	Nitrate + Nitrite as N	**-0.49*** **	**-0.41** **	**-0.35***	0.12	-0.05	-0.06	-0.01
	Total Kjeldahl Nitrogen	**0.48*** **	0.17	0.09	0.02	0.02	-0.07	-0.12
	Orthophosphate as P	**-0.25**	**-0.49*** **	-0.07	-0.12	-0.04	**-0.41** **	**-0.39***
	Total Phosphorus	**-0.26**	**-0.52*** **	0.00	-0.02	0.15	**-0.25**	-0.22
Metals	Arsenic	0.14	**-0.29**	0.12	0.09	0.06	**-0.24**	-0.20
	Barium	**-0.33***	**-0.44** **	0.09	-0.04	0.08	-0.03	-0.05
	Iron	0.19	-0.13	**0.30**	0.00	0.16	-0.17	-0.14
	Manganese	-0.14	**-0.55*** **	**0.28**	-0.08	0.15	**-0.46** **	**-0.42** **
	Strontium	**0.62*** **	**0.42** **	0.14	0.04	-0.01	0.12	0.02
	Uranium	**-0.32***	**-0.31**	-0.08	-0.04	0.00	**-0.35***	**-0.32***
Pesticides	Atrazine	**-0.37***	-0.20	**-0.25**	0.20	-0.11	-0.02	0.05
	Acetochlor ESA	**-0.53*** **	**-0.46** **	0.01	**0.31**	-0.15	**-0.30**	**-0.28**
	Alachlor ESA	**-0.45** **	**-0.35***	-0.04	**0.37***	-0.02	0.04	0.08
	Metolachlor ESA	**-0.64*** **	**-0.58*** **	-0.12	0.24	-0.07	-0.10	-0.04
	Metolachlor OXA	**-0.31**	**-0.46*** **	0.18	0.16	0.07	**-0.25**	-0.20
	Sum of acetanilide metabolites	**-0.64*** **	**-0.56*** **	-0.11	**0.27**	-0.06	-0.09	-0.04
	Number of pesticides	**-0.64*** **	**-0.60*** **	-0.10	0.22	-0.02	-0.11	-0.06
	Number of microbial indicators	0.04	0.04	0.17	0.01	-0.19	0.02	-0.01
CECs	PMMV	-0.15	-0.21	-0.09	0.06	-0.10	-0.13	-0.09
	Number of microbes detected by qPCR	-0.18	-0.11	0.00	0.09	-0.09	-0.09	-0.13
	Number of pharmaceuticals	0.02	-0.08	0.03	-0.10	-0.01	-0.06	-0.14
	Sum of pharmaceuticals	0.04	-0.05	-0.01	-0.09	-0.01	-0.09	-0.14

Items in bold with gray shading are significant at P<0.05, *P<0.01, **P<0.001, ***P<0.0001

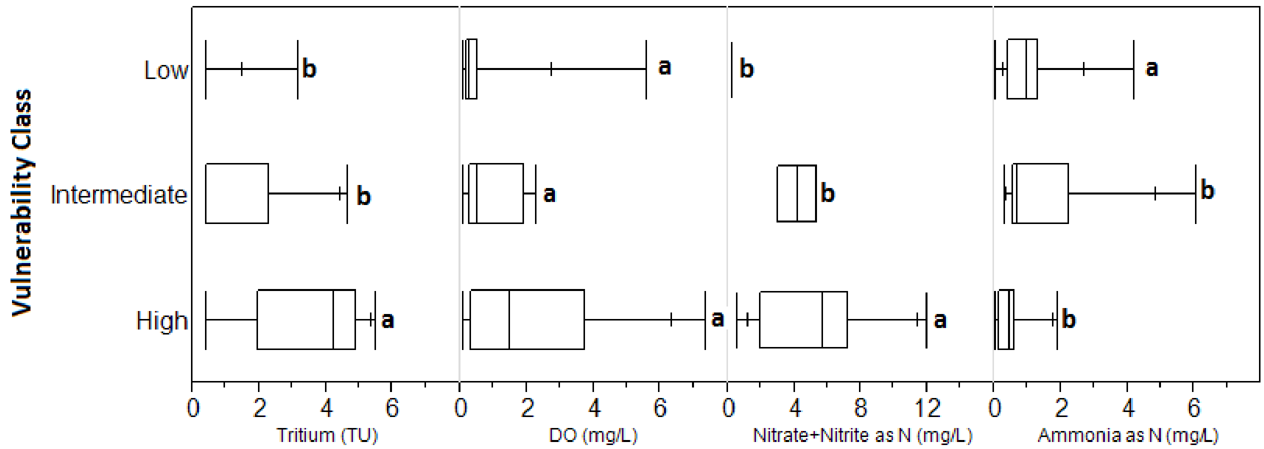

Figure 15. Boxplots representing distributions of concentrations of common water-quality parameters. Letters indicate significant differences between well vulnerability classes.

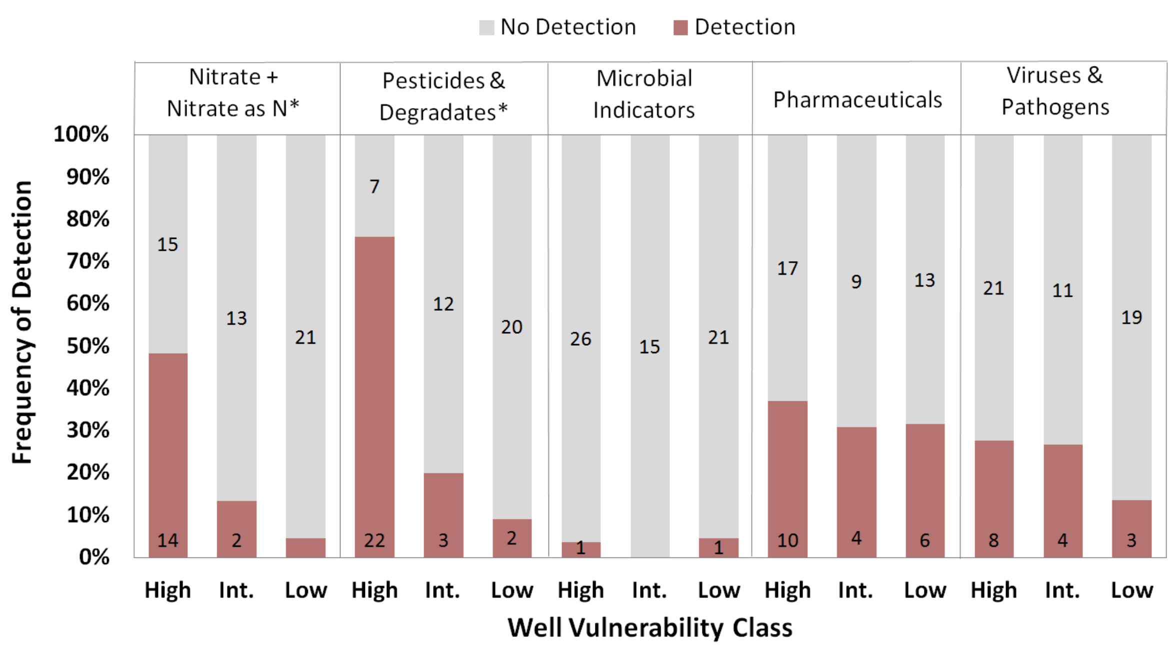

Figure 16. Graph of detection frequencies of contaminant groups by well vulnerability classes. Numbers of detections are located within the columns. *Asterisks indicate contaminant groups for which differences between vulnerability classes are significant.

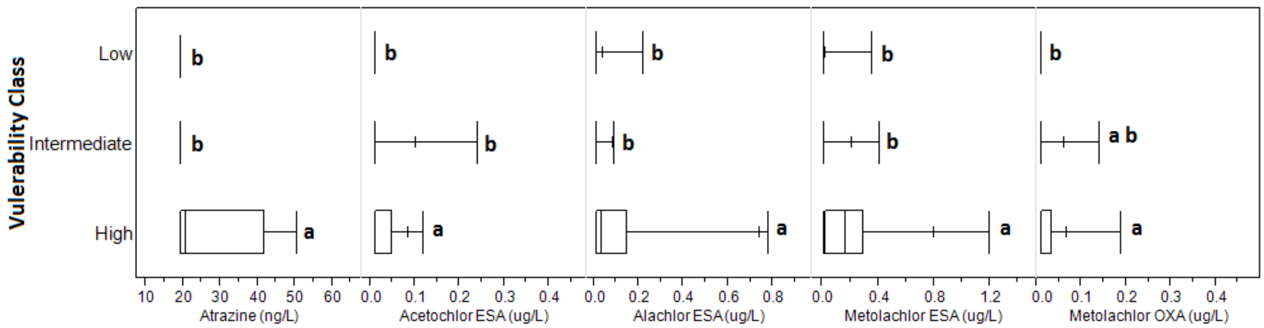

Figure 17. Boxplots representing distributions of the five most commonly detected pesticides/degradates by well vulnerability class. Letters indicate differences between classes as determined by Wilcoxon rank sum analyses.

Further examination of results from high vulnerability wells was conducted to determine whether concentrations of surface-derived contaminants could be associated with nearby land use. These analyses were limited to nitrate and the five most commonly detected pesticides/degradates due to the low detection rates of other contaminant groups. Figure 18 shows the results of these analyses with non-detections excluded; however, the same statistical differences were seen when the analyses included non-detections. Highly vulnerable wells surrounded by grasses had significantly lower nitrate + nitrite concentrations than those in developed areas or areas surrounded by row crop. While the differences were not significant due to low detection frequencies, the median and maximum atrazine concentrations were higher in wells surrounded by developed and grassy areas, than for wells surrounded mostly by row crops. The highest median observed concentration of acetochlor ESA was associated with grassed areas. Wells in developed areas contained significantly higher concentrations of alachlor ESA. No significant differences were observed between land use categories for metolachlor ESA, the most commonly detected pesticide degradate. Although the differences were not significant, it appears that metolachlor OXA occurred at lower concentrations in wells surrounded by developed land than the other land uses.

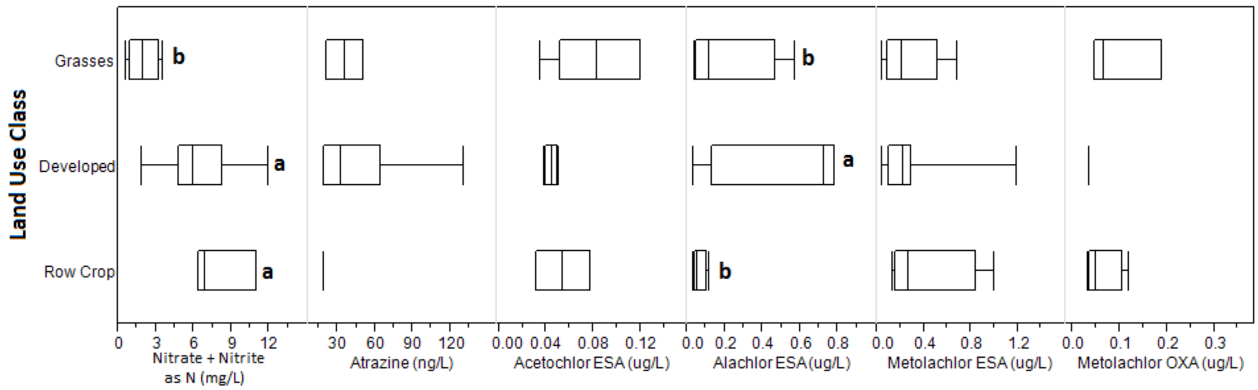

Figure 18. Boxplots representing distributions of detected concentrations of nitrate and the five most commonly detected pesticides/degradates in samples from high vulnerability wells by land use class. Lettering indicates differences between classes as determined by Wilcoxon rank sum analyses with non-detections excluded. Where no letters are displayed, no significant differences were found.

DISCUSSION

The results of this 2013 survey provide a baseline for evaluation of CECs in Iowa's groundwater. In addition, these results expand our understanding of water-quality parameters and contaminants that have previously been studied.

Tritium concentrations found in this study were within a reasonable range, given other recent tritium analyses of readily recharged groundwater and surface water in Iowa (Schilling and Tassier-Surine, 2006; Fields et al., 2012) and southern Wisconsin (Bradbury et al., 2010). These recent studies suggest that precipitation entering groundwater systems in the area currently contain 5-10 TU. Interpretations of tritium concentrations must consider that groundwater can be a mixture of waters of various ages. Groundwater containing as much as 15% post-1953 recharge may not have detectable tritium at the detection limit used in the current study. In general, highly vulnerable wells had younger water than the intermediate and low vulnerability wells, as determined by tritium content; thus, the vulnerability classification serves as a reasonably reliable water age predictor. The detection of tritium in a few individual wells classified as low vulnerability suggests that additional investigation of the hydrogeology surrounding these wells may be necessary. If the tritium analysis had a lower quantitation limit, differentiation between estimated ages of water in intermediate and low vulnerability wells may have been improved.

Continued assessment of nitrate concentrations in Iowa's drinking-water sources is imperative in order to meet drinking water standards aimed at protecting the health of infants, and to assess additional public health risks (Ward et al, 2005). Comparison between the results of this study and previous groundwater surveys are difficult because of differences in analytes, analytical methods, limits of quantitation, and well selection protocols; nevertheless, these comparisons help us assess risk and are useful for informing future investigations. For example, both occurrence and concentrations of nitrate + nitrite as N measured in this study were lower than levels of nitrate as N found in the SWRL2 study of private wells. The frequency of detection of nitrate in the SWRL2 study was 49% (CHEEC, 2009) compared to 26% in this study. The maximum concentration of nitrate found in SWRL2 was 63 mg/L nitrate as N (CHEEC, 2009), whereas the maximum for this study was 12 mg/L. Although nitrate + nitrite (as N) was measured for this study, and only nitrate (as N) was measured for the SWRL study, the values for these two tests should be comparable in an aquatic environment.

Like nitrate, bacterial indicators of surface-related contamination were found less frequently in this study than in SWRL2. *E. coli* were not detected in any wells in this study, whereas they were found in 11% of wells in SWRL2 (CHEEC, 2009). Enterococci bacteria were found in 2% of the wells in this study, compared to 19% of SWRL2 wells (CHEEC, 2009). These differences do not necessarily indicate an improvement in statewide groundwater quality, but could result from differences between the populations of wells sampled, including the locations, construction methods, age, maintenance status, or source-water protection activities.

Both this 2013 study and SWRL2 report 8% of wells in exceedance of 0.010 mg/L arsenic, a naturally-derived contaminant. The IGWM network, which includes arsenic analyses for 2,289 samples of raw public well groundwater, shows 10% exceedance of the arsenic MCL (Libra, 2011). As shown in Figure 14, redox conditions (as indicated by DO concentrations) play an important role in determining whether arsenic will be present in groundwater samples. Many others have also documented the effects of redox conditions on arsenic mobility. For example, Gotkowitz et al. (2004) documented sources of arsenic and differences between the effects of redox conditions on arsenic mobility within the aquifer and the borehole. Additional work is necessary to better understand the relationships between geologic formations, redox conditions, and arsenic occurrence in groundwater, and to determine if other arsenic hotspots exist, like the area in Cerro Gordo County, recently documented by Schnoebelen and Walsh (2014). The current IGWM network averages less than one well per county, which is insufficient to identify localized areas with high concentrations of arsenic in groundwater.

In a study of agricultural chemicals in 1,019 public water supply wells in Iowa, atrazine, alachlor, cyanazine, and metolachlor detection frequenciesof 13.2%, 3.3%, 4.1%, and 14.1%, respectively for the period from 1992-1995 at the detection limit of 0.1 μg/L

(Kolpin et al., 1997b). Since this previous study, cyanazine has been voluntarily removed from the market, alachlor is in the process of being replaced with acetochlor, and metolachlor had a change in formulation, which resulted in lower rates per acre being applied. Data from Iowa indicate reductions in annual use of these pesticides from 1992-2011 (USGS, 2013a). Our study found a 13% detection frequency for atrazine at a lower detection limit (0.01 µg/L). Cyanazine was not detected at the 0.01 µg/L detection limit, and neither alachlor or metolachlor were detected at 0.025 µg/L. Our results indicate a possible reduction in risks from these four compounds; however, differences in sample populations and timing between these studies indicates that caution is necessary when drawing comparisons. Interpretation of these results should also take into consideration seasonal variations in pesticide applications. For this study, samples were taken in late winter, prior to the typical application period for pre- and post-emergent herbicides. Monitoring of shallower, typically more susceptible, private wells has shown atrazine detections from 8-19% of the wells sampled, at a detection limit of 0.1 µg/L (Kross et al., 1990; Iowa DNR, 2004; CHEEC, 2009).

As with previous studies (Kolpin et al., 1996; 1997a), pesticide degradate occurrence was higher than that of the parent compounds for pesticides with comparable detection limits. In this study, the three most commonly detected pesticides degradates were metolachlor ESA (41%), alachlor ESA (29%), and acetochlor ESA (20%). OXA degradates of these acetanilide herbicides generally occurred less frequently than the ESA degradates. Testing on human health effects indicates that acetanilide herbicide degradates may be less potent than their parent compounds (Gadagbui et al., 2010); however, studies are limited and complicated by the potential for synergistic effects of contaminant mixtures (Toccalino et al. 2012). Drinking water standards for individual degradates or mixtures may be assigned in the future (US EPA, 2014b). Continued monitoring of vulnerable groundwater supplies for these contaminants should be a priority.

Over a decade has passed since Kolpin et al. (2004) reported no detections of glyphosate or AMPA in 86 Iowa raw PWS well samples. In a more recent nationwide study that included groundwater samples from Iowa, 5.8% of over 1,171 samples had detections of glyphosate and 14.3% had detections of AMPA (Battaglin et al., 2014). Despite increased usage and sales, glyphosate remained undetected in this 2013 Iowa study, suggesting that under drought or post-drought conditions, the risks of glyphosate reaching and/or persisting in groundwater is low. AMPA was found in 2 (3%) of the samples at the limit of quantitation (0.02 µg/L). It is possible that the AMPA was detected more frequently than glyphosate because it persists in soils for slightly longer than its parent compound, glyphosate (Bergstrom et al., 2011); however, glyphosate is not the only potential source of AMPA. AMPA can also be formed from the breakdown of phosphonic acids, such as those found in cleaning products (Skark et al., 1998). Additional groundwater monitoring shortly after application and/or during wetter periods would be necessary to fully understand potential risks from these compounds.

Studies in Wisconsin showed virus detection rates of 20 to 40% during normal-to-wet weather (Bradbury et al., 2013), with detections dropping to 2 to 4% during or following very dry periods (Gotkowitz et al., 2014). Excluding the results of PMMV analyses in this study, which were not included in the studies in Wisconsin, our results are consistent with their results during very dry periods. Variations in the levels of viruses in wastewater sources could also play a role. Shedding of enteric viruses, for example, often varies seasonally in human and animal wastes. Communities generally have a higher incidence of enterovirus circulating in late summer months and early autumn and infections are more common in these months (Nelson et al., 1979). Norovirus infections tend to be more frequent in late summer and early autumn as well (Rohayem, 2009). It is also possible that the population of wells selected for this study may be less vulnerable or less prone to preferential flow than the wells studied in Wisconsin. No significant correlations were observed between 7-day, 30-day, or 60-day antecedent rainfall estimates and virus occurrence. Further study is needed to better establish the relationship between climate, subsurface conditions, and virus occurrence in groundwater.

The detection frequency of PMMV in this study (17%) was relatively high compared to all other viruses, pathogenic bacteria, and microbial indicators. PMMV has been reported to be present at consistently high concentrations in human wastewater influent and effluent and has been suggested as a promising indicator for human enteric viruses in aquatic environments (Kitajima et al., 2014). Future studies are needed to understand why PMMV was detected far more than all the other enteric viruses in this study and determine the source(s) of these viruses, such as wastewater treatment effluents or leaking sanitary sewers as described by Davison et al. (2013). It should be noted that there is currently no direct evidence of PMMV human infections, although one study found an association between PMMV ingestion and itching, abdominal pain, and fever, which the authors concede could have been caused by confounding factors, such as eating spicy food (Colson et al., 2010). Atrazine was the only commonly analyzed parameter that correlated significantly to PMMV concentrations and to the number of microbe detections by qPCR. Confidence in these correlation is low given that both atrazine and the microbes detected by qPCR occurred in less than one-third of the samples. Further investigation revealed that four of the 11 PMMV-positive samples contained detectable concentrations of atrazine.

The frequency of detection of one or more pharmaceutical compounds in untreated groundwater in this study (35%) was greater than reported by a California study (2.3%; Fram and Belitz, 2011) but less than a national study of susceptible groundwater (81%; Barnes et al., 2008). The most commonly detected pharmaceutical in this study was caffeine (25%), which is a higher detection frequency than reported by Barnes et al. (2008) for untreated public water supply wells. In a study targeting vulnerable wells in urbanized areas of Minnesota by Erickson et al. (2014), the antibiotic sulfamethoxazole was the most commonly detected pharmaceutical (11.4% greater than 5 ng/L), while caffeine was only detected once (<1% of samples above 60 ng/L). Whereas our study targeted only public water supply wells, the Minnesota study included monitoring wells, three of which were in close proximity to landfills, and one of these had 10 CEC detections in a single well (Erickson et al., 2014).

Analyses revealed significant correlations between nitrate + nitrite, atrazine, several pesticide degradate compounds, and tritium (a measure of relative water age), and to a less degree, chloride. However, none of the commonly measured water-quality parameters were good predictors of CEC concentrations. Additionally, the well vulnerability categories are good predictors of the occurrence of nitrate + nitrite and pesticide degradates, but no differences between microbial or pharmaceutical occurrence were found between well vulnerability classes. Larger sample size, or different hydrological conditions, could result in more significant results if detection rates are increased. Results of analysis of alachlor ESA concentrations in high vulnerability wells by land use suggests greater use of alachlor in developed areas, but it is also possible that characteristics of the subsurface control the fate and transport of this compound: the four wells with highest alachlor ESA concentrations are within a limited geographical region (~35 miles) dominated by karst.

Our analyses showed no correlation between pharmaceutical data and any of the physical well characteristics, land use, precipitation values, or commonly measured water-quality parameters. Well vulnerability class, based on confining layer thickness, was also not a useful predictor. Additional research is needed to improve our ability to understand the fate and transport of pharmaceutical compounds in groundwater.

Correlation analyses revealed that more recently drilled wells have lower concentrations of nitrate + nitrite and atrazine, but higher turbidity, iron, and manganese values. This correlation may result from improved well construction, source water protection activities, and required separation distances from contaminant sources. Recently, there has been an emphasis on properly installing casings to depths that take advantage of existing geologic confining layers as a natural protective layer. It is also possible that communities prefer to use protected bedrock aquifers rather than aquifers with known surface contamination, despite the potential for naturally-derived contamination.

CONCLUSIONS

The primary objective of this study was to document the occurrence of a large suite of potential contaminants in wells that are representative of the various groundwater resources in this state. While this study was unique in its coverage of contaminants of emerging concern, it highlights the fact that well-known naturally derived and surface-derived contaminants like arsenic and nitrate continue to pose water-quality challenges for residents of this state. Arsenic was detected in 36% of the samples and 8% exceeded the MCL of 0.010 µg/L. Nitrate + nitrite was detected in 26% of the wells sampled and 3% of these samples exceeded the MCL of 10 mg/L. Occurrence of microbial indicators was low (6%).

At 41% detection, the most commonly detected contaminant group was pesticide compounds. Of these, the most common were acetanilide degradates. None of the measured concentrations of pesticide compounds exceeded current benchmark levels; however, several of these compounds are listed on the EPA's CCL and could be subject to drinking water standards in the future. Despite heavy use in the past decade, glyphosate was not detected, and its metabolite, AMPA, was only detected in two of the 60 wells tested (3%) at the detection limit of 0.02 µg/L.

Pharmaceuticals were the most commonly detected CEC, as a group, with at least one pharmaceutical detected in 35% of the samples. While detection of pharmaceuticals was relatively high given the recent drought conditions and the proportion of low vulnerability wells included in the study, concentrations of these chemicals were low. Most pharmaceutical detections were at concentrations below the state-of-the-art method reporting levels and the maximum measured concentration was 826 ng/L acetaminophen (parts per trillion). For perspective, it would take almost 200,000 cups of untreated well water to equal the dose of acetaminophen recommended for infants (40 mg).

Viruses and pathogenic bacteria were detected in 21% of the samples by qPCR. Most of the microbes detected were not pathogenic to humans. The human pathogens, human polyomavirus, GII norovirus and *Campylobacter* were each detected once at concentrations close to their respective quantitation limits. The most common virus detected was PMMV (17% of samples). Our results confirms what other studies have shown, that transport of viruses to groundwater is possible, even in wells considered to be protected from surface contamination. Further study will be necessary to determine possible sources of the viruses and bacterial pathogen that were detected, and to see if trends respond to changes in precipitation and subsurface conditions.

A secondary objective of this study was to determine if any commonly measured analytes could be used as indicators for pharmaceuticals, viruses, and pathogenic bacteria. While common indicators of contamination from the surface were positively correlated to each other, they showed no significant correlation to CECs. On the other hand, individual analytes within each group of contaminants appear to be promising indicators for their respective groups. Metolachlor ESA was the most frequently detected pesticide and also the pesticide with the highest measured concentrations. Additionally, metolachlor was always present in wells where pesticides or pesticide degradates were detected. For pharmaceuticals, caffeine was the most commonly detected compound, although, concentrations were often below the method reporting level. The study confirms that PMMV is a promising indicator for virus occurrence in groundwater. Additional research is necessary to determine potential sources of PMMV in Iowa.

The final objective of this study was to determine if a system of vulnerability classification based on confining layer thickness, originally developed for nitrate, was applicable to groups of CECs. While we confirmed that this vulnerability classification method is well-suited to predict the occurrence of nitrate and degradates of acetanilide pesticides, it is not reliable for prediction of occurrence of pharmaceuticals or viruses. The lack of predictability of pharmaceutical and virus occurrence also means that identification of preferential transport pathways will become more important for source water protection assessments, where risks from these contaminants are identified.

Results of this study point to differences in the potential sources and behaviors of these contaminant groups, and the need to look more closely at potential transport pathways and other interactions, specifically for pharmaceuticals and viruses. As this was the first time groundwater was systematically sampled for these CECs, additional monitoring will be necessary to determine whether the results presented here are consistent with sampling under different (wetter) hydrological conditions. This study will provide a baseline for future studies aimed at evaluating groundwater-quality trends and risk assessment related to viruses and pharmaceuticals. Additionally, follow-up investigations of individual PWS with CECs detections are recommended to determine the possible sources of this surface-related contamination.

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APPENDIX A

Well Name	Well Characteristics: PWS ID Number	Well Number	USGS ID	Date Drilled	Well Depth (m)	Well Depth (ft)	Aquifer Group	Confining Layer Thickness (m)	Confining Layer Thickness (ft)	Vulner-ability Class	Pumping Rate (1000L/day)	Pumping Rate (gpd)	Land Use Class*	Antecedent Precipitation: 7-day (cm)	30-day (cm)	60-day (cm)
Adel #3	2503003	34349	413749093592601	8/19/1977	13.41	44	All.	1	3	High	385	101656	grasses	1.65	3.18	4.60
Alburnett #3	5704012	72342	420859091373701	5/10/2010	121.3	398	S-D	20	65	Int.	63088	16666	row crop	0.56	8.61	12.67
Algona #8	5502015	60210	430412094142301	10/27/2003	49.99	164	D-C	22	73	Int.	776955	205250	developed	0.00	2.21	4.78
Altoona #3	7707030	23701	413931093292001	2/15/1976	772.1	2533	C-O	126	415	Low	1414483	373667	developed	7.92	15.88	20.83
Andover #1	2307001	61574	415844090150801	7/8/2008	237.7	780	C-O	70	230	Low	757	200	row crop	0.89	19.56	26.24
Anita #4	1503053	65303	412708094461101	4/28/2008	72.54	238	D-C	17	57	Int.	101260	26750	developed	2.29	4.29	7.04
Atkins #3	603072	62894	415932091514001	1/1/2005	170.1	558	S-D	18	60	Int.	310404	82000	developed	5.49	8.46	11.02
Audubon #13	505077	36202	414315094524201	2/19/1968	10.52	34.5	All.	5	16	High	65613	17333	row crop	4.06	6.27	8.74
Avoca Reg. Water #19	8300184	63981	413022095202301	6/27/2007	10.06	33	All.	2	6	High	96906	25600	grasses	0.33	5.79	8.13
Badger #3	9405082	23299	423650094085501	6/1/1973	167	548	Miss.	41	135	Low	123026	32500	row crop	0.05	4.98	8.23
Battle Creek #3	4709090	23199	421908095353701	6/30/1972	17.98	59	All.	5	17	High	100313	26500	developed	6.10	9.55	13.79
Blue Grass #1a	8215021	22757	413040090455001	7/1/1971	195.1	640	S-D	40	130	Low	157727	41667	developed	0.66	8.69	13.64
Bristow #2	1222044	20256	424627092542302	9/11/1967	54.86	180	S-D	21	69	Int.	52996	14000	row crop	4.75	15.85	24.28
Calamus 2007	2320062	64546	414932090450801	3/10/2006	393.2	1290	C-O	110	362	Low	142710	37700	row crop	5.49	8.36	14.99
Carson #7	7809078	58045	411401095241401	9/16/2003	47.24	155	D-C	37	120	Low	54056	14280	developed	0.46	5.00	7.09
Cascade #4	3118080	23975	421731091011501	6/16/1976	74.37	244	S-D	7	23	High	368131	97250	row crop	4.72	7.75	12.98
Cedar Falls #8	709084	37620	423045092283401	1/1/1971	67.06	220	S-D	32	105	Low	2058317	543750	grasses	0.08	8.46	14.20
Cedar Falls #9	709084	37621	423341092273001	1/1/1975	83.82	275	S-D	6	21	High	2058317	543750	developed	0.08	8.46	14.20
Cedar Falls #9 (RS)	709084	37621	423341092273001	1/1/1975	83.82	275	S-D	6	21	High	2058317	543750	developed	3.51	24.18	41.91
Charles City #8	3405012	67030	430444092403001	4/3/2009	70.1	230	S-D	2	7	High	1766522	466666	developed	0.23	6.71	9.88
Cherokee #10	1811101	42300	424340095331301	8/9/1996	75.9	249	D-C	37	120	Low	312770	82625	developed	0.33	4.32	6.15
Clayton #1	2203039	26579	425400091091601	12/31/1981	114.3	375	C-O	2	6	High	82143	21700	grasses	5.59	7.19	16.41
Coralville #10	5208071	31377	414145091350101	8/1/1990	521.2	1710	C-O	61	200	Low	2124228	561162	developed	0.03	19.94	27.10
De Witt #7	2330036	57176	414907090333301	1/23/2003	409.3	1343	C-O	61	200	Low	701758	185385	grasses	5.28	8.64	15.54
Decorah #7	9630012	39057	431829091472001	1/1/1980	15.24	50	All.	0	1	High	772224	204000	grasses	4.29	7.49	13.69
Dumont #2	1240081	34682	424455092582001	1/25/1983	86.87	285	S-D	15	50	Int.	117348	31000	developed	4.83	17.63	26.44
Duncombe #4	9427082	39389	422811093591901	1/1/1988	167.6	550	Miss.	44	145	Low	75708	20000	row crop	0.05	5.69	8.99
Elgin #2	3338010	39679	425717091382602	1/1/1955	67.06	220	C-O	0	0	High	92743	24500	developed	5.16	6.63	16.92
Fairfield #6	5131033	35411	410040091560901	6/13/1994	634.6	2082	C-O	151	495	Low	2321717	613333	grasses	0.03	7.04	11.35
Fremont #2-88	6234070	29828	411239092261901	7/12/1988	21.64	71	BSG	17	55	Int.	88011	23250	developed	6.63	7.77	15.62
Gilbert #3	8531083	39923	420626093404101	4/2/1972	47.85	157	BSG	32	106	Low	325545	86000	row crop	5.54	6.43	12.80
Independence #3	1037070	1856	422808091531801	12/30/1943	93.57	307	S-D	6	20	High	549642	145200	developed	4.70	20.19	24.23
Independence #7	1037070	28344	422814091540401	1/1/1984	80.77	265	S-D	8	25	High	549642	145200	developed	1.37	5.36	9.83
Independence #7 (RS)	1037070	1856	422814091540401	1/1/1984	80.77	265	S-D	8	25	High	549642	145200	developed	3.05	22.38	39.04
Ionia #2	1946078	28342	430211092270702	2/10/1983	76.81	252	S-D	42	138	Low	77601	20500	developed	0.28	8.03	12.17
Janesville #3	932001	28340	423902092272502	1/1/1984	32	105	S-D	0	0	High	130597	34500	developed	0.03	5.61	10.08

RS = samples obtained during the June resampling period

Aquifer abbreviations: All. = Alluvium, S-D = Silurian-Devonian, D-C = Dakota Cretaceous, C-O = Cambrian-Ordovician, Miss. = Mississippian, and BSG = Buried sand & gravel.

***Primary land use class within 1000 feet of the well as determined by 2012 satellite imagery (USDA, 2013).**

APPENDIX A

	Well Characteristics													Antecedent Precipitation		
Well Name	PWS ID Number	Well Number	USGS ID	Date Drilled	Well Depth (m)	Well Depth (ft)	Aquifer Group	Confining Layer Thickness (m)	Confining Layer Thickness (ft)	Vulner-ability Class	Pumping Rate (1000L/day)	Pumping Rate (gpd)	Land Use Class*	7-day (cm)	30-day (cm)	60-day (cm)
Joice #1	9835001	64060	432157093271701	5/17/2007	91.44	300	S-D	28	93	Int.	18927	5000	grasses	0.00	3.05	5.51
Jolley #1	1335001	27238	422844094431301	1/1/1984	135.6	445	Miss.	34	110	Low	18927	5000	developed	0.33	3.43	5.82
Knierim #1	1340001	24966	422656094271901	5/5/1978	51.82	170	BSG	38	125	Low	39368	10400	row crop	0.25	4.75	7.67
Lansing #4	345054	24826	432202091133001	1/1/1977	245.4	805	C-O	0	0	High	347122	91700	grasses	4.39	7.52	13.74
Lyon-Sioux RWS-3	6000733	40669	431808096140101	1/1/1978	10.36	34	All.	3	10	High	370213	97800	grasses	0.03	2.69	4.55
Marshalltown #5	6469042	40763	420420092552701	1/1/1972	67.67	222	BSG	30	100	Int.	2119830	560000	grasses	7.09	8.13	16.10
Massena #6	1558055	62594	411501094465901	6/13/2006	10.06	33	All.	4	12	High	32555	8600	row crop	2.06	4.37	7.16
Mount Vernon #9	5758021	64887	415539091243301	6/17/2008	110	361	S-D	49	162	Low	404093	106750	row crop	0.89	8.89	14.35
Moville #5	9753022	51614	422933096041501	11/16/1999	74.37	244	D-C	8	27	High	344472	91000	developed	1.04	4.83	6.78
Nevada #8	8562044	64759	415919093341001	3/7/2008	27.74	91	All.	5	18	High	1684507	445000	grasses	5.72	6.48	12.60
New Venna #4	3165014	35996	423228091064701	5/20/1995	297.5	976	C-O	34	110	Low	115834	30600	grasses	0.99	8.08	13.34
Nora Springs #4	3423069	64868	430842093002601	6/4/2008	96.01	315	S-D	14	45	High	246525	65125	developed	3.07	10.52	15.01
Orchardview Est. #1	5282304	36817	414313091280701	9/16/1995	148.4	487	S-D	17	55	Int.	19684	5200	grasses	0.89	4.90	8.31
Perry #22	2561036	32303	415030094014301	5/28/1991	39.01	128	BSG	23	77	Int.	241683	63846	row crop	1.24	2.74	3.94
Perry #9R	2561036	28614	415057094065301	9/21/1987	13.94	46	All.	1	3	High	241683	63846	grasses	0.51	2.46	3.63
Perry #9R (RS)	2561036	28614	415057094065301	9/21/1987	13.94	46	All.	1	3	High	241683	63846	grasses	3.30	17.63	33.58
Primghar #8	7155059	57231	430516095373502	4/4/2002	182.9	600	D-C	109	359	Low	255515	67500	developed	0.15	4.55	6.40
Quimby #3	1855066	57083	423744095383302	7/20/2005	85.34	280	D-C	24	80	Int.	68137	18000	developed	5.38	8.51	11.53
Riverview Estates #1	5200347	16174	414254091321201	11/5/1963	89.31	293	S-D	9	31	High	45425	12000	grasses	0.89	4.95	8.31
Rockford #2	3430091	25694	430315092563401	1/1/1978	65.23	214	S-D	2	6	High	144792	38250	developed	3.68	12.17	17.45
Shelby #6A	8369038	46400	413054095254501	7/3/1998	14.63	48	All.	8	25	High	41640	11000	row crop	7.39	12.07	18.31
Sigourney #02-5	5475050	55861	412109092115201	10/18/2001	20.42	67	Miss.	15	48	High	503460	133000	row crop	6.99	7.77	15.34
Sioux Center #13	8486053	42486	430449096061301	1/1/1992	13.41	44	All.	2	5	High	257677	68071	row crop	0.13	4.52	6.43
Stacyville #3	6677089	63960	432610092465803	6/7/2007	88.39	290	S-D	8	26	High	143846	38000	developed	3.15	13.31	18.95
Steamboat Rock #1	4289094	5188	422453093035001	9/28/1951	35.05	115	Miss.	14	47	High	45425	12000	grasses	0.05	6.35	9.96
Storm Lake #18	1178097	64085	423849095142501	6/28/2007	29.26	96	BSG	16	52	Int.	1630815	430816	grasses	0.15	1.75	3.20
Toledo #2	8676027	24528	415935092351801	1/1/1977	606.6	1990	C-O	143	470	Low	522387	138000	developed	4.90	9.27	13.28
Van Meter #3	2570046	57592	413148093571103	7/14/2003	20.12	66	All.	3	9	High	170798	45120	developed	1.78	3.73	5.00
Van Meter #3 (RS)	2570046	57592	413148093571103	7/14/2003	20.12	66	All.	3	9	High	170798	45120	developed	3.25	16.36	27.86
Ventura #1	1785032	25538	430756093263201	12/19/1977	152.4	500	S-D	34	110	Low	279363	73800	grasses	0.00	3.76	6.81
Walnut #2	7872062	22927	412832095132701	1/1/1971	803.1	2635	C-O	78	255	Low	133750	35333	developed	0.66	6.05	8.66
Waverly #6	990085	26606	424341092291901	1/1/1980	52.43	172	S-D	0	1	High	855503	226000	developed	0.03	4.95	8.86
Waverly #6 (RS)	990085	26606	424341092291901	1/1/1980	52.43	172	S-D	0	1	High	855503	226000	developed	6.88	25.48	40.46
Winthrop #3	1093031	25801	422833091431701	1/1/1980	70.1	230	S-D	30	100	Int.	302833	80000	developed	10.54	14.99	22.23
Woodward St. Hos. #2	800923	43160	414915093561001	9/9/1965	34.75	114	BSG	18	60	Int.	397468	105000	row crop	0.51	2.95	4.50

RS = samples obtained during the June resampling period

Aquifer abbreviations: All. = Alluvium, S-D = Silurian-Devonian, D-C = Dakota Cretaceous, C-O = Cambrian-Ordovician, Miss. = Mississippian, and BSG = Buried sand & gravel.

*Primary land use class within 1000 feet of the well as determined by 2012 satellite imagery (USDA, 2013).

APPENDIX B

		Age —(TU)—		General Water Quality —(mg/L)—								
Well/Sample Name	**Sample Date-Time**	**Tritium**	**± 1 std. deviation**	**pH**	**Conductivity (umho/cm)**	**Total Hardness**	**Total Alkalinity**	**Dissolved Oxygen**	**Total Organic Carbon**	**Total Dissolved Solids**	**Total Suspended Solids**	**Turbidity (NTU)**
Adel #3	3/5/2013 14:10	4.5	0.5	7.1	740	360	310	<0.1	2.5	480	4	13.0
Alburnett #3	3/18/2013 14:00	<0.8	0.3	7.4	480	240	260	0.3	1.1	250	<1	<1.0
Algona #8	3/26/2013 14:15	2.9	0.4	7.1	790	390	400	<0.1	2.4	510	4	29.0
Altoona #3	4/23/2013 14:30	<0.8	0.3	7.2	640	240	260	0.1	<0.5	430	<1	1.1
Altoona #3 (blank)	4/23/2013 14:00					1	2		<0.5	<1	<1	<1.0
Andover #1	4/29/2013 12:15	<0.8	0.3	7.2	640	280	270	0.1	<0.5	350	<1	5.5
Andover #1 (lab rep)	4/29/2013 12:15	<0.8	0.4									
Anita #4	3/13/2013 14:40	<0.8	0.3	7.0	860	380	280	1.6	1.0	580	1	2.5
Atkins #3	3/12/2013 12:45	<0.8	0.3	7.2	790	290	400	0.1	2.9	450	<1	25.0
Audubon #13	3/12/2013 14:15	4.5	0.5	7.2	600	270	240	2.6	1.1	390	<1	<1.0
Avoca Reg. Water #19	3/19/2013 15:15	4.4	0.5	7.6	510	210	91	1.2	1.2	300	1	2.6
Badger #3	3/26/2013 12:50	<0.8	0.3	6.9	730	410	390	<0.1	1.7	510	<1	<1.0
Battle Creek #3	4/9/2013 13:00	2.7	0.4	7.4	640	320	300	3.7	0.7	420	<1	<1.0
Blue Grass #1a	3/20/2013 13:15	<0.8	0.3	7.1	630	320	360	0.9	0.7	360	<1	<1.0
Bristow #2	4/22/2013 15:10	4.7	0.5	7.4	540	290	230	1.9	0.6	330	<1	<1.0
Calamus 2007	3/11/2013 15:40	<0.8	0.3	7.4	1300	260	250	0.3	1.0	740	<1	4.9
Carson #7	3/19/2013 13:45	<0.8	0.4	7.3	800	310	420	<0.1	1.7	480	2	5.0
Cascade #4	3/13/2013 14:00	3.9	0.5	7.1	800	420	350	6.1	1.0	480	<1	<1.0
Cedar Falls #8	3/27/2013 13:45	3.2	0.5	7.4	460	230	220	0.2	1.1	260	<1	<1.0
Cedar Falls #9	3/27/2013 16:00			7.4	520	260	220	3.4	0.9	310	<1	<1.0
Cedar Falls #9 (RS)	6/12/2013 14:00			7.4	520			3.0				
Charles City #8	3/25/2013 14:45			7.4	460	230	230	<0.1	1.7	280	1	14.0
Cherokee #10	4/8/2013 12:30	<0.8	0.3	7.1	1100	600	280	<0.1	1.0	920	2	11.0
Clayton #1	4/10/2013 13:50	<0.8	0.3	7.4	420	280	260	0.1	0.6	280	<1	<1.0
Coralville #10	5/1/2013 13:15			7.2	1550	460	240	0.1	<0.5	1110	<1	6.9
Coralville #10 (field rep)	5/1/2013 13:15			7.2	1550	460	240	0.1	<0.5	1170	<1	6.8
De Witt #7	3/11/2013 15:00	<0.8	0.3	7.5	950	240	260	0.9	1.3	550	<1	1.1
De Witt #7 (lab rep)	3/11/2013 15:00	<0.8	0.3									
Decorah #7	4/9/2013 13:35	5.4	0.6	7.2	640	320	270	1.5	1.0	370	<1	<1.0
Dumont #2	4/22/2013 15:35	<0.8	0.3	7.7	1000	560	220	<0.1	0.8	730	<1	6.7
Duncombe #4	3/27/2013 12:55	<0.8	0.3	7.1	940	450	360	<0.1	1.8	610	<1	<1.0
Elgin #2	4/10/2013 13:15			7.2	630	330	260	0.4	0.9	380	<1	<1.0
Fairfield #6	4/3/2013 13:15	<0.8	0.4	7.4	1800	300	250	0.3	1.2	1150	<1	<1.0
Fairfield #6 (field rep)	4/3/2013 13:15			7.4	1800	310	240	0.3	1.2	1150	<1	<1.0
Fremont #2-88	4/15/2013 15:20			7.0	670	350	370	<0.1	1.1	400	2	12.0
Gilbert #3	4/16/2013 15:30			7.4	730	310	400	<0.1	3.1	410	8	36.0
Independence #3	5/8/2013 12:30	4.1	0.5	7.3	580	310	260	0.1	0.6	340	2	<1.0
Independence #7	4/8/2013 13:30	4.9	0.6	7.3	640	310	260	<0.1	0.8	390	<1	1.5
Independence #7 (RS)	6/11/2013 12:50			7.0	380			<0.1				
Ionia #2	3/25/2013 16:15	<0.8	0.3	7.3	590	290	290	0.3	1.9	340	<1	5.5
Janesville #3	4/2/2013 14:40			7.5	530	260	210	7.4	0.8	320	<1	<1.0

blank = field blank

lab rep = laboratory replicate

field rep = field replicate

RS = samples obtained during the June resampling period

APPENDIX B

APPENDIX B

Well/Sample Name	Sample Date-Time	Age (TU)				General Water Quality (mg/L)						
		Tritium	± 1 std. deviation	pH	Conductivity (umho/cm)	Total Hardness	Total Alkalinity	Dissolved Oxygen	Total Organic Carbon	Total Dissolved Solids	Total Suspended Solids	Turbidity (NTU)
Joice #1	3/26/2013 12:45	<0.8	0.4	7.2	620	340	330	0.5	2.1	340	2	14.0
Jolley #1	3/25/2013 14:40			6.9	1400	780	390	5.6	2.6	1200	4	20.0
Knierim #1	3/25/2013 13:40	<0.8	0.4	7.3	1400	590	480	<0.1	5.0	1000	1	16.0
Lansing #4	4/9/2013 14:35	<0.8	0.3	7.6	620	170	230	<0.1	<0.5	370	<1	2.2
Lyon-Sioux RWS-3	4/2/2013 13:43	5.5	0.6	7.3	710	350	230	3.8	1.7	450	<1	<1.0
Marshalltown #5	4/15/2013 14:15	<0.8	0.5	7.3	900	430	300	0.3	1.2	640	7	31.0
Massena #6	3/13/2013 13:45			7.0	490	220	210	<0.1	2.3	280	46	190.0
Mount Vernon #9	3/18/2013 16:00			7.4	480	250	260	0.3	0.7	270	<1	<1.0
Mount Vernon (blank)	3/18/2013 14:45					<1	<1		0.8	<1	<1	<1.0
Moville #5	4/1/2013 16:10			7.1	600	330	280	0.9	1.0	390	<1	<1.0
Moville #5 (field rep)	4/1/2013 16:10			7.1	600	340	290	0.9	0.9	400	<1	<1.0
Nevada #8	4/16/2013 14:15	4.9	0.6	7.1	770	370	250	<0.1	1.8	470	10	60.0
New Venna #4	3/19/2013 16:00			7.4	550	200	250	0.2	0.8	310	<1	2.3
Nora Springs #4	4/23/2013 12:05	0.9	0.3	7.2	600	310	310	<0.1	1.2	340	<1	<1.0
Orchardview Est. #1	3/4/2013 12:00	<0.8	0.3	7.0	730	380	390	2.3	1.4	420	<1	<1.0
Perry #22	3/4/2013 15:25	<0.8	0.3	7.1	840	390	420	<0.1	2.3	510	6	34.0
Perry #9R	3/6/2013 15:15	5.3	0.6	7.0	670		300	0.1	1.6	470	3	21.0
Perry #9R (RS)	6/18/2013 11:00			7.0	740			0.2				
Primghar #8	4/3/2013 13:30	<0.8	0.4	7.3	1800	1100	1100	<0.1	2.9	1970	8	34.0
Quimby #3	4/9/2013 12:55			7.1	900	490	270	<0.1	1.0	750	3	13.0
Riverview Estates #1	3/4/2013 14:40	<0.8	0.4	7.4	850	400	420	<0.1	1.3	500	<1	<1.0
Rockford #2	4/23/2013 13:05	1.6	0.4	7.3	500	280	240	<0.1	0.7	280	<1	1.0
Rockford #2 (field rep)	4/23/2013 13:05			7.3	500	270	240	<0.1	0.8	270	<1	<1.0
Shelby #6A	4/22/2013 14:30	4.8	0.6	7.0	650	320	280	<0.1	2.6	400	18	93.0
Shelby #6A (field rep)	4/22/2013 14:30			7.0	650	320	280	<0.1	2.6	400	17	81.0
Sigourney #02-5	4/15/2013 17:00	2.1	0.4	7.3	560	280	270	<0.1	0.9	320	4	13.0
Sigourney (blank)	4/15/2013 12:45					<1	3		<0.5	4	1	<1.0
Sioux Center #13	4/2/2013 12:42	4.4	0.5	7.1	1100	560	340	1.2	2.3	740	1	<1.0
Stacyville #3	4/24/2013 13:40			7.3	510	270	240	<0.1	1.2	280	<1	12.0
Steamboat Rock #1	4/1/2013 14:35	4	0.5	7.2	720	360	330	4.8	1.1	420	<1	<1.0
Storm Lake #18	4/8/2013 13:35	3.9	0.5	7.1	840	460	340	<0.1	2.8	580	7	28.0
Toledo #2	3/12/2013 15:10			7.2	1000	400	310	<0.1	1.1	690	1	2.7
Van Meter #3	3/5/2013 15:10	4	0.5	6.9	840	440	360	0.3	1.0	520	<1	<1.0
Van Meter #3 (RS)	6/18/2013 9:00			6.8	880			0.4				
Ventura #1	3/26/2013 13:15	<0.8	0.3	7.2	610	320	340	<0.1	1.9	340	<1	6.9
Walnut #2	3/18/2013 14:30	<0.8	0.4	7.3	2300	680	170	0.2	1.1	1600	2	8.6
Walnut (blank)	3/18/2013 13:45					<1	<1		0.8	<1	<1	<1.0
Waverly #6	4/2/2013 13:05	5.4	0.6	7.4	620	300	250	3.7	0.9	350	<1	<1.0
Waverly #6 (RS)	6/12/2013 10:30			7.3	610			3.7				
Winthrop #3	4/17/2013 12:05			7.3	710	320	320	<0.1	1.3	440	4	13.0
Woodward St. Hos. #2	3/6/2013 13:25	<0.8	0.4	7.7	730		420	<0.1	4.1	430	7	17.0

blank = field blank
lab rep = laboratory replicate
field rep = field replicate
RS = samples obtained during the June resampling period

APPENDIX B

		Major Ions (mg/L)											Nutrients (mg/L)				
Well/Sample Name	Sample Date-Time	Bromide	Chloride	Fluoride	Sulfate	Silica as SiO_2	Carbonate Alkalinity	Bicarbonate Alkalinity	Calcium	Magnesium	Potassium	Sodium	Ammonia as N	Nitrate + Nitrite as N	Total Kjeldahl Nitrogen as N	Ortho-Phosphate as P	Total Phosphorus as P
Adel #3	3/5/2013 14:10	<0.25	32.0	0.32	67	22.0	<1	310	88	33	3.3	26.0	0.81	0.61	1.1	0.10	0.160
Alburnett #3	3/18/2013 14:00	<0.25	<0.5	0.34	6	8.5	<1	260	64	22	1.3	8.3	0.67	<0.10	0.4	<0.020	<0.020
Algona #8	3/26/2013 14:15	<0.5	11.0	0.47	92	21.0	<1	400	100	32	3.8	52.0	0.72	<0.10	0.8	0.08	0.120
Altoona #3	4/23/2013 14:30	<0.5	12.0	1.69	100	11.0	<1	260	57	26	12.0	54.0	0.64	<0.10	0.6	<0.020	0.050
Altoona #3 (blank)	4/23/2013 14:00	<0.5	<1.0	<0.10	<1.0	<1.0	<1	2	<1.0	<0.5	<1.0	<0.5	<0.05	<0.10	<0.1	<0.020	0.08
Andover #1	4/29/2013 12:15	<0.5	24.0	0.43	47	8.3	<1	270	68	29	8.6	20.0	0.35	<0.10	0.4	<0.020	<0.020
Anita #4	3/13/2013 14:40	<0.25	1.0	0.50	190	23.0	<1	280	100	32	3.0	41.0	0.86	<0.10	<0.1	<0.020	0.050
Atkins #3	3/12/2013 12:45	<0.25	2.0	0.48	52	7.4	<1	400	64	31	6.0	68.0	6.10	<0.10	6.4	0.02	0.030
Audubon #13	3/12/2013 14:15	<0.25	8.2	0.53	55	24.0	<1	240	89	20	1.0	9.4	<0.05	6.90	<0.1	0.10	0.130
Avoca Reg. Water #19	3/19/2013 15:15	<0.25	47.0	0.49	90	11.0	<1	91	64	13	1.3	17.0	<0.050	<0.10	<0.1	0.04	0.070
Badger #3	3/26/2013 12:50	<0.5	5.5	2.29	90	7.6	<1	390	87	46	6.7	38.0	0.29	<0.10	0.1	<0.020	0.020
Battle Creek #3	4/9/2013 13:00	<0.5	10.0	0.27	34	29.0	<1	300	88	25	2.9	20.0	<0.05	6.00	<0.1	0.78	1.600
Blue Grass #1a	3/20/2013 13:15	<0.25	<0.5	0.31	11	16.0	<1	360	79	34	1.2	14.0	0.06	<0.10	<0.1	<0.020	<0.020
Bristow #2	4/22/2013 15:10	<0.5	14.0	0.19	34	13.0	<1	230	76	23	1.1	5.2	<0.05	5.40	<0.1	0.02	0.060
Calamus 2007	3/11/2013 15:40	0.59	160.0	1.10	150	8.6	<1	250	60	27	13.0	170.0	1.30	<0.10	0.8	<0.020	0.030
Carson #7	3/19/2013 13:45	<0.25	3.4	0.35	26	21.0	<1	420	85	27	1.5	66.0	1.00	<0.10	0.9	0.19	0.200
Cascade #4	3/13/2013 14:00	<0.25	28.0	0.18	33	18.0	<1	350	100	43	1.2	11.0	<0.05	6.40	<0.1	<0.020	0.030
Cedar Falls #8	3/27/2013 13:45	<0.5	7.2	0.72	23	12.0	<1	220	64	21	1.6	5.8	0.28	<0.10	0.3	<0.020	0.020
Cedar Falls #9	3/27/2013 16:00	<0.5	11.0	0.20	21	18.0	<1	220	72	22	1.2	5.5	<0.05	8.30	0.1	0.04	0.040
Cedar Falls #9 (RS)	6/12/2013 14:00		11.0														
Charles City #8	3/25/2013 14:45	<0.5	3.6	0.77	22	13.0	<1	230	67	19	1.4	5.0	0.56	<0.10	<0.1	<0.020	0.060
Cherokee #10	4/8/2013 12:30	<0.5	2.4	0.71	410	28.0	<1	280	170	46	4.9	48.0	0.53	<0.10	0.5	<0.020	0.040
Clayton #1	4/10/2013 13:50	<0.5	<1.0	0.21	15	12.0	<1	260	61	29	<1.0	2.7	<0.05	<0.10	<0.1	<0.020	0.030
Coralville #10	5/1/2013 13:15	<0.5	40.0	1.48	520	8.8	<1	240	97	52	16.0	180.0	1.20	<0.10	0.8	<0.020	0.030
Coralville #10 (field rep)	5/1/2013 13:15	<0.5	39.0	1.47	530	8.9	<1	240	96	52	16.0	180.0	1.30	<0.10	1.0	<0.020	0.020
De Witt #7	3/11/2013 15:00	0.35	100.0	1.00	89	8.8	<1	260	49	25	12.0	110.0	1.10	<0.10	0.5	<0.020	0.030
Decorah #7	4/9/2013 13:35	<0.5	33.0	0.12	22	14.0	<1	270	94	21	2.8	14.0	<0.05	2.00	<0.1	<0.020	0.030
Dumont #2	4/22/2013 15:35	<0.5	<1.0	0.88	340	13.0	<1	220	170	37	1.2	6.7	0.45	<0.10	0.7	0.02	0.100
Duncombe #4	3/27/2013 12:55	<0.5	8.9	2.46	180	7.7	<1	360	95	54	9.7	43.0	0.84	<0.10	0.9	<0.020	<0.020
Elgin #2	4/10/2013 13:15	<0.5	17.0	0.25	50	11.0	<1	260	92	26	2.4	4.7	<0.05	4.80	<0.1	<0.020	0.030
Fairfield #6	4/3/2013 13:15	<0.5	140.0	1.81	460	11.0	<1	250	74	30	17.0	280.0	1.40	<0.10	1.5	<0.020	<0.020
Fairfield #6 (field rep)	4/3/2013 13:15	<0.5	140.0	2.05	460	11.0	<1	240	73	30	17.0	280.0	1.30	<0.10	1.3	<0.020	<0.020
Fremont #2-88	4/15/2013 15:20	<0.5	3.0	0.53	16	27.0	<1	370	93	25	2.0	20.0	0.34	<0.10	0.5	0.03	0.040
Gilbert #3	4/16/2013 15:30	<0.5	1.2	0.57	<1.0	18.0	<1	400	74	29	4.4	39.0	2.90	<0.10	1.9	0.24	0.350
Independence #3	5/8/2013 12:30	<0.5	12.0	0.18	51	9.6	<1	260	91	22	1.6	5.5	0.05		<0.1	<0.020	0.040
Independence #7	4/8/2013 13:30	<0.5	24.0	0.27	54	11.0	<1	260	90	23	2.0	13.0	0.07	<0.10	<0.1	<0.020	<0.020
Independence #7 (RS)	6/11/2013 12:50		33.0														
Ionia #2	3/25/2013 16:15	<0.5	<1.0	0.95	42	11.0	<1	290	72	26	2.6	16.0	2.00	<0.10	2.2	<0.020	0.020
Janesville #3	4/2/2013 14:40	<0.5	12.0	0.16	16	15.0	<1	210	70	22	1.0	4.4	<0.050	12.00	<0.1	0.02	0.030

blank = field blank
field rep = field replicate
RS = samples obtained during the June resampling period

APPENDIX B

		Major Ions (mg/L)											Nutrients (mg/L)				
Well/Sample Name	Sample Date-Time	Bromide	Chloride	Fluoride	Sulfate	Silica as SiO_2	Carbonate Alkalinity	Bicarbonate Alkalinity	Calcium	Magnesium	Potassium	Sodium	Ammonia as N	Nitrate + Nitrite as N	Total Kjeldahl Nitrogen as N	Ortho-Phosphate as P	Total Phosphorus as P
Joice #1	3/26/2013 12:45	<0.5	3.3	0.33	12	24.0	<1	330	87	26	1.8	10.0	0.56	<0.10	0.4	0.09	0.160
Jolley #1	3/25/2013 14:40	<0.5	1.6	1.18	530	13.0	<1	390	180	83	3.7	71.0	0.41	<0.10	0.5	0.03	0.060
Knierim #1	3/25/2013 13:40	<0.5	6.0	0.43	360	29.0	<1	480	140	68	5.3	110.0	4.20	<0.10	4.0	0.25	0.300
Lansing #4	4/9/2013 14:35	<0.5	40.0	0.19	47	8.8	<1	230	34	20	4.3	77.0	0.16	<0.10	<0.1	0.66	0.700
Lyon-Sioux RWS-3	4/2/2013 13:43	<0.5	34.0	0.41	93	19.0	<1	230	89	32	2.6	16.0	<0.05	3.60	0.1	0.05	0.060
Marshalltown #5	4/15/2013 14:15	<0.5	1.5	0.54	230	17.0	<1	300	110	44	3.6	47.0	2.20	3.00	2.0	0.03	0.060
Massena #6	3/13/2013 13:45	<0.25	9.5	0.26	23	28.0	<1	210	63	16	1.2	11.0	0.49	<0.10	0.7	0.09	0.910
Mount Vernon #9	3/18/2013 16:00	<0.25	<0.5	0.36	7	14.0	<1	260	59	28	<1.0	4.9	<0.05	0.25	<0.1	<0.020	<0.020
Mount Vernon (blank)	3/18/2013 14:45	<0.5	<1.0	<0.10	<1.0	<1.0	<1	<1	<1.0	<0.5	<1.0	<0.5	<0.05	<0.10	<0.1	<0.020	<0.02
Moville #5	4/1/2013 16:10	<0.5	5.3	0.23	42	22.0	<1	280	93	25	3.3	8.0	<0.05	5.40	<0.1	0.05	0.060
Moville #5 (field rep)	4/1/2013 16:10	<0.5	5.3	0.22	42	21.0	<1	290	95	26	3.3	8.1	<0.05	5.40	<0.1	0.05	0.070
Nevada #8	4/16/2013 14:15	<0.5	40.0	0.31	85	24.0	<1	250	97	28	2.8	15.0	0.57	<0.10	0.7	0.03	0.140
New Venna #4	3/19/2013 16:00	<0.25	5.0	1.00	45	7.8	<1	250	47	23	8.3	37.0	0.67	<0.10	0.5	<0.020	<0.020
Nora Springs #4	4/23/2013 12:05	<0.5	12.0	1.14	15	12.0	<1	310	81	28	2.9	9.5	0.41	<0.10	0.4	<0.020	0.070
Orchardview Est. #1	3/4/2013 12:00	<0.25	6.4	0.34	22	16.0	<1	390	97	32	2.0	16.0	0.55	<0.10	0.7	<0.020	<0.020
Perry #22	3/4/2013 15:25	<0.25	2.6	0.40	60	30.0	<1	420	100	30	3.3	38.0	1.10	<0.10	0.9	<0.020	0.150
Perry #9R	3/6/2013 15:15	<0.25	13.0	0.34	93	25.0	<1	300	110	29	1.9	6.6	<0.05	<0.10	0.2	0.02	0.040
Perry #9R (RS)	6/18/2013 11:00		14.0														
Primghar #8	4/3/2013 13:30	<0.5	16.0	0.54	970	22.0	<1	370	310	100	9.1	130.0	1.30	<0.10	1.4	0.10	0.110
Quimby #3	4/9/2013 12:55	<0.5	3.3	0.86	290	18.0	<1	270	140	37	6.6	38.0	0.62	<0.10	0.4	<0.020	0.030
Riverview Estates #1	3/4/2013 14:40	<0.25	1.3	0.26	78	12.0	<1	420	100	37	3.5	30.0	1.70	<0.10	1.9	0.05	<0.020
Rockford #2	4/23/2013 13:05	<0.5	3.8	0.74	28	14.0	<1	240	66	22	1.1	4.0	0.14	<0.10	1.8	<0.020	0.100
Rockford #2 (field rep)	4/23/2013 13:05	<0.5	4.0	0.72	29	14.0	<1	240	66	22	1.1	4.0	0.16	<0.10	<0.1	<0.020	0.100
Shelby #6A	4/22/2013 14:30	<0.5	14.0	0.39	49	37.0	<1	280	86	25	3.8	11.0	1.90	<0.10	0.3	0.60	0.810
Shelby #6A (field rep)	4/22/2013 14:30	<0.5	14.0	0.39	48	36.0	<1	280	87	25	3.7	11.0	1.80	<0.10	1.8	0.23	0.820
Sigourney #02-5	4/15/2013 17:00	<0.5	17.0	0.32	18	16.0	<1	270	72	22	1.2	18.0	0.23	<0.10	0.3	0.02	0.070
Sigourney (blank)	4/15/2013 12:45	<0.5	<1.0	<0.10	<1.0	11.0	<1	<1	<1.0	<0.5	<1.0	<0.5	<0.05	<0.10	<0.1	<0.020	0.02
Sioux Center #13	4/2/2013 12:42	<0.5	50.0	0.49	170	19.0	<1	340	150	54	2.1	23.0	0.05	11.00	0.3	0.04	0.050
Stacyville #3	4/24/2013 13:40	<0.5	1.4	0.66	14	16.0	<1	240	67	20	2.0	5.7	0.54	<0.10	0.7	<0.020	0.050
Steamboat Rock #1	4/1/2013 14:35	<0.5	20.0	0.19	31	22.0	<1	330	93	33	2.0	12.0	<0.05	1.90	<0.1	<0.020	0.050
Storm Lake #18	4/8/2013 13:35	<0.5	19.0	0.51	120	29.0	<1	340	120	37	2.2	16.0	0.61	<0.10	0.9	0.07	0.220
Toledo #2	3/12/2013 15:10	<0.25	7.8	1.20	250	8.3	<1	310	90	43	16.0	71.0	1.10	<0.10	0.8	<0.020	0.020
Van Meter #3	3/5/2013 15:10	<0.25	39.0	0.22	54	25.0	<1	360	110	36	1.5	14.0	<0.05	1.90	0.1	0.03	0.040
Van Meter #3 (RS)	6/18/2013 9:00		44.0														
Ventura #1	3/26/2013 13:15	<0.5	2.1	0.44	11	19.0	<1	340	85	28	2.1	11.0	0.46	<0.10	0.4	0.08	0.190
Walnut #2	3/18/2013 14:30	<0.5	230.0	3.00	710	11.0	<1	170	180	60	36.0	230.0	1.30	<0.10	0.5	<0.020	0.030
Walnut (blank)	3/18/2013 13:45	<0.5	<1.0	0.12	<1.0	<1.0	<1	<1	<1.0	<0.5	<1.0	<0.5	<0.05	<0.10	<0.1	<0.020	<0.02
Waverly #6	4/2/2013 13:05	<0.5	20.0	0.16	22	15.0	<1	250	81	26	1.3	7.7	<0.05	6.90	<0.1	<0.020	0.030
Waverly #6 (RS)	6/12/2013 10:30		21.0														
Winthrop #3	4/17/2013 12:05	<0.5	1.1	0.37	78	14.0	<1	320	69	37	3.1	31.0	2.30	<0.10	1.2	<0.020	0.200
Woodward St. Hos. #2	3/6/2013 13:25	<0.25	1.0	0.40	<1.0	23.0	<1	420	66	30	5.4	49.0	3.60	<0.10	3.9	0.28	0.370

blank = field blank

field rep = field replicate

RS = samples obtained during the June resampling period

APPENDIX B

Well/Sample Name	Sample Date-Time	Metals (dissolved) (mg/L) Aluminum	Antimony	Arsenic	Barium	Beryllium	Chromium	Cobalt	Copper	Iron
Adel #3	3/5/2013 14:10	<0.1	<0.005	<0.001	0.31	<0.002	<0.01	<0.05	<0.01	1.40
Alburnett #3	3/18/2013 14:00	<0.1	<0.005	<0.001	0.11	<0.002	<0.01	<0.05	<0.01	0.03
Algona #8	3/26/2013 14:15	<0.1	<0.005	0.012	0.09	<0.002	<0.01	<0.05	<0.01	2.80
Altoona #3	4/23/2013 14:30	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.17
Altoona #3 (blank)	4/23/2013 14:00	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	<0.02
Andover #1	4/29/2013 12:15	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.50
Anita #4	3/13/2013 14:40	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.11
Atkins #3	3/12/2013 12:45	<0.1	<0.005	<0.001	0.19	<0.002	<0.01	<0.05	<0.01	0.03
Audubon #13	3/12/2013 14:15	<0.1	<0.005	<0.001	0.10	<0.002	<0.01	<0.05	<0.01	<0.02
Avoca Reg. Water #19	3/19/2013 15:15	<0.1	<0.005	0.001	0.08	<0.002	<0.01	<0.05	<0.01	0.34
Badger #3	3/26/2013 12:50	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	<0.02
Battle Creek #3	4/9/2013 13:00	<0.1	<0.005	<0.001	0.16	<0.002	<0.01	<0.05	<0.01	0.05
Blue Grass #1a	3/20/2013 13:15	<0.1	<0.005	<0.001	0.30	<0.002	<0.01	<0.05	<0.01	<0.02
Bristow #2	4/22/2013 15:10	<0.1	<0.005	<0.001	0.10	<0.002	<0.01	<0.05	<0.01	0.03
Calamus 2007	3/11/2013 15:40	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.45
Carson #7	3/19/2013 13:45	<0.1	<0.005	<0.001	0.34	<0.002	<0.01	<0.05	<0.01	0.61
Cascade #4	3/13/2013 14:00	<0.1	<0.005	<0.001	0.15	<0.002	<0.01	<0.05	<0.01	<0.02
Cedar Falls #8	3/27/2013 13:45	<0.1	<0.005	0.001	0.16	<0.002	<0.01	<0.05	<0.01	0.08
Cedar Falls #9	3/27/2013 16:00	<0.1	<0.005	<0.001	0.10	<0.002	<0.01	<0.05	<0.01	<0.02
Cedar Falls #9 (RS)	6/12/2013 14:00									
Charles City #8	3/25/2013 14:45	<0.1	<0.005	<0.001	0.34	<0.002	<0.01	<0.05	<0.01	1.20
Cherokee #10	4/8/2013 12:30	<0.1	<0.005	0.005	<0.05	<0.002	<0.01	<0.05	<0.01	0.12
Clayton #1	4/10/2013 13:50	<0.1	<0.005	<0.001	0.09	<0.002	<0.01	<0.05	<0.01	0.08
Coralville #10	5/1/2013 13:15	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.51
Coralville #10 (field rep)	5/1/2013 13:15	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.57
De Witt #7	3/11/2013 15:00	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.15
Decorah #7	4/9/2013 13:35	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	<0.02
Dumont #2	4/22/2013 15:35	<0.1	<0.005	<0.001	0.08	<0.002	<0.01	<0.05	<0.01	0.70
Duncombe #4	3/27/2013 12:55	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	<0.02
Elgin #2	4/10/2013 13:15	<0.1	<0.005	<0.001	0.09	<0.002	<0.01	<0.05	<0.01	<0.02
Fairfield #6	4/3/2013 13:15	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.05
Fairfield #6 (field rep)	4/3/2013 13:15	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.05
Fremont #2-88	4/15/2013 15:20	<0.1	<0.005	0.007	0.24	<0.002	<0.01	<0.05	<0.01	1.10
Gilbert #3	4/16/2013 15:30	<0.1	<0.005	0.028	0.81	<0.002	<0.01	<0.05	<0.01	3.70
Independence #3	5/8/2013 12:30	<0.1	<0.005	<0.001	0.07	<0.002	<0.01	<0.05	<0.01	0.09
Independence #7	4/8/2013 13:30	<0.1	<0.005	0.001	0.06	<0.002	<0.01	<0.05	<0.01	0.12
Independence #7 (RS)	6/11/2013 12:50									
Ionia #2	3/25/2013 16:15	<0.1	<0.005	0.006	0.05	<0.002	<0.01	<0.05	<0.01	0.45
Janesville #3	4/2/2013 14:40	<0.1	<0.005	<0.001	0.09	<0.002	<0.01	<0.05	<0.01	<0.02

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

APPENDIX B

Well/Sample Name	Sample Date-Time	Metals (dissolved) (mg/L)								
		Aluminum	Antimony	Arsenic	Barium	Beryllium	Chromium	Cobalt	Copper	Iron
Joice #1	3/26/2013 12:45	<0.1	<0.005	<0.001	0.16	<0.002	<0.01	<0.05	<0.01	1.50
Jolley #1	3/25/2013 14:40	<0.1	<0.005	0.002	<0.05	<0.002	<0.01	<0.05	<0.01	1.80
Knierim #1	3/25/2013 13:40	<0.1	<0.005	<0.001	0.06	<0.002	<0.01	<0.05	<0.01	1.80
Lansing #4	4/9/2013 14:35	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.35
Lyon-Sioux RWS-3	4/2/2013 13:43	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	<0.02
Marshalltown #5	4/15/2013 14:15	<0.1	<0.005	0.001	<0.05	<0.002	<0.01	<0.05	<0.01	2.70
Massena #6	3/13/2013 13:45	<0.1	<0.005	0.017	0.27	<0.002	<0.01	<0.05	<0.01	16.00
Mount Vernon #9	3/18/2013 16:00	<0.1	<0.005	0.004	0.37	<0.002	<0.01	<0.05	<0.01	0.04
Mount Vernon (blank)	3/18/2013 14:45	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	<0.02
Moville #5	4/1/2013 16:10	<0.1	<0.005	<0.001	0.14	<0.002	<0.01	<0.05	<0.01	<0.02
Moville #5 (field rep)	4/1/2013 16:10	<0.1	<0.005	<0.001	0.13	<0.002	<0.01	<0.05	<0.01	<0.02
Nevada #8	4/16/2013 14:15	<0.1	<0.005	0.003	0.27	<0.002	<0.01	<0.05	<0.01	5.50
New Venna #4	3/19/2013 16:00	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.25
Nora Springs #4	4/23/2013 12:05	<0.1	<0.005	<0.001	1.60	<0.002	<0.01	<0.05	<0.01	0.14
Orchardview Est. #1	3/4/2013 12:00	<0.1	<0.005	<0.001	0.12	<0.002	<0.01	<0.05	<0.01	0.10
Perry #22	3/4/2013 15:25	<0.1	<0.005	0.008	0.14	<0.002	<0.01	<0.05	<0.01	2.60
Perry #9R	3/6/2013 15:15	<0.1	<0.005	0.004	0.07	<0.002	<0.01	<0.05	<0.01	1.70
Perry #9R (RS)	6/18/2013 11:00									
Primghar #8	4/3/2013 13:30	<0.1	<0.005	0.005	<0.05	<0.002	<0.01	<0.05	<0.01	3.10
Quimby #3	4/9/2013 12:55	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	1.20
Riverview Estates #1	3/4/2013 14:40	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.08
Rockford #2	4/23/2013 13:05	<0.1	<0.005	<0.001	0.19	<0.002	<0.01	<0.05	<0.01	0.13
Rockford #2 (field rep)	4/23/2013 13:05	<0.1	<0.005	<0.001	0.20	<0.002	<0.01	<0.05	<0.01	0.14
Shelby #6A	4/22/2013 14:30	<0.1	<0.005	0.033	0.81	<0.002	<0.01	<0.05	<0.01	8.20
Shelby #6A (field rep)	4/22/2013 14:30	<0.1	<0.005	0.033	0.81	<0.002	<0.01	<0.05	<0.01	8.10
Sigourney #02-5	4/15/2013 17:00	<0.1	<0.005	0.002	0.20	<0.002	<0.01	<0.05	<0.01	1.20
Sigourney (blank)	4/15/2013 12:45	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	<0.02
Sioux Center #13	4/2/2013 12:42	<0.1	<0.005	<0.001	0.11	<0.002	<0.01	<0.05	<0.01	0.08
Stacyville #3	4/24/2013 13:40	<0.1	<0.005	0.001	0.11	<0.002	<0.01	<0.05	<0.01	1.00
Steamboat Rock #1	4/1/2013 14:35	<0.1	<0.005	<0.001	0.19	<0.002	<0.01	<0.05	<0.01	<0.02
Storm Lake #18	4/8/2013 13:35	<0.1	<0.005	0.002	0.07	<0.002	<0.01	<0.05	<0.01	3.40
Toledo #2	3/12/2013 15:10	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	0.19
Van Meter #3	3/5/2013 15:10	<0.1	<0.005	<0.001	0.13	<0.002	<0.01	<0.05	<0.01	0.07
Van Meter #3 (RS)	6/18/2013 9:00									
Ventura #1	3/26/2013 13:15	<0.1	<0.005	0.001	0.18	<0.002	<0.01	<0.05	<0.01	0.69
Walnut #2	3/18/2013 14:30	<0.1	<0.005	0.002	<0.05	<0.002	<0.01	<0.05	<0.01	0.65
Walnut (blank)	3/18/2013 13:45	<0.1	<0.005	<0.001	<0.05	<0.002	<0.01	<0.05	<0.01	<0.02
Waverly #6	4/2/2013 13:05	<0.1	<0.005	<0.001	0.09	<0.002	<0.01	<0.05	<0.01	<0.02
Waverly #6 (RS)	6/12/2013 10:30									
Winthrop #3	4/17/2013 12:05	<0.1	<0.005	0.005	<0.05	<0.002	<0.01	<0.05	<0.01	1.30
Woodward St. Hos. #2	3/6/2013 13:25	<0.1	<0.005	0.026	1.60	<0.002	<0.01	<0.05	<0.01	1.80

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

APPENDIX B

Well/Sample Name	Sample Date-Time	Metals (dissolved) (mg/L) Lead	Manganese	Nickel	Selenium	Strontium	Thallium	Titanium	Uranium	Vanadium	Zinc
Adel #3	3/5/2013 14:10	<0.001	0.36	<0.05	<0.01	0.28	<0.001	<0.05	0.002	<0.05	0.02
Alburnett #3	3/18/2013 14:00	<0.001	<0.02	<0.05	<0.01	0.29	<0.001	<0.05	<0.001	<0.05	<0.02
Algona #8	3/26/2013 14:15	<0.001	0.08	<0.05	<0.01	0.41	<0.001	<0.05	<0.001	<0.05	<0.02
Altoona #3	4/23/2013 14:30	<0.001	<0.02	<0.05	<0.01	1.20	<0.001	<0.05	<0.001	<0.05	<0.02
Altoona #3 (blank)	4/23/2013 14:00	<0.001	<0.02	<0.05	<0.01	<0.02	<0.001	<0.05	<0.001	<0.05	<0.02
Andover #1	4/29/2013 12:15	<0.001	<0.02	<0.05	<0.01	1.50	<0.001	<0.05	<0.001	<0.05	<0.02
Anita #4	3/13/2013 14:40	<0.001	0.66	<0.05	<0.01	0.69	<0.001	<0.05	0.004	<0.05	<0.02
Atkins #3	3/12/2013 12:45	<0.001	<0.02	<0.05	<0.01	1.00	<0.001	<0.05	<0.001	<0.05	<0.02
Audubon #13	3/12/2013 14:15	<0.001	0.02	<0.05	0.01	0.19	<0.001	<0.05	0.002	<0.05	<0.02
Avoca Reg. Water #19	3/19/2013 15:15	<0.001	0.08	<0.05	<0.01	0.18	<0.001	<0.05	<0.001	<0.05	<0.02
Badger #3	3/26/2013 12:50	<0.001	<0.02	<0.05	<0.01	1.00	<0.001	<0.05	<0.001	<0.05	<0.02
Battle Creek #3	4/9/2013 13:00	<0.001	0.08	<0.05	<0.01	0.46	<0.001	<0.05	<0.001	<0.05	<0.02
Blue Grass #1a	3/20/2013 13:15	<0.001	<0.02	<0.05	<0.01	0.17	<0.001	<0.05	<0.001	<0.05	<0.02
Bristow #2	4/22/2013 15:10	<0.001	<0.02	<0.05	<0.01	0.12	<0.001	<0.05	<0.001	<0.05	<0.02
Calamus 2007	3/11/2013 15:40	<0.001	<0.02	<0.05	<0.01	2.20	<0.001	<0.05	<0.001	<0.05	<0.02
Carson #7	3/19/2013 13:45	<0.001	0.12	<0.05	<0.01	0.68	<0.001	<0.05	<0.001	<0.05	<0.02
Cascade #4	3/13/2013 14:00	<0.001	<0.02	<0.05	<0.01	0.14	<0.001	<0.05	0.002	<0.05	<0.02
Cedar Falls #8	3/27/2013 13:45	<0.001	0.04	<0.05	<0.01	0.59	<0.001	<0.05	<0.001	<0.05	<0.02
Cedar Falls #9	3/27/2013 16:00	<0.001	<0.02	<0.05	<0.01	0.13	<0.001	<0.05	<0.001	<0.05	<0.02
Cedar Falls #9 (RS)	6/12/2013 14:00										
Charles City #8	3/25/2013 14:45	<0.001	<0.02	<0.05	<0.01	3.00	<0.001	<0.05	<0.001	<0.05	<0.02
Cherokee #10	4/8/2013 12:30	<0.001	0.38	<0.05	<0.01	1.50	<0.001	<0.05	<0.001	<0.05	<0.02
Clayton #1	4/10/2013 13:50	0.002	0.06	<0.05	<0.01	0.08	<0.001	<0.05	<0.001	<0.05	<0.02
Coralville #10	5/1/2013 13:15	<0.001	<0.02	<0.05	<0.01	3.20	<0.001	<0.05	<0.001	<0.05	<0.02
Coralville #10 (field rep)	5/1/2013 13:15	<0.001	<0.02	<0.05	<0.01	3.50	<0.001	<0.05	<0.001	<0.05	<0.02
De Witt #7	3/11/2013 15:00	<0.001	<0.02	<0.05	<0.01	2.00	<0.001	<0.05	<0.001	<0.05	<0.02
Decorah #7	4/9/2013 13:35	<0.001	<0.02	<0.05	<0.01	<0.02	<0.001	<0.05	<0.001	<0.05	<0.02
Dumont #2	4/22/2013 15:35	<0.001	<0.02	<0.05	<0.01	1.90	<0.001	<0.05	<0.001	<0.05	<0.02
Duncombe #4	3/27/2013 12:55	<0.001	<0.02	<0.05	0.01	8.50	<0.001	<0.05	<0.001	<0.05	<0.02
Elgin #2	4/10/2013 13:15	<0.001	<0.02	<0.05	<0.01	0.18	<0.001	<0.05	0.002	<0.05	<0.02
Fairfield #6	4/3/2013 13:15	<0.001	<0.02	<0.05	<0.01	2.40	<0.001	<0.05	<0.001	<0.05	<0.02
Fairfield #6 (field rep)	4/3/2013 13:15	<0.001	<0.02	<0.05	<0.01	2.30	<0.001	<0.05	<0.001	<0.05	<0.02
Fremont #2-88	4/15/2013 15:20	0.011	0.16	<0.05	<0.01	0.45	<0.001	<0.05	0.004	<0.05	<0.02
Gilbert #3	4/16/2013 15:30	<0.001	0.09	<0.05	<0.01	0.98	<0.001	<0.05	<0.001	<0.05	<0.02
Independence #3	5/8/2013 12:30	<0.001	<0.02	<0.05	<0.01	0.16	<0.001	<0.05	0.001	<0.05	<0.02
Independence #7	4/8/2013 13:30	<0.001	0.02	<0.05	<0.01	0.22	<0.001	<0.05	<0.001	<0.05	<0.02
Independence #7 (RS)	6/11/2013 12:50										
Ionia #2	3/25/2013 16:15	<0.001	<0.02	<0.05	<0.01	0.51	<0.001	<0.05	<0.001	<0.05	<0.02
Janesville #3	4/2/2013 14:40	<0.001	<0.02	<0.05	<0.01	0.11	<0.001	<0.05	<0.001	<0.05	<0.02

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

Well/Sample Name	Sample Date-Time	Metals (dissolved) (mg/L)									
		Lead	Manganese	Nickel	Selenium	Strontium	Thallium	Titanium	Uranium	Vanadium	Zinc
Joice #1	3/26/2013 12:45	<0.001	0.05	<0.05	<0.01	0.22	<0.001	<0.05	<0.001	<0.05	<0.02
Jolley #1	3/25/2013 14:40	<0.001	0.05	<0.05	<0.01	0.44	<0.001	<0.05	0.002	<0.05	0.03
Knierim #1	3/25/2013 13:40	<0.001	0.06	<0.05	<0.01	1.30	<0.001	<0.05	<0.001	<0.05	<0.02
Lansing #4	4/9/2013 14:35	<0.001	<0.02	<0.05	<0.01	0.21	<0.001	<0.05	<0.001	<0.05	0.02
Lyon-Sioux RWS-3	4/2/2013 13:43	<0.001	<0.02	<0.05	<0.01	0.33	<0.001	<0.05	0.007	<0.05	<0.02
Marshalltown #5	4/15/2013 14:15	<0.001	0.04	<0.05	<0.01	0.94	<0.001	<0.05	<0.001	<0.05	<0.02
Massena #6	3/13/2013 13:45	<0.001	1.20	<0.05	<0.01	0.22	<0.001	<0.05	<0.001	<0.05	0.07
Mount Vernon #9	3/18/2013 16:00	<0.001	<0.02	<0.05	<0.01	0.13	<0.001	<0.05	<0.001	<0.05	<0.02
Mount Vernon (blank)	3/18/2013 14:45	<0.001	<0.02	<0.05	<0.01	<0.02	<0.001	<0.05	<0.001	<0.05	<0.02
Moville #5	4/1/2013 16:10	<0.001	0.05	<0.05	0.01	0.29	<0.001	<0.05	0.005	<0.05	<0.02
Moville #5 (field rep)	4/1/2013 16:10	<0.001	0.05	<0.05	0.01	0.28	<0.001	<0.05	0.005	<0.05	<0.02
Nevada #8	4/16/2013 14:15	<0.001	0.56	<0.05	<0.01	0.20	<0.001	<0.05	<0.001	<0.05	<0.02
New Venna #4	3/19/2013 16:00	<0.001	<0.02	<0.05	<0.01	0.85	<0.001	<0.05	<0.001	<0.05	<0.02
Nora Springs #4	4/23/2013 12:05	<0.001	<0.02	<0.05	<0.01	0.42	<0.001	<0.05	<0.001	<0.05	<0.02
Orchardview Est. #1	3/4/2013 12:00	<0.001	<0.02	<0.05	<0.01	0.35	<0.001	<0.05	<0.001	<0.05	<0.02
Perry #22	3/4/2013 15:25	<0.001	0.14	<0.05	<0.01	0.42	<0.001	<0.05	<0.001	<0.05	<0.02
Perry #9R	3/6/2013 15:15	<0.001	0.41	<0.05	<0.01	0.21	<0.001	<0.05	0.007	<0.05	<0.02
Perry #9R (RS)	6/18/2013 11:00										
Primghar #8	4/3/2013 13:30	<0.001	0.44	<0.05	<0.01	2.70	<0.001	<0.05	0.002	<0.05	<0.02
Quimby #3	4/9/2013 12:55	<0.001	0.17	<0.05	<0.01	1.40	<0.001	<0.05	<0.001	<0.05	<0.02
Riverview Estates #1	3/4/2013 14:40	<0.001	<0.02	<0.05	<0.01	0.57	<0.001	<0.05	<0.001	<0.05	<0.02
Rockford #2	4/23/2013 13:05	<0.001	<0.02	<0.05	<0.01	2.70	<0.001	<0.05	<0.001	<0.05	<0.02
Rockford #2 (field rep)	4/23/2013 13:05	<0.001	<0.02	<0.05	<0.01	2.60	<0.001	<0.05	<0.001	<0.05	<0.02
Shelby #6A	4/22/2013 14:30	<0.001	0.54	<0.05	<0.01	0.38	<0.001	<0.05	<0.001	<0.05	<0.02
Shelby #6A (field rep)	4/22/2013 14:30	<0.001	0.54	<0.05	<0.01	0.37	<0.001	<0.05	<0.001	<0.05	<0.02
Sigourney #02-5	4/15/2013 17:00	<0.001	0.12	<0.05	<0.01	0.23	<0.001	<0.05	<0.001	<0.05	0.03
Sigourney (blank)	4/15/2013 12:45	<0.001	<0.02	<0.05	<0.01	<0.02	<0.001	<0.05	<0.001	<0.05	<0.02
Sioux Center #13	4/2/2013 12:42	<0.001	0.06	<0.05	<0.01	0.57	<0.001	<0.05	0.016	<0.05	<0.02
Stacyville #3	4/24/2013 13:40	<0.001	0.02	<0.05	<0.01	0.23	<0.001	<0.05	<0.001	<0.05	<0.02
Steamboat Rock #1	4/1/2013 14:35	<0.001	<0.02	<0.05	<0.01	0.21	<0.001	<0.05	<0.001	<0.05	<0.02
Storm Lake #18	4/8/2013 13:35	<0.001	0.33	<0.05	<0.01	0.42	<0.001	<0.05	<0.001	<0.05	<0.02
Toledo #2	3/12/2013 15:10	<0.001	<0.02	<0.05	<0.01	2.70	<0.001	<0.05	<0.001	<0.05	<0.02
Van Meter #3	3/5/2013 15:10	<0.001	0.22	<0.05	<0.01	0.35	<0.001	<0.05	0.003	<0.05	<0.02
Van Meter #3 (RS)	6/18/2013 9:00										
Ventura #1	3/26/2013 13:15	<0.001	0.03	<0.05	<0.01	0.27	<0.001	<0.05	<0.001	<0.05	0.03
Walnut #2	3/18/2013 14:30	<0.001	<0.02	<0.05	<0.01	6.10	<0.001	<0.05	<0.001	<0.05	<0.02
Walnut (blank)	3/18/2013 13:45	<0.001	<0.02	<0.05	<0.01	<0.02	<0.001	<0.05	<0.001	<0.05	<0.02
Waverly #6	4/2/2013 13:05	<0.001	<0.02	<0.05	<0.01	0.13	<0.001	<0.05	<0.001	<0.05	<0.02
Waverly #6 (RS)	6/12/2013 10:30										
Winthrop #3	4/17/2013 12:05	<0.001	0.13	<0.05	<0.01	0.71	<0.001	<0.05	<0.001	<0.05	<0.02
Woodward St. Hos. #2	3/6/2013 13:25	<0.001	0.06	<0.05	<0.01	0.71	<0.001	<0.05	<0.001	<0.05	<0.02

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

Well/Sample Name	Sample Date-Time	Viruses & Pathogens (genomic copies/L)												
		Adenovirus C,D,F	Adenovirus A	Adenovirus B	Enterovirus	GI Norovirus	GII Norovirus	Human Polyomavirus	Hepatitis E Virus	Bovine Polyomavirus	Pepper Mild Mottle Virus (PMMV)	*Campylobacter*	*Salmonella*	Enterohemorrhagic *E. coli*
Adel #3	3/5/2013 14:10	0	0	0	0	0	0	0	0	0	0	0	0	0
Alburnett #3	3/18/2013 14:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Algona #8	3/26/2013 14:15	0	0	0	0	0	0	0	0	0	4.64	0	0	0
Altoona #3	4/23/2013 14:30	0	0	0	0	0	0	0	0	0	0	0	0	0
Andover #1	4/29/2013 12:15	0	0	0	0	0	0	0	0	0	0	0	0	0
Andover (blank)	4/29/2013 12:15	0	0	0	0	0	0	0	0	0	0	0	0	0
Anita #4	3/13/2013 14:40	0	0	0	0	0	0	0	0	0	0	0	0	0
Atkins #3	3/12/2013 12:45	0	0	0	0	0	0	0	0	0	0	0	0	0
Audubon #13	3/12/2013 14:15	0	0	0	0	0	0	0	0	0	4.28	0	0	0
Avoca Reg. Water #19	3/19/2013 15:15	0	0	0	0	0	0	0	0	0	0	0	0	0
Badger #3	3/26/2013 12:50	0	0	0	0	0	0	0	0	0	0	0	0	0
Battle Creek #3	4/9/2013 13:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue Grass #1a	3/20/2013 13:15	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue Grass (blank)	3/20/2013 13:15	0	0	0	0	0	0	0	0	0	0	0	0	0
Bristow #2	4/22/2013 15:10	0	0	0	0	0	0	0	0	0	0	0	0	0
Calamus 2007	3/11/2013 15:40	0	0	0	0	0	0	0	0	0	0	0	0	0
Carson #7	3/19/2013 13:45	0	0	0	0	0	0	0	0	0	0	0	0	0
Cascade #4	3/13/2013 14:00	0	0	0	0	0	4.23	0	0	0	0	0	0	0
Cedar Falls #8	3/27/2013 13:45	0	0	0	0	0	0	0	0	0	0	0	0	0
Cedar Falls #9	3/27/2013 16:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Cedar Falls #9 (RS)	6/12/2013 14:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Charles City #8	3/25/2013 14:45	0	0	0	0	0	0	0	0	0	0	0	0	0
Cherokee #10	4/8/2013 12:30	0	0	0	0	0	0	0	0	0	0	0	0	0
Clayton #1	4/10/2013 13:50	0	0	0	0	0	0	0	0	0	0	0	0	0
Clayton (blank)	4/10/2013 13:50	0	0	0	0	0	0	0	0	0	0	0	0	0
Coralville #10	5/1/2013 13:15	0	0	0	0	0	0	0	0	0	0	0	0	0
De Witt #7	3/11/2013 15:00	0	0	0	0	0	0	0	0	0	4.92	0	0	0
Decorah #7	4/9/2013 13:35	0	0	0	0	0	0	0	0	0	3.06	0	0	0
Dumont #2	4/22/2013 15:35	0	0	0	0	0	0	0	0	0	1.33	0	0	0
Duncombe #4	3/27/2013 12:55	0	0	0	0	0	0	0	0	0	0	0	0	0
Elgin #2	4/10/2013 13:15	0	0	0	0	0	0	0	0	0	0	0	0	0
Fairfield #6	4/3/2013 13:15	0	0	0	0	0	0	0	0	0	0	0	0	0
Fremont #2-88	4/15/2013 15:20	0	0	0	0	0	0	0	0	0	0	0	0	0
Gilbert #3	4/16/2013 15:30	0	0	0	0	0	0	0	0	0	0	0	0	0
Independence #3	5/8/2013 12:30	0	0	0	0	0	0	0	0	0	1.12	0	0	0
Independence #7	4/8/2013 13:30	0	0	0	0	0	0	0	0	0	0	0	0	0
Independence #7 (RS)	6/11/2013 12:50	0	0	0	0	0	0	0	0	0	0	0	0	0
Ionia #2	3/25/2013 16:15	0	0	0	0	0	0	3.07	0	0	0	0	0	0
Janesville #3	4/2/2013 14:40	0	0	0	0	0	0	0	0	0	2.64	0	0	0

blank = field blank

RS = samples obtained during the June resampling period

APPENDIX B

Well/Sample Name	Sample Date-Time	Viruses & Pathogens (genomic copies/L)												
		Adenovirus C,D,F	Adenovirus A	Adenovirus B	Enterovirus	GI Norovirus	GII Norovirus	Human Polyomavirus	Hepatitis E Virus	Bovine Polyomavirus	Pepper Mild Mottle Virus (PMMV)	*Campylobacter*	*Salmonella*	Enterohemorrhagic *E. coli*
Joice #1	3/26/2013 12:45	0	0	0	0	0	0	0	0	0	0	0.40	0	0
Jolley #1	3/25/2013 14:40	0	0	0	0	0	0	0	0	0	0	0	0	0
Knierim #1	3/25/2013 13:40	0	0	0	0	0	0	0	0	0	6.38	0	0	0
Lansing #4	4/9/2013 14:35	0	0	0	0	0	0	0	0	0	0	0	0	0
Lyon-Sioux RWS-3	4/2/2013 13:43	0	0	0	0	0	0	0	0	0	0	0	0	0
Marshalltown #5	4/15/2013 14:15	0	0	0	0	0	0	0	0	0	0	0	0	0
Massena #6	3/13/2013 13:45	0	0	0	0	0	0	0	0	0.46	0	0	0	0
Mount Vernon #9	3/18/2013 16:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Moville #5	4/1/2013 16:10	0	0	0	0	0	0	0	0	0	0	0	0	0
Nevada #8	4/16/2013 14:15	0	0	0	0	0	0	0	0	0	0	0	0	0
New Venna #4	3/19/2013 16:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Nora Springs #4	4/23/2013 12:05	0	0	0	0	0	0	0	0	0	0	0	0	0
Orchardview Est. #1	3/4/2013 12:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Perry #22	3/4/2013 15:25	0	0	0	0	0	0	0	0	0	3.26	0	0	0
Perry #9R	3/6/2013 15:15	0	0	0	0	0	0	0	0	0	4.30	0	0	0
Perry #9R (RS)	6/18/2013 11:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Primghar #8	4/3/2013 13:30	0	0	0	0	0	0	0	0	0	0	0	0	0
Quimby #3	4/9/2013 12:55	0	0	0	0	0	0	0	0	0	0	0	0	0
Riverview Estates #1	3/4/2013 14:40	0	0	0	0	0	0	0	0	0	0	0	0	0
Rockford #2	4/23/2013 13:05	0	0	0	0	0	0	0	0	0	0	0	0	0
Shelby #6A	4/22/2013 14:30	0	0	0	0	0	0	0	0	0	0	0	0	0
Sigourney #02-5	4/15/2013 17:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Sioux Center #13	4/2/2013 12:42	0	0	0	0	0	0	0	0	0	0	0	0	0
Stacyville #3	4/24/2013 13:40	0	0	0	0	0	0	0	0	0	0	0	0	0
Steamboat Rock #1	4/1/2013 14:35	0	0	0	0	0	0	0	0	0	0	0	0	0
Storm Lake #18	4/8/2013 13:35	0	0	0	0	0	0	0	0	0	0	0	0	0
Toledo #2	3/12/2013 15:10	0	0	0	0	0	0	0	0	0	0	0	0	0
Van Meter #3	3/5/2013 15:10	0	0	0	0	0	0	0	0	0	0	0	0	0
Van Meter #3 (RS)	6/18/2013 9:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Ventura #1	3/26/2013 13:15	0	0	0	0	0	0	0	0	0	0	0	0	0
Walnut #2	3/18/2013 14:30	0	0	0	0	0	0	0	0	0	0	0	0	0
Waverly #6	4/2/2013 13:05	0	0	0	0	0	0	0	0	0	4.73	0	0	0
Waverly #6 (RS)	6/12/2013 10:30	0	0	0	0	0	0	0	0	0	0	0	0	0
Winthrop #3	4/17/2013 12:05	0	0	0	0	0	0	0	0	0	0	0	0	0
Woodward St. Hos. #2	3/6/2013 13:25	0	0	0	0	0	0	0	0	0	0	0	0	0

RS = samples obtained during the June resampling period

APPENDIX B

Microbial Indicators

Well/Sample Name	Sample Date-Time	Coliphage Male Specific (PFU/100mL)	Coliphage Somatic (PFU/100mL)	*E.coli* (MPN/ 100mL)	Enterococci (MPN/ 100mL)	Total Coliform Bacteria (MPN/100mL)
Adel #3	3/5/2013 14:10	<1.0	<1.0	<1.0	<1.0	<1.0
Alburnett #3	3/18/2013 14:00	<1.0	<1.0	<1.0	<1.0	<1.0
Algona #8	3/26/2013 14:15	<1.0	<1.0	<1.0	<1.0	<1.0
Altoona #3	4/23/2013 14:30	<1.0	<1.0	<1.0	<1.0	<1.0
Altoona #3 (blank)	4/23/2013 14:00	<1.0	<1.0	<1.0	<1.0	<1.0
Andover #1	4/29/2013 12:15	<1.0	<1.0	<1.0	<1.0	<1.0
Anita #4	3/13/2013 14:40	<1.0	<1.0	<1.0	<1.0	<1.0
Atkins #3	3/12/2013 12:45	<1.0	<1.0	<1.0	<1.0	<1.0
Audubon #13	3/12/2013 14:15	<1.0	<1.0	<1.0	<1.0	<1.0
Avoca Reg. Water #19	3/19/2013 15:15	<1.0	<1.0	<1.0	<1.0	<1.0
Badger #3	3/26/2013 12:50	<1.0	<1.0	<1.0	<1.0	<1.0
Battle Creek #3	4/9/2013 13:00	<1.0	<1.0	<1.0	<1.0	<1.0
Blue Grass #1a	3/20/2013 13:15	<1.0	<1.0	<1.0	<1.0	<1.0
Bristow #2	4/22/2013 15:10	<1.0	<1.0	<1.0	<1.0	<1.0
Calamus 2007	3/11/2013 15:40	<1.0	<1.0	<1.0	<1.0	<1.0
Carson #7	3/19/2013 13:45	<1.0	<1.0	<1.0	<1.0	1.00
Cascade #4	3/13/2013 14:00	<1.0	<1.0	<1.0	<1.0	<1.0
Cedar Falls #8	3/27/2013 13:45	<1.0	<1.0	<1.0	<1.0	<1.0
Cedar Falls #9	3/27/2013 16:00	<1.0	<1.0	<1.0	<1.0	<1.0
Cedar Falls #9 (RS)	6/12/2013 14:00			<1.0	<1.0	<1.0
Charles City #8	3/25/2013 14:45	<1.0	<1.0	<1.0	<1.0	<1.0
Cherokee #10	4/8/2013 12:30	<1.0	<1.0	<1.0	<1.0	<1.0
Clayton #1	4/10/2013 13:50	<1.0	<1.0	<1.0	<1.0	<1.0
Coralville #10	5/1/2013 13:15	<1.0	<1.0	<1.0	<1.0	<1.0
Coralville #10 (field rep)	5/1/2013 13:15	<1.0	<1.0	<1.0	<1.0	<1.0
De Witt #7	3/11/2013 15:00	<1.0	<1.0	<1.0	<1.0	<1.0
Decorah #7	4/9/2013 13:35	<1.0	<1.0	<1.0	<1.0	<1.0
Dumont #2	4/22/2013 15:35	<1.0	<1.0	<1.0	<1.0	<1.0
Duncombe #4	3/27/2013 12:55	<1.0	<1.0	<1.0	<1.0	<1.0
Elgin #2	4/10/2013 13:15	<1.0	<1.0	<1.0	<1.0	<1.0
Fairfield #6	4/3/2013 13:15	<1.0	<1.0	<1.0	1.0	<1.0
Fairfield #6 (field rep)	4/3/2013 13:15	<1.0	<1.0	<1.0	1.0	<1.0
Fremont #2-88	4/15/2013 15:20	<1.0	<1.0	<1.0	<1.0	<1.0
Gilbert #3	4/16/2013 15:30	<1.0	<1.0	<1.0	<1.0	<1.0
Independence #3	5/8/2013 12:30	<1.0	<1.0	<1.0	<1.0	<1.0
Independence #7	4/8/2013 13:30	<1.0	<1.0	<1.0	<1.0	<1.0
Independence #7 (RS)	6/11/2013 12:50			<1.0	<1.0	<1.0
Ionia #2	3/25/2013 16:15	<1.0	<1.0	<1.0	<1.0	<1.0
Janesville #3	4/2/2013 14:40	3.0	<1.0	<1.0	<1.0	<1.0

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

Microbial Indicators

Well/Sample Name	Sample Date-Time	Coliphage Male Specific (PFU/100mL)	Coliphage Somatic (PFU/100mL)	*E.coli* (MPN/ 100mL)	Enterococci (MPN/ 100mL)	Total Coliform Bacteria (MPN/100mL)
Joice #1	3/26/2013 12:45	<1.0	<1.0	<1.0	<1.0	<1.0
Jolley #1	3/25/2013 14:40	<1.0	<1.0	<1.0	<1.0	<1.0
Knierim #1	3/25/2013 13:40	<1.0	<1.0	<1.0	<1.0	<1.0
Lansing #4	4/9/2013 14:35	<1.0	<1.0	<1.0	<1.0	<1.0
Lyon-Sioux RWS-3	4/2/2013 13:43	<1.0	<1.0	<1.0	<1.0	<1.0
Marshalltown #5	4/15/2013 14:15	<1.0	<1.0	<1.0	<1.0	<1.0
Massena #6	3/13/2013 13:45	<1.0	<1.0	<1.0	<1.0	<1.0
Mount Vernon #9	3/18/2013 16:00	<1.0	<1.0	<1.0	<1.0	<1.0
Mount Vernon #9 (blank)	3/18/2013 14:45	<1.0	<1.0	<1.0	<1.0	<1.0
Moville #5	4/1/2013 16:10	<1.0	<1.0	<1.0	<1.0	<1.0
Moville #5 (field rep)	4/1/2013 16:10	<1.0	<1.0	<1.0	<1.0	<1.0
Nevada #8	4/16/2013 14:15	<1.0	<1.0	<1.0	<1.0	<1.0
New Venna #4	3/19/2013 16:00	<1.0	<1.0	<1.0	<1.0	<1.0
Nora Springs #4	4/23/2013 12:05	<1.0	<1.0	<1.0	<1.0	1.0
Orchardview Est. #1	3/4/2013 12:00	<1.0	<1.0	<1.0	<1.0	<1.0
Perry #22	3/4/2013 15:25	<1.0	<1.0	<1.0	<1.0	<1.0
Perry #9R	3/6/2013 15:15	<1.0	<1.0	<1.0	<1.0	<1.0
Perry #9R (RS)	6/18/2013 11:00			<1.0	<1.0	4.1
Primghar #8	4/3/2013 13:30	<1.0	<1.0	<1.0	<1.0	<1.0
Quimby #3	4/9/2013 12:55	<1.0	<1.0	<1.0	<1.0	<1.0
Riverview Estates #1	3/4/2013 14:40	<1.0	<1.0	<1.0	<1.0	<1.0
Rockford #2	4/23/2013 13:05	<1.0	<1.0	<1.0	<1.0	<1.0
Rockford #2 (field rep)	4/23/2013 13:05	<1.0	<1.0	<1.0	<1.0	<1.0
Shelby #6A	4/22/2013 14:30	<1.0	<1.0	<1.0	<1.0	<1.0
Shelby #6A (field rep)	4/22/2013 14:30	<1.0	<1.0	<1.0	<1.0	<1.0
Sigourney #02-5	4/15/2013 17:00	<1.0	<1.0	<1.0	<1.0	<1.0
Sigourney (blank)	4/15/2013 12:45	<1.0	<1.0	<1.0	<1.0	<1.0
Sioux Center #13	4/2/2013 12:42	<1.0	<1.0	<1.0	<1.0	<1.0
Stacyville #3	4/24/2013 13:40	<1.0	<1.0	<1.0	<1.0	<1.0
Steamboat Rock #1	4/1/2013 14:35	<1.0	<1.0	<1.0	<1.0	<1.0
Storm Lake #18	4/8/2013 13:35	<1.0	<1.0	<1.0	<1.0	<1.0
Toledo #2	3/12/2013 15:10	<1.0	<1.0	<1.0	<1.0	<1.0
Van Meter #3	3/5/2013 15:10	<1.0	<1.0	<1.0	<1.0	<1.0
Van Meter #3 (RS)	6/18/2013 9:00			<1.0	<1.0	<1.0
Ventura #1	3/26/2013 13:15	<1.0	<1.0	<1.0	<1.0	<1.0
Walnut #2	3/18/2013 14:30	<1.0	<1.0	<1.0	<1.0	<1.0
Walnut (blank)	3/18/2013 13:45	<1.0	<1.0	<1.0	<1.0	<1.0
Waverly #6	4/2/2013 13:05	<1.0	<1.0	<1.0	<1.0	<1.0
Waverly #6 (RS)	6/12/2013 10:30			<1.0	<1.0	<1.0
Winthrop #3	4/17/2013 12:05	<1.0	<1.0	<1.0	<1.0	<1.0
Woodward St. Hos. #2	3/6/2013 13:25	<1.0	<1.0	<1.0	<1.0	<1.0

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

Well/Sample Name	Sample Date-Time	Pesticides and Pesticide Degradates (µg/L) Analyzed by USGS: Atrazine using the pharm method	Glyphosate	Aminomethyl-phosphonic acid (AMPA)	Glufosinate
Adel #3	3/5/2013 14:10				
Alburnett #3	3/18/2013 14:00	<0.02	<0.02	<0.02	<0.02
Algona #8	3/26/2013 14:15	<0.02	<0.02	<0.02	<0.02
Algona #8 (field rep)	3/26/2013 14:20	<0.02	<0.02	<0.02	<0.02
Altoona #3	4/23/2013 14:30				
Andover #1	4/29/2013 12:15	<0.02	<0.02	<0.02	<0.02
Anita #4	3/13/2013 14:40				
Atkins #3	3/12/2013 12:45	<0.02	<0.02	<0.02	<0.02
Audubon #13	3/12/2013 14:15	<0.02	<0.02	0.02	<0.02
Audubon #13 (field rep)	3/12/2013 14:20	<0.02	<0.02	0.02	<0.02
Avoca Reg. Water #19	3/19/2013 15:15	<0.02	<0.02	<0.02	<0.02
Badger #3	3/26/2013 12:50	<0.02	<0.02	<0.02	<0.02
Battle Creek #3	4/9/2013 13:00	<0.02	<0.02	<0.02	<0.02
Blue Grass #1a	3/20/2013 13:15	<0.02	<0.02	<0.02	<0.02
Bristow #2	4/22/2013 15:10	det	<0.02	<0.02	<0.02
Calamus 2007	3/11/2013 15:40	<0.02	<0.02	<0.02	<0.02
Carson #7	3/19/2013 13:45	<0.02	<0.02	<0.02	<0.02
Cascade #4	3/13/2013 14:00	det	<0.02	0.02	<0.02
Cedar Falls #8	3/27/2013 13:45	<0.02	<0.02	<0.02	<0.02
Cedar Falls #9	3/27/2013 16:00				
Cedar Falls #9 (RS)	6/12/2013 14:00	<0.02	<0.02	<0.02	<0.02
Charles City #8	3/25/2013 14:45	<0.02	<0.02	<0.02	<0.02
Cherokee #10	4/8/2013 12:30	<0.02	<0.02	<0.02	<0.02
Clayton #1	4/10/2013 13:50	<0.02	<0.02	<0.02	<0.02
Coralville #10	5/1/2013 13:15				
De Witt #7	3/11/2013 15:00	<0.02	<0.02	<0.02	<0.02
Decorah #7	4/9/2013 13:35	0.05	<0.02	<0.02	<0.02
Decorah #7 (field rep)	4/9/2013 13:40	0.04	<0.02	<0.02	<0.02
Dumont #2	4/22/2013 15:35	<0.02	<0.02	<0.02	<0.02
Duncombe #4	3/27/2013 12:55	<0.02	<0.02	<0.02	<0.02
Elgin #2	4/10/2013 13:15	<0.02	<0.02	<0.02	<0.02
Fairfield #6	4/3/2013 13:15	<0.02	<0.02	<0.02	<0.02
Fremont #2-88	4/15/2013 15:20	<0.02	<0.02	<0.02	<0.02
Gilbert #3	4/16/2013 15:30	<0.02	<0.02	<0.02	<0.02
Independence #3	5/8/2013 12:30	det	<0.02	<0.02	<0.02
Independence #7	4/8/2013 13:30	<0.02	<0.02	<0.02	<0.02
Independence #7 (RS)	6/11/2013 12:50	det	<0.02	<0.02	<0.02
Ionia #2	3/25/2013 16:15	<0.02	<0.02	<0.02	<0.02
Janesville #3	4/2/2013 14:40	0.04	<0.02	<0.02	<0.02

RS = samples obtained during the June resampling period

field rep = field replicate

APPENDIX B

Well/Sample Name	Sample Date-Time	Pesticides and Pesticide Degradates (µg/L) Analyzed by USGS: Atrazine using the pharm method	Glyphosate	Aminomethyl-phosphonic acid (AMPA)	Glufosinate
Joice #1	3/26/2013 12:45				
Jolley #1	3/25/2013 14:40	<0.02	<0.02	<0.02	<0.02
Knierim #1	3/25/2013 13:40	<0.02	<0.02	<0.02	<0.02
Lansing #4	4/9/2013 14:35	<0.02	<0.02	<0.02	<0.02
Lyon-Sioux RWS-3	4/2/2013 13:43	0.02	<0.02	<0.02	<0.02
Marshalltown #5	4/15/2013 14:15	<0.02	<0.02	<0.02	<0.02
Massena #6	3/13/2013 13:45	<0.02	<0.02	<0.02	<0.02
Mount Vernon #9	3/18/2013 16:00	<0.02	<0.02	<0.02	<0.02
Mount Vernon #9 (field rep)	3/18/2013 16:05	<0.02	<0.02	<0.02	<0.02
Moville #5	4/1/2013 16:10	<0.02	<0.02	<0.02	<0.02
Nevada #8	4/16/2013 14:15	<0.02	<0.02	<0.02	<0.02
Nevada #8 (blank)	4/16/2013 14:20	<0.02	<0.02	<0.02	<0.02
New Venna #4	3/19/2013 16:00	<0.02	<0.02	<0.02	<0.02
Nora Springs #4	4/23/2013 12:05	<0.02	<0.02	<0.02	<0.02
Orchardview Est. #1	3/4/2013 12:00	<0.02	<0.02	<0.02	<0.02
Perry #22	3/4/2013 15:25	<0.02	<0.02	<0.02	<0.02
Perry #9R	3/6/2013 15:15	<0.02	<0.02	<0.02	<0.02
Perry #9R (RS)	6/18/2013 11:00	0.13	<0.02	<0.02	<0.02
Primghar #8	4/3/2013 13:30	<0.02	<0.02	<0.02	<0.02
Quimby #3	4/9/2013 12:55	<0.02	<0.02	<0.02	<0.02
Riverview Estates #1	3/4/2013 14:40	<0.02	<0.02	<0.02	<0.02
Rockford #2	4/23/2013 13:05	<0.02	<0.02	<0.02	<0.02
Shelby #6A	4/22/2013 14:30	<0.02	<0.02	<0.02	<0.02
Sigourney #02-5	4/15/2013 17:00	<0.02	<0.02	<0.02	<0.02
Sioux Center #13	4/2/2013 12:42	<0.02	<0.02	<0.02	<0.02
Stacyville #3	4/24/2013 13:40	<0.02	<0.02	<0.02	<0.02
Steamboat Rock #1	4/1/2013 14:35	<0.02	<0.02	<0.02	<0.02
Storm Lake #18	4/8/2013 13:35	<0.02	<0.02	<0.02	<0.02
Toledo #2	3/12/2013 15:10	<0.02	<0.02	<0.02	<0.02
Van Meter #3	3/5/2013 15:10				
Van Meter #3 (RS)	6/18/2013 9:00	<0.02	<0.02	<0.02	<0.02
Van Meter #3 (RS) (field rep)	6/18/2013 9:05	<0.02			
Ventura #1	3/26/2013 13:15				
Walnut #2	3/18/2013 14:30	<0.02	<0.02	<0.02	<0.02
Waverly #6	4/2/2013 13:05	0.03	<0.02	<0.02	<0.02
Waverly #6 (RS)	6/12/2013 10:30	0.04	<0.02	<0.02	<0.02
Winthrop #3	4/17/2013 12:05	<0.02*	<0.02	<0.02	<0.02
Winthrop #3 (blank)	4/17/2013 12:10	<0.02*	<0.02	<0.02	<0.02
Woodward St. Hos. #2	3/6/2013 13:25	<0.02	<0.02	<0.02	<0.02

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

*USGS pharmaceutical analyses were run on a frozen field replicate collected 1 minute later

APPENDIX B

Pesticides and Pesticide Degradates
(µg/L)
Analyzed by SHL

Well/Sample Name	Sample Date-Time	Acetochlor	Acetochlor ESA	Acetochlor OXA	Alachlor	Alachlor ESA	Alachlor OXA	Dimethenamid	Dimethenamid ESA	Dimethenamid OXA	Metolachlor	Metolachlor ESA	Metolachlor OXA
Adel #3	3/5/2013 14:10	<0.025	0.120	0.082	<0.025	0.041	<0.025	<0.025	<0.025	<0.025	<0.025	0.250	0.067
Alburnett #3	3/18/2013 14:00	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Algona #8	3/26/2013 14:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Altoona #3	4/23/2013 14:30	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Altoona #3 (blank)	4/23/2013 14:00	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Andover #1	4/29/2013 12:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Anita #4	3/13/2013 14:40	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Atkins #3	3/12/2013 12:45	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Audubon #13	3/12/2013 14:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.030	0.035	<0.025	<0.025	0.200	<0.025
Avoca Reg. Water #19	3/19/2013 15:15	<0.025	0.058	0.039	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.093	<0.025
Badger #3	3/26/2013 12:50	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Battle Creek #3	4/9/2013 13:00	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.050	<0.025
Blue Grass #1a	3/20/2013 13:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Bristow #2	4/22/2013 15:10	<0.025	<0.025	<0.025	<0.025	0.093	<0.025	<0.025	<0.025	<0.025	<0.025	0.075	<0.025
Calamus 2007	3/11/2013 15:40	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Carson #7	3/19/2013 13:45	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Cascade #4	3/13/2013 14:00	<0.025	0.032	<0.025	<0.025	0.120	<0.025	<0.025	<0.025	<0.025	<0.025	1.000	<0.025
Cedar Falls #8	3/27/2013 13:45	<0.025	<0.025	<0.025	<0.025	0.220	<0.025	<0.025	<0.025	<0.025	<0.025	0.360	<0.025
Cedar Falls #9	3/27/2013 16:00	<0.025	<0.025	<0.025	<0.025	0.410	<0.025	<0.025	<0.025	<0.025	<0.025	1.200	<0.025
Cedar Falls #9 (RS)	6/12/2013 14:00												
Charles City #8	3/25/2013 14:45	<0.025	<0.025	<0.025	<0.025	0.130	<0.025	<0.025	<0.025	<0.025	<0.025	0.260	<0.025
Cherokee #10	4/8/2013 12:30	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Clayton #1	4/10/2013 13:50	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Coralville #10	5/1/2013 13:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Coralville #10 (field rep)	5/1/2013 13:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
De Witt #7	3/11/2013 15:00	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Decorah #7	4/9/2013 13:35	<0.025	0.035	<0.025	<0.025	0.070	<0.025	<0.025	<0.025	<0.025	<0.025	0.170	<0.025
Dumont #2	4/22/2013 15:35	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Duncombe #4	3/27/2013 12:55	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Elgin #2	4/10/2013 13:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.230	<0.025
Fairfield #6	4/3/2013 13:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Fairfield #6 (field rep)	4/3/2013 13:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Fremont #2-88	4/15/2013 15:20	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Gilbert #3	4/16/2013 15:30	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Independence #3	5/8/2013 12:30	<0.025	0.044	<0.025	<0.025	0.740	<0.025	<0.025	<0.025	<0.025	<0.025	0.140	<0.025
Independence #7	4/8/2013 13:30	<0.025	0.045	<0.025	<0.025	0.780	0.110	<0.025	<0.025	<0.025	<0.025	0.230	0.035
Independence #7 (RS)	6/11/2013 12:50												
Ionia #2	3/25/2013 16:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Janesville #3	4/2/2013 14:40	<0.025	0.051	<0.025	<0.025	0.730	<0.025	<0.025	<0.025	<0.025	<0.025	0.280	<0.025

blank = field blank
RS = samples obtained during the June resampling period
field rep = field replicate

APPENDIX B

Pesticides and Pesticide Degradates
(µg/L)
Analyzed by SHL

Well/Sample Name	Sample Date-Time	Acetochlor	Acetochlor ESA	Acetochlor OXA	Alachlor	Alachlor ESA	Alachlor OXA	Dimethenamid	Dimethenamid ESA	Dimethenamid OXA	Metolachlor	Metolachlor ESA	Metolachlor OXA
Joice #1	3/26/2013 12:45	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Jolley #1	3/25/2013 14:40	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Knierim #1	3/25/2013 13:40	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Lansing #4	4/9/2013 14:35	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Lyon-Sioux RWS-3	4/2/2013 13:43	<0.025	0.082	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.520	0.048
Marshalltown #5	4/15/2013 14:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Massena #6	3/13/2013 13:45	<0.025	<0.025	<0.025	<0.025	0.062	<0.025	<0.025	<0.025	<0.025	<0.025	0.130	0.034
Mount Vernon #9	3/18/2013 16:00	<0.025	<0.025	<0.025	<0.025	0.052	<0.025	<0.025	<0.025	<0.025	<0.025	0.032	<0.025
Mount Vernon #9 (blank)	3/18/2013 14:45	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Moville #5	4/1/2013 16:10	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Moville #5 (field rep)	4/1/2013 16:10	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Nevada #8	4/16/2013 14:15	<0.025	0.120	0.048	<0.025	0.570	0.040	<0.025	<0.025	<0.025	<0.025	0.690	0.190
New Venna #4	3/19/2013 16:00	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Nora Springs #4	4/23/2013 12:05	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Orchardview Est. #1	3/4/2013 12:00	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.088	<0.025
Perry #22	3/4/2013 15:25	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Perry #9R	3/6/2013 15:15	<0.025	0.085	<0.025	<0.025	0.170	<0.025	<0.025	<0.025	<0.025	<0.025	0.210	<0.025
Perry #9R (RS)	6/18/2013 11:00												
Primghar #8	4/3/2013 13:30	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Quimby #3	4/9/2013 12:55	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Riverview Estates #1	3/4/2013 14:40	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Rockford #2	4/23/2013 13:05	<0.025	<0.025	<0.025	<0.025	0.037	<0.025	<0.025	<0.025	<0.025	<0.025	0.053	<0.025
Rockford #2 (field rep)	4/23/2013 13:05	<0.025	<0.025	<0.025	<0.025	0.036	<0.025	<0.025	<0.025	<0.025	<0.025	0.051	<0.025
Shelby #6A	4/22/2013 14:30	<0.025	<0.025	<0.025	<0.025	0.036	<0.025	<0.025	<0.025	<0.025	<0.025	0.350	0.040
Shelby #6A (field rep)	4/22/2013 14:30	<0.025	<0.025	<0.025	<0.025	0.038	<0.025	<0.025	<0.025	<0.025	<0.025	0.340	0.038
Sigourney #02-5	4/15/2013 17:00	<0.025	<0.025	<0.025	<0.025	0.055	<0.025	<0.025	<0.025	<0.025	<0.025	0.170	0.059
Sigourney #02-5 (blank)	4/15/2013 12:45	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Sioux Center #13	4/2/2013 12:42	<0.025	0.077	0.093	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.800	0.120
Stacyville #3	4/24/2013 13:40	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Steamboat Rock #1	4/1/2013 14:35	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.040	<0.025
Storm Lake #18	4/8/2013 13:35	<0.025	0.240	0.290	<0.025	0.087	0.046	<0.025	<0.025	<0.025	<0.025	0.410	0.140
Toledo #2	3/12/2013 15:10	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Van Meter #3	3/5/2013 15:10	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Van Meter #3 (RS)	6/18/2013 9:00												
Ventura #1	3/26/2013 13:15	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Walnut #2	3/18/2013 14:30	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Walnut #2 (blank)	3/18/2013 13:45	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Waverly #6	4/2/2013 13:05	<0.025	0.038	<0.025	<0.025	0.780	<0.025	<0.025	<0.025	<0.025	<0.025	0.300	<0.025
Waverly #6 (RS)	6/12/2013 10:30												
Winthrop #3	4/17/2013 12:05	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Woodward St. Hos. #2	3/6/2013 13:25	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025

blank = field blank
RS = samples obtained during the June resampling period
field rep = field replicate

Pesticides and Pesticide Degradates

(µg/L)

Analyzed by SHL

Well/Sample Name	Sample Date-Time	Ametryn	Atrazine	Desethyl Atrazine	Deisopropyl Atrazine	Bromacil	Butachlor	Butylate	Carbaryl	Carbofuran	Clomazone	Cyanazine	EPTC	Metribuzin	Pendimethalin	Prometon	Propachlor	Propazine	Simazine	Triallat	Trifluralin
Adel #3	3/5/2013 14:10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Alburnett #3	3/18/2013 14:00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Algona #8	3/26/2013 14:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Altoona #3	4/23/2013 14:30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Altoona #3 (blank)	4/23/2013 14:00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Andover #1	4/29/2013 12:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Anita #4	3/13/2013 14:40	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Atkins #3	3/12/2013 12:45	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Audubon #13	3/12/2013 14:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Avoca Reg. Water #19	3/19/2013 15:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Badger #3	3/26/2013 12:50	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Battle Creek #3	4/9/2013 13:00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Blue Grass #1a	3/20/2013 13:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bristow #2	4/22/2013 15:10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Calamus 2007	3/11/2013 15:40	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Carson #7	3/19/2013 13:45	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cascade #4	3/13/2013 14:00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cedar Falls #8	3/27/2013 13:45	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cedar Falls #9	3/27/2013 16:00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cedar Falls #9 (RS)	6/12/2013 14:00																				
Charles City #8	3/25/2013 14:45	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cherokee #10	4/8/2013 12:30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Clayton #1	4/10/2013 13:50	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Coralville #10	5/1/2013 13:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Coralville #10 (field rep)	5/1/2013 13:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
De Witt #7	3/11/2013 15:00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Decorah #7	4/9/2013 13:35	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dumont #2	4/22/2013 15:35	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Duncombe #4	3/27/2013 12:55	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Elgin #2	4/10/2013 13:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Fairfield #6	4/3/2013 13:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Fairfield #6 (field rep)	4/3/2013 13:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Fremont #2-88	4/15/2013 15:20	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Gilbert #3	4/16/2013 15:30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Independence #3	5/8/2013 12:30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Independence #7	4/8/2013 13:30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Independence #7 (RS)	6/11/2013 12:50																				
Ionia #2	3/25/2013 16:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Janesville #3	4/2/2013 14:40	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

APPENDIX B

Pesticides and Pesticide Degradates
(µg/L)
Analyzed by SHL

Well/Sample Name	Sample Date-Time	Ametryn	Atrazine	Desethyl Atrazine	Deisopropyl Atrazine	Bromacil	Butachlor	Butylate	Carbaryl	Carbofuran	Clomazone	Cyanazine	EPTC	Metribuzin	Pendimethalin	Prometon	Propachlor	Propazine	Simazine	Triallat	Trifluralin
Joice #1	3/26/2013 12:45	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Jolley #1	3/25/2013 14:40	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Knierim #1	3/25/2013 13:40	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lansing #4	4/9/2013 14:35	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lyon-Sioux RWS-3	4/2/2013 13:43	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Marshalltown #5	4/15/2013 14:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Massena #6	3/13/2013 13:45	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mount Vernon #9	3/18/2013 16:00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mount Vernon #9 (blank)	3/18/2013 14:45	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Moville #5	4/1/2013 16:10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Moville #5 (field rep)	4/1/2013 16:10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nevada #8	4/16/2013 14:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
New Venna #4	3/19/2013 16:00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nora Springs #4	4/23/2013 12:05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Orchardview Est. #1	3/4/2013 12:00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Perry #22	3/4/2013 15:25	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Perry #9R	3/6/2013 15:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Perry #9R (RS)	6/18/2013 11:00																				
Primghar #8	4/3/2013 13:30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Quimby #3	4/9/2013 12:55	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Riverview Estates #1	3/4/2013 14:40	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Rockford #2	4/23/2013 13:05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Rockford #2 (field rep)	4/23/2013 13:05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Shelby #6A	4/22/2013 14:30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Shelby #6A (field rep)	4/22/2013 14:30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sigourney #02-5	4/15/2013 17:00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sigourney #02-5 (blank)	4/15/2013 12:45	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sioux Center #13	4/2/2013 12:42	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Stacyville #3	4/24/2013 13:40	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Steamboat Rock #1	4/1/2013 14:35	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Storm Lake #18	4/8/2013 13:35	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Toledo #2	3/12/2013 15:10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Van Meter #3	3/5/2013 15:10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Van Meter #3 (RS)	6/18/2013 9:00																				
Ventura #1	3/26/2013 13:15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Walnut #2	3/18/2013 14:30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Walnut #2 (blank)	3/18/2013 13:45	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Waverly #6	4/2/2013 13:05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Waverly #6 (RS)	6/12/2013 10:30																				
Winthrop #3	4/17/2013 12:05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Woodward St. Hos. #2	3/6/2013 13:25	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

blank = field blank
RS = samples obtained during the June resampling period
field rep = field replicate

		Detected Pharmaceuticals (ng/L)													
Well/Sample Name	Sample Date-Time	acetaminophen	atenolol	caffeine	1,7-dimethylxanthine	carisoprodol	chlorpheniramine	diphenhydramine	lidocaine	nicotine	cotinine	sulfamethoxazole	thiabendazole	tramadol	warfarin
Adel #3	3/5/2013 14:10														
Alburnett #3	3/18/2013 14:00	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Algona #8	3/26/2013 14:15	<7.13	<13.3	det	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Algona #8 (field rep)	3/26/2013 14:20	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Altoona #3	4/23/2013 14:30														
Andover #1	4/29/2013 12:15	<7.13	<13.3	173	det	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Anita #4	3/13/2013 14:40														
Atkins #3	3/12/2013 12:45	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Audubon #13	3/12/2013 14:15	<7.13	<13.3	det	<87.7	<12.5	<4.68	24.5	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Audubon #13 (field rep)	3/12/2013 14:20	<7.13	<13.3	det	det	<12.5	<4.68	<5.79	19.8	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Avoca Reg. Water #19	3/19/2013 15:15	<7.13	<13.3	<90.7	<87.7	det	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	7.78
Badger #3	3/26/2013 12:50	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Battle Creek #3	4/9/2013 13:00	<7.13	<13.3	det	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Blue Grass #1a	3/20/2013 13:15	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Bristow #2	4/22/2013 15:10	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Calamus 2007	3/11/2013 15:40	<7.13	<13.3	det	det	<12.5	<4.68	<5.79	det	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Carson #7	3/19/2013 13:45	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Cascade #4	3/13/2013 14:00	<7.13	<13.3	det	det	<12.5	<4.68	<5.79	48.6	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Cedar Falls #8	3/27/2013 13:45	826	<13.3	<90.7	det	<12.5	<4.68	145	det	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Cedar Falls #9	3/27/2013 16:00														
Cedar Falls #9 (RS)	6/12/2013 14:00	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Charles City #8	3/25/2013 14:45	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Cherokee #10	4/8/2013 12:30	<7.13	<13.3	det	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Clayton #1	4/10/2013 13:50	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Coralville #10	5/1/2013 13:15														
De Witt #7	3/11/2013 15:00	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Decorah #7	4/9/2013 13:35	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Decorah #7 (field rep)	4/9/2013 13:40	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Dumont #2	4/22/2013 15:35	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Duncombe #4	3/27/2013 12:55	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Elgin #2	4/10/2013 13:15	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Fairfield #6	4/3/2013 13:15	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Fremont #2-88	4/15/2013 15:20	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Gilbert #3	4/16/2013 15:30	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Independence #3	5/8/2013 12:30	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Independence #7	4/8/2013 13:30	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Independence #7 (RS)	6/11/2013 12:50	<7.13	det	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Ionia #2	3/25/2013 16:15	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Janesville #3	4/2/2013 14:40	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

APPENDIX B

Well/Sample Name	Sample Date-Time	Detected Pharmaceuticals (ng/L) acetaminophen	atenolol	caffeine	1,7-dimethylxanthine	carisoprodol	chlorpheniramine	diphenhydramine	lidocaine	nicotine	cotinine	sulfamethoxazole	thiabendazole	tramadol	warfarin
Joice #1	3/26/2013 12:45														
Jolley #1	3/25/2013 14:40	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Knierim #1	3/25/2013 13:40	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Lansing #4	4/9/2013 14:35	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Lyon-Sioux RWS-3	4/2/2013 13:43	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	det	<4.1	<15.1	<6.03
Marshalltown #5	4/15/2013 14:15	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Massena #6	3/13/2013 13:45	<7.13	<13.3	det	det	<12.5	<4.68	<5.79	det	<57.8	<6.37	<26.1	127	<15.1	<6.03
Mount Vernon #9	3/18/2013 16:00	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Mount Vernon #9 (field rep)	3/18/2013 16:05	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Moville #5	4/1/2013 16:10	<7.13	<13.3	det	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Nevada #8	4/16/2013 14:15	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Nevada #8 (blank)	4/16/2013 14:20	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
New Venna #4	3/19/2013 16:00	<7.13	<13.3	<90.7	<87.7	<12.5	det	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Nora Springs #4	4/23/2013 12:05	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Orchardview Est. #1	3/4/2013 12:00	<7.13	<13.3	det	det	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Perry #22	3/4/2013 15:25	<7.13	<13.3	det	det	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Perry #9R	3/6/2013 15:15	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Perry #9R (RS)	6/18/2013 11:00	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Primghar #8	4/3/2013 13:30	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Quimby #3	4/9/2013 12:55	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Riverview Estates #1	3/4/2013 14:40	<7.13	<13.3	det	det	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Rockford #2	4/23/2013 13:05	<7.13	<13.3	det	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Shelby #6A	4/22/2013 14:30	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Sigourney #02-5	4/15/2013 17:00	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Sioux Center #13	4/2/2013 12:42	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Stacyville #3	4/24/2013 13:40	<7.13	<13.3	det	<87.7	<12.5	<4.68	<5.79	<15.2	det	det	<26.1	<4.1	<15.1	<6.03
Steamboat Rock #1	4/1/2013 14:35	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Storm Lake #18	4/8/2013 13:35	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Toledo #2	3/12/2013 15:10	<7.13	<13.3	det	det	<12.5	<4.68	<5.79	det	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Van Meter #3	3/5/2013 15:10														
Van Meter #3 (RS)	6/18/2013 9:00	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Van Meter #3 (RS) (field rep)	6/18/2013 9:05	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Ventura #1	3/26/2013 13:15														
Walnut #2	3/18/2013 14:30	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Waverly #6	4/2/2013 13:05	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Waverly #6 (RS)	6/12/2013 10:30	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	det	<6.03
Winthrop #3	4/17/2013 12:06	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Winthrop #3 (blank)	4/17/2013 12:11	<7.13	<13.3	<90.7	<87.7	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03
Woodward St. Hos. #2	3/6/2013 13:25	<7.13	<13.3	det	det	<12.5	<4.68	<5.79	<15.2	<57.8	<6.37	<26.1	<4.1	<15.1	<6.03

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

APPENDIX B

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L)														
		abacavir	acyclovir	albuterol	alprazolam	amitriptyline	amphetamine	antipyrine	benztropine	betamethasone	buproprion	carbamazepine	cimetidine	citalopram	clonidine	codeine
Adel #3	3/5/2013 14:10															
Alburnett #3	3/18/2013 14:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<18.4	<4.18	<27.8	<6.58	<60.8	<88.3
Algona #8	3/26/2013 14:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Algona #8 (field rep)	3/26/2013 14:20	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Altoona #3	4/23/2013 14:30															
Andover #1	4/29/2013 12:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Anita #4	3/13/2013 14:40															
Atkins #3	3/12/2013 12:45	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<18.5	<4.18	<27.8	<6.58	<60.8	<88.3
Audubon #13	3/12/2013 14:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<19.9	<4.18	<27.8	<6.58	<60.8	<88.3
Audubon #13 (field rep)	3/12/2013 14:20	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20.1	<4.18	<27.8	<6.58	<60.8	<88.3
Avoca Reg. Water #19	3/19/2013 15:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20.4	<4.18	<27.8	<6.58	<60.8	<88.3
Badger #3	3/26/2013 12:50	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Battle Creek #3	4/9/2013 13:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Blue Grass #1a	3/20/2013 13:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<19.3	<4.18	<27.8	<6.58	<60.8	<88.3
Bristow #2	4/22/2013 15:10	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Calamus 2007	3/11/2013 15:40	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Carson #7	3/19/2013 13:45	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<22.9	<4.18	<27.8	<6.58	<60.8	<88.3
Cascade #4	3/13/2013 14:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Cedar Falls #8	3/27/2013 13:45	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Cedar Falls #9	3/27/2013 16:00															
Cedar Falls #9 (RS)	6/12/2013 14:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Charles City #8	3/25/2013 14:45	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Cherokee #10	4/8/2013 12:30	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Clayton #1	4/10/2013 13:50	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Coralville #10	5/1/2013 13:15															
De Witt #7	3/11/2013 15:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Decorah #7	4/9/2013 13:35	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Decorah #7 (field rep)	4/9/2013 13:40	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Dumont #2	4/22/2013 15:35	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Duncombe #4	3/27/2013 12:55	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Elgin #2	4/10/2013 13:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Fairfield #6	4/3/2013 13:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Fremont #2-88	4/15/2013 15:20	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Gilbert #3	4/16/2013 15:30	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Independence #3	5/8/2013 12:30	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Independence #7	4/8/2013 13:30	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Independence #7 (RS)	6/11/2013 12:50	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Ionia #2	3/25/2013 16:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Janesville #3	4/2/2013 14:40	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3

RS = samples obtained during the June resampling period

field rep = field replicate

APPENDIX B

Undetected Pharmaceuticals (ng/L)

Well/Sample Name	Sample Date-Time	abacavir	acyclovir	albuterol	alprazolam	amitriptyline	amphetamine	antipyrine	benztropine	betamethasone	buproprion	carbamazepine	cimetidine	citalopram	clonidine	codeine
Joice #1	3/26/2013 12:45															
Jolley #1	3/25/2013 14:40	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Knierim #1	3/25/2013 13:40	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Lansing #4	4/9/2013 14:35	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Lyon-Sioux RWS-3	4/2/2013 13:43	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Marshalltown #5	4/15/2013 14:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Massena #6	3/13/2013 13:45	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<18.0	<4.18	<27.8	<6.58	<60.8	<88.3
Mount Vernon #9	3/18/2013 16:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Mount Vernon #9 (field rep)	3/18/2013 16:05	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<22.9	<4.18	<27.8	<6.58	<60.8	<88.3
Moville #5	4/1/2013 16:10	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Nevada #8	4/16/2013 14:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Nevada #8 (blank)	4/16/2013 14:20	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
New Venna #4	3/19/2013 16:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<19.2	<4.18	<27.8	<6.58	<60.8	<88.3
Nora Springs #4	4/23/2013 12:05	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Orchardview Est. #1	3/4/2013 12:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<22.5	<4.18	<27.8	<6.58	<60.8	<88.3
Perry #22	3/4/2013 15:25	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20.2	<4.18	<27.8	<6.58	<60.8	<88.3
Perry #9R	3/6/2013 15:15	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Perry #9R (RS)	6/18/2013 11:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Primghar #8	4/3/2013 13:30	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Quimby #3	4/9/2013 12:55	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Riverview Estates #1	3/4/2013 14:40	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<22.8	<4.18	<27.8	<6.58	<60.8	<88.3
Rockford #2	4/23/2013 13:05	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Shelby #6A	4/22/2013 14:30	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Sigourney #02-5	4/15/2013 17:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Sioux Center #13	4/2/2013 12:42	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Stacyville #3	4/24/2013 13:40	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<12.2	<27.8	<6.58	<60.8	<88.3
Steamboat Rock #1	4/1/2013 14:35	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Storm Lake #18	4/8/2013 13:35	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Toledo #2	3/12/2013 15:10	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Van Meter #3	3/5/2013 15:10															
Van Meter #3 (RS)	6/18/2013 9:00	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Van Meter #3 (RS) (field rep)	6/18/2013 9:05	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Ventura #1	3/26/2013 13:15															
Walnut #2	3/18/2013 14:30	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Waverly #6	4/2/2013 13:05	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<20	<4.18	<27.8	<6.58	<60.8	<88.3
Waverly #6 (RS)	6/12/2013 10:30	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Winthrop #3*	4/17/2013 12:06	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Winthrop #3 (blank)*	4/17/2013 12:11	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<17.8	<4.18	<27.8	<6.58	<60.8	<88.3
Woodward St. Hos. #2	3/6/2013 13:25	<8.21	<22.2	<6.06	<21.3	<37.2	<8.14	<116	<15.8	<114	<22.2	<4.18	<27.8	<6.58	<60.8	<88.3

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

*USGS pharmaceutical analyses were run on a frozen field replicate

APPENDIX B

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L)															
		dehydronifedipine	desvenlafaxine	dextromethorphan	diazepam	diltiazem	duloxetine	erythromycin	ezetimibe	fadrozole	famotidine	fenofibrate	fexofenadine	fluconazole	fluoxetine	fluticasone	fluvoxamine
Adel #3	3/5/2013 14:10																
Alburnett #3	3/18/2013 14:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Algona #8	3/26/2013 14:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Algona #8 (field rep)	3/26/2013 14:20	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Altoona #3	4/23/2013 14:30																
Andover #1	4/29/2013 12:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Anita #4	3/13/2013 14:40																
Atkins #3	3/12/2013 12:45	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Audubon #13	3/12/2013 14:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Audubon #13 (field rep)	3/12/2013 14:20	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Avoca Reg. Water #19	3/19/2013 15:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Badger #3	3/26/2013 12:50	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Battle Creek #3	4/9/2013 13:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Blue Grass #1a	3/20/2013 13:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Bristow #2	4/22/2013 15:10	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Calamus 2007	3/11/2013 15:40	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Carson #7	3/19/2013 13:45	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Cascade #4	3/13/2013 14:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Cedar Falls #8	3/27/2013 13:45	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Cedar Falls #9	3/27/2013 16:00																
Cedar Falls #9 (RS)	6/12/2013 14:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Charles City #8	3/25/2013 14:45	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Cherokee #10	4/8/2013 12:30	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Clayton #1	4/10/2013 13:50	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Coralville #10	5/1/2013 13:15																
De Witt #7	3/11/2013 15:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Decorah #7	4/9/2013 13:35	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Decorah #7 (field rep)	4/9/2013 13:40	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Dumont #2	4/22/2013 15:35	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Duncombe #4	3/27/2013 12:55	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Elgin #2	4/10/2013 13:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Fairfield #6	4/3/2013 13:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Fremont #2-88	4/15/2013 15:20	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Gilbert #3	4/16/2013 15:30	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Independence #3	5/8/2013 12:30	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Independence #7	4/8/2013 13:30	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Independence #7 (RS)	6/11/2013 12:50	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Ionia #2	3/25/2013 16:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Janesville #3	4/2/2013 14:40	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8

RS = samples obtained during the June resampling period
field rep = field replicate

APPENDIX B

		Undetected Pharmaceuticals (ng/L)															
Well/Sample Name	Sample Date-Time	dehydronifedipine	desvenlafaxine	dextromethorphan	diazepam	diltiazem	duloxetine	erythromycin	ezetimibe	fadrozole	famotidine	fenofibrate	fexofenadine	fluconazole	fluoxetine	fluticasone	fluvoxamine
Joice #1	3/26/2013 12:45																
Jolley #1	3/25/2013 14:40	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Knierim #1	3/25/2013 13:40	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Lansing #4	4/9/2013 14:35	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Lyon-Sioux RWS-3	4/2/2013 13:43	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Marshalltown #5	4/15/2013 14:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Massena #6	3/13/2013 13:45	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Mount Vernon #9	3/18/2013 16:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Mount Vernon #9 (field rep)	3/18/2013 16:05	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Moville #5	4/1/2013 16:10	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Nevada #8	4/16/2013 14:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Nevada #8 (blank)	4/16/2013 14:20	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
New Venna #4	3/19/2013 16:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Nora Springs #4	4/23/2013 12:05	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Orchardview Est. #1	3/4/2013 12:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Perry #22	3/4/2013 15:25	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Perry #9R	3/6/2013 15:15	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Perry #9R (RS)	6/18/2013 11:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Primghar #8	4/3/2013 13:30	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Quimby #3	4/9/2013 12:55	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Riverview Estates #1	3/4/2013 14:40	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Rockford #2	4/23/2013 13:05	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Shelby #6A	4/22/2013 14:30	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Sigourney #02-5	4/15/2013 17:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Sioux Center #13	4/2/2013 12:42	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Stacyville #3	4/24/2013 13:40	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Steamboat Rock #1	4/1/2013 14:35	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Storm Lake #18	4/8/2013 13:35	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Toledo #2	3/12/2013 15:10	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Van Meter #3	3/5/2013 15:10																
Van Meter #3 (RS)	6/18/2013 9:00	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Van Meter #3 (RS) (field rep)	6/18/2013 9:05	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Ventura #1	3/26/2013 13:15																
Walnut #2	3/18/2013 14:30	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Waverly #6	4/2/2013 13:05	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Waverly #6 (RS)	6/12/2013 10:30	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Winthrop #3*	4/17/2013 12:06	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Winthrop #3 (blank)*	4/17/2013 12:11	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8
Woodward St. Hos. #2	3/6/2013 13:25	<24.5	<7.49	<8.2	<2.24	<10.2	<36.6	<53.1	<63.5	<7.32	<10.7	<6.28	<19.9	<71	<26.9	<4.62	<53.8

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

*USGS pharmaceutical analyses were run on a frozen field replicate

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L)												
		glipizide	glyburide	hydrocodone	hydrocortisone	hydroxyzine	iminostilbene	ketoconazole	lamivudine	loperamide	loratadine	lorazepam	meprobamate	metaxalone
Adel #3	3/5/2013 14:10													
Alburnett #3	3/18/2013 14:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Algona #8	3/26/2013 14:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Algona #8 (field rep)	3/26/2013 14:20	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Altoona #3	4/23/2013 14:30													
Andover #1	4/29/2013 12:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Anita #4	3/13/2013 14:40													
Atkins #3	3/12/2013 12:45	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Audubon #13	3/12/2013 14:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Audubon #13 (field rep)	3/12/2013 14:20	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Avoca Reg. Water #19	3/19/2013 15:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Badger #3	3/26/2013 12:50	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Battle Creek #3	4/9/2013 13:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Blue Grass #1a	3/20/2013 13:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Bristow #2	4/22/2013 15:10	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Calamus 2007	3/11/2013 15:40	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Carson #7	3/19/2013 13:45	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Cascade #4	3/13/2013 14:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Cedar Falls #8	3/27/2013 13:45	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Cedar Falls #9	3/27/2013 16:00													
Cedar Falls #9 (RS)	6/12/2013 14:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Charles City #8	3/25/2013 14:45	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Cherokee #10	4/8/2013 12:30	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Clayton #1	4/10/2013 13:50	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Coralville #10	5/1/2013 13:15													
De Witt #7	3/11/2013 15:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Decorah #7	4/9/2013 13:35	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Decorah #7 (field rep)	4/9/2013 13:40	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Dumont #2	4/22/2013 15:35	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Duncombe #4	3/27/2013 12:55	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Elgin #2	4/10/2013 13:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Fairfield #6	4/3/2013 13:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Fremont #2-88	4/15/2013 15:20	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Gilbert #3	4/16/2013 15:30	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Independence #3	5/8/2013 12:30	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Independence #7	4/8/2013 13:30	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Independence #7 (RS)	6/11/2013 12:50	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Ionia #2	3/25/2013 16:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Janesville #3	4/2/2013 14:40	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6

RS = samples obtained during the June resampling period

field rep = field replicate

APPENDIX B

Undetected Pharmaceuticals (ng/L)

Well/Sample Name	Sample Date-Time	glipizide	glyburide	hydrocodone	hydrocortisone	hydroxyzine	iminostilbene	ketoconazole	lamivudine	loperamide	loratadine	lorazepam	meprobamate	metaxalone
Joice #1	3/26/2013 12:45													
Jolley #1	3/25/2013 14:40	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Knierim #1	3/25/2013 13:40	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Lansing #4	4/9/2013 14:35	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Lyon-Sioux RWS-3	4/2/2013 13:43	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Marshalltown #5	4/15/2013 14:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Massena #6	3/13/2013 13:45	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Mount Vernon #9	3/18/2013 16:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Mount Vernon #9 (field rep)	3/18/2013 16:05	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Moville #5	4/1/2013 16:10	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Nevada #8	4/16/2013 14:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Nevada #8 (blank)	4/16/2013 14:20	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
New Venna #4	3/19/2013 16:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Nora Springs #4	4/23/2013 12:05	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Orchardview Est. #1	3/4/2013 12:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Perry #22	3/4/2013 15:25	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Perry #9R	3/6/2013 15:15	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Perry #9R (RS)	6/18/2013 11:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Primghar #8	4/3/2013 13:30	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Quimby #3	4/9/2013 12:55	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Riverview Estates #1	3/4/2013 14:40	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Rockford #2	4/23/2013 13:05	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Shelby #6A	4/22/2013 14:30	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Sigourney #02-5	4/15/2013 17:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Sioux Center #13	4/2/2013 12:42	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Stacyville #3	4/24/2013 13:40	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Steamboat Rock #1	4/1/2013 14:35	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Storm Lake #18	4/8/2013 13:35	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Toledo #2	3/12/2013 15:10	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Van Meter #3	3/5/2013 15:10													
Van Meter #3 (RS)	6/18/2013 9:00	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Van Meter #3 (RS) (field rep)	6/18/2013 9:05	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Ventura #1	3/26/2013 13:15													
Walnut #2	3/18/2013 14:30	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Waverly #6	4/2/2013 13:05	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Waverly #6 (RS)	6/12/2013 10:30	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Winthrop #3*	4/17/2013 12:06	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Winthrop #3 (blank)*	4/17/2013 12:11	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6
Woodward St. Hos. #2	3/6/2013 13:25	<34.6	<3.95	<10.5	<147	<7.43	<145	<113	<16.1	<11.5	<6.95	<116	<86	<15.6

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

*USGS pharmaceutical analyses were run on a frozen field replicate

APPENDIX B

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L) metformin	methadone	methocarbamol	methotrexate	methyl-1h benzotriazole	metoprolol	morphine	nadolol	n-desmethyldiltiazem	nevirapine	nizatidine	nordiazepam	norethindrone
Adel #3	3/5/2013 14:10													
Alburnett #3	3/18/2013 14:00	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Algona #8	3/26/2013 14:15	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Algona #8 (field rep)	3/26/2013 14:20	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Altoona #3	4/23/2013 14:30													
Andover #1	4/29/2013 12:15	UTA	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Anita #4	3/13/2013 14:40													
Atkins #3	3/12/2013 12:45	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Audubon #13	3/12/2013 14:15	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Audubon #13 (field rep)	3/12/2013 14:20	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Avoca Reg. Water #19	3/19/2013 15:15	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Badger #3	3/26/2013 12:50	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Battle Creek #3	4/9/2013 13:00	<13.1	UTA	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Blue Grass #1a	3/20/2013 13:15	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Bristow #2	4/22/2013 15:10	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Calamus 2007	3/11/2013 15:40	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Carson #7	3/19/2013 13:45	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Cascade #4	3/13/2013 14:00	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Cedar Falls #8	3/27/2013 13:45	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Cedar Falls #9	3/27/2013 16:00													
Cedar Falls #9 (RS)	6/12/2013 14:00	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Charles City #8	3/25/2013 14:45	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Cherokee #10	4/8/2013 12:30	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Clayton #1	4/10/2013 13:50	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Coralville #10	5/1/2013 13:15													
De Witt #7	3/11/2013 15:00	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Decorah #7	4/9/2013 13:35	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Decorah #7 (field rep)	4/9/2013 13:40	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Dumont #2	4/22/2013 15:35	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Duncombe #4	3/27/2013 12:55	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Elgin #2	4/10/2013 13:15	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Fairfield #6	4/3/2013 13:15	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Fremont #2-88	4/15/2013 15:20	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Gilbert #3	4/16/2013 15:30	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Independence #3	5/8/2013 12:30	UTA	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Independence #7	4/8/2013 13:30	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Independence #7 (RS)	6/11/2013 12:50	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Ionia #2	3/25/2013 16:15	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Janesville #3	4/2/2013 14:40	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9

RS = samples obtained during the June resampling period

field rep = field replicate

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L) metformin	methadone	methocarbamol	methotrexate	methyl-1h benzotriazole	metoprolol	morphine	nadolol	n-desmethyldiltiazem	nevirapine	nizatidine	nordiazepam	norethindrone
Joice #1	3/26/2013 12:45													
Jolley #1	3/25/2013 14:40	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Knierim #1	3/25/2013 13:40	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Lansing #4	4/9/2013 14:35	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Lyon-Sioux RWS-3	4/2/2013 13:43	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Marshalltown #5	4/15/2013 14:15	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Massena #6	3/13/2013 13:45	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Mount Vernon #9	3/18/2013 16:00	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Mount Vernon #9 (field rep)	3/18/2013 16:05	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Moville #5	4/1/2013 16:10	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Nevada #8	4/16/2013 14:15	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Nevada #8 (blank)	4/16/2013 14:20	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
New Venna #4	3/19/2013 16:00	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Nora Springs #4	4/23/2013 12:05	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Orchardview Est. #1	3/4/2013 12:00	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Perry #22	3/4/2013 15:25	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Perry #9R	3/6/2013 15:15	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14.(	<80.8	<12.4	<15.1	:19.(	<41.4	<10.9
Perry #9R (RS)	6/18/2013 11:00	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Primghar #8	4/3/2013 13:30	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Quimby #3	4/9/2013 12:55	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Riverview Estates #1	3/4/2013 14:40	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Rockford #2	4/23/2013 13:05	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Shelby #6A	4/22/2013 14:30	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Sigourney #02-5	4/15/2013 17:00	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Sioux Center #13	4/2/2013 12:42	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Stacyville #3	4/24/2013 13:40	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Steamboat Rock #1	4/1/2013 14:35	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Storm Lake #18	4/8/2013 13:35	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Toledo #2	3/12/2013 15:10	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Van Meter #3	3/5/2013 15:10													
Van Meter #3 (RS)	6/18/2013 9:00	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Van Meter #3 (RS) (field rep)	6/18/2013 9:05	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Ventura #1	3/26/2013 13:15													
Walnut #2	3/18/2013 14:30	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Waverly #6	4/2/2013 13:05	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Waverly #6 (RS)	6/12/2013 10:30	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Winthrop #3*	4/17/2013 12:06	UTA	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Winthrop #3 (blank)*	4/17/2013 12:11	UTA	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9
Woodward St. Hos. #2	3/6/2013 13:25	<13.1	<7.61	<8.72	<52.4	<141	<27.5	<14	<80.8	<12.4	<15.1	<19	<41.4	<10.9

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

*USGS pharmaceutical analyses were run on a frozen field replicate

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L)												
		norfluoxetine	norsertraline	norverapamil	omeprazole	orlistat	oseltamivir	oxazepam	oxycodone	paroxetine	penciclovir	pentoxifylline	phenazopyridine	phendimetrazine
Adel #3	3/5/2013 14:10													
Alburnett #3	3/18/2013 14:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Algona #8	3/26/2013 14:15	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Algona #8 (field rep)	3/26/2013 14:20	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Altoona #3	4/23/2013 14:30													
Andover #1	4/29/2013 12:15	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Anita #4	3/13/2013 14:40													
Atkins #3	3/12/2013 12:45	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Audubon #13	3/12/2013 14:15	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Audubon #13 (field rep)	3/12/2013 14:20	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Avoca Reg. Water #19	3/19/2013 15:15	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Badger #3	3/26/2013 12:50	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Battle Creek #3	4/9/2013 13:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Blue Grass #1a	3/20/2013 13:15	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Bristow #2	4/22/2013 15:10	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Calamus 2007	3/11/2013 15:40	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Carson #7	3/19/2013 13:45	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Cascade #4	3/13/2013 14:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Cedar Falls #8	3/27/2013 13:45	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Cedar Falls #9	3/27/2013 16:00													
Cedar Falls #9 (RS)	6/12/2013 14:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Charles City #8	3/25/2013 14:45	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Cherokee #10	4/8/2013 12:30	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Clayton #1	4/10/2013 13:50	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Coralville #10	5/1/2013 13:15													
De Witt #7	3/11/2013 15:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Decorah #7	4/9/2013 13:35	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Decorah #7 (field rep)	4/9/2013 13:40	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Dumont #2	4/22/2013 15:35	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Duncombe #4	3/27/2013 12:55	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Elgin #2	4/10/2013 13:15	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Fairfield #6	4/3/2013 13:15	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Fremont #2-88	4/15/2013 15:20	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Gilbert #3	4/16/2013 15:30	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Independence #3	5/8/2013 12:30	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Independence #7	4/8/2013 13:30	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Independence #7 (RS)	6/11/2013 12:50	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Ionia #2	3/25/2013 16:15	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Janesville #3	4/2/2013 14:40	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1

RS = samples obtained during the June resampling period

field rep = field replicate

APPENDIX B

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L)												
		norfluoxetine	norsertraline	norverapamil	omeprazole	orlistat	oseltamivir	oxazepam	oxycodone	paroxetine	penciclovir	pentoxifylline	phenazopyridine	phendimetrazine
Joice #1	3/26/2013 12:45													
Jolley #1	3/25/2013 14:40	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Knierim #1	3/25/2013 13:40	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Lansing #4	4/9/2013 14:35	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Lyon-Sioux RWS-3	4/2/2013 13:43	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Marshalltown #5	4/15/2013 14:15	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Massena #6	3/13/2013 13:45	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Mount Vernon #9	3/18/2013 16:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Mount Vernon #9 (field rep)	3/18/2013 16:05	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Moville #5	4/1/2013 16:10	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Nevada #8	4/16/2013 14:15	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Nevada #8 (blank)	4/16/2013 14:20	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
New Venna #4	3/19/2013 16:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Nora Springs #4	4/23/2013 12:05	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Orchardview Est. #1	3/4/2013 12:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Perry #22	3/4/2013 15:25	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Perry #9R	3/6/2013 15:15	<199	<192	<8.58	<5.62	<52.0	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Perry #9R (RS)	6/18/2013 11:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Primghar #8	4/3/2013 13:30	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Quimby #3	4/9/2013 12:55	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Riverview Estates #1	3/4/2013 14:40	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Rockford #2	4/23/2013 13:05	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Shelby #6A	4/22/2013 14:30	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Sigourney #02-5	4/15/2013 17:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Sioux Center #13	4/2/2013 12:42	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Stacyville #3	4/24/2013 13:40	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Steamboat Rock #1	4/1/2013 14:35	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Storm Lake #18	4/8/2013 13:35	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Toledo #2	3/12/2013 15:10	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Van Meter #3	3/5/2013 15:10													
Van Meter #3 (RS)	6/18/2013 9:00	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Van Meter #3 (RS) (field rep)	6/18/2013 9:05	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Ventura #1	3/26/2013 13:15													
Walnut #2	3/18/2013 14:30	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Waverly #6	4/2/2013 13:05	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Waverly #6 (RS)	6/12/2013 10:30	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Winthrop #3*	4/17/2013 12:06	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Winthrop #3 (blank)*	4/17/2013 12:11	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1
Woodward St. Hos. #2	3/6/2013 13:25	<199	<192	<8.58	<5.62	<52	<14.6	<140	<24.9	<20.6	<40.2	<9.35	<13.3	<31.1

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

*USGS pharmaceutical analyses were run on a frozen field replicate

APPENDIX B

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L)											
		phenytoin	piperonyl butoxide	prednisolone	prednisone	promethazine	propoxyphene	propranolol	pseudoephedrine	quinine	raloxifene	ranitidine	sertraline
Adel #3	3/5/2013 14:10												
Alburnett #3	3/18/2013 14:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Algona #8	3/26/2013 14:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Algona #8 (field rep)	3/26/2013 14:20	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Altoona #3	4/23/2013 14:30												
Andover #1	4/29/2013 12:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Anita #4	3/13/2013 14:40												
Atkins #3	3/12/2013 12:45	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Audubon #13	3/12/2013 14:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Audubon #13 (field rep)	3/12/2013 14:20	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Avoca Reg. Water #19	3/19/2013 15:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Badger #3	3/26/2013 12:50	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Battle Creek #3	4/9/2013 13:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Blue Grass #1a	3/20/2013 13:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Bristow #2	4/22/2013 15:10	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Calamus 2007	3/11/2013 15:40	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Carson #7	3/19/2013 13:45	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Cascade #4	3/13/2013 14:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Cedar Falls #8	3/27/2013 13:45	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Cedar Falls #9	3/27/2013 16:00												
Cedar Falls #9 (RS)	6/12/2013 14:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Charles City #8	3/25/2013 14:45	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Cherokee #10	4/8/2013 12:30	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Clayton #1	4/10/2013 13:50	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Coralville #10	5/1/2013 13:15												
De Witt #7	3/11/2013 15:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Decorah #7	4/9/2013 13:35	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Decorah #7 (field rep)	4/9/2013 13:40	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Dumont #2	4/22/2013 15:35	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Duncombe #4	3/27/2013 12:55	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Elgin #2	4/10/2013 13:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Fairfield #6	4/3/2013 13:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Fremont #2-88	4/15/2013 15:20	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Gilbert #3	4/16/2013 15:30	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Independence #3	5/8/2013 12:30	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Independence #7	4/8/2013 13:30	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Independence #7 (RS)	6/11/2013 12:50	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Ionia #2	3/25/2013 16:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Janesville #3	4/2/2013 14:40	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2

RS = samples obtained during the June resampling period

field rep = field replicate

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L)											
		phenytoin	piperonyl butoxide	prednisolone	prednisone	promethazine	propoxyphene	propranolol	pseudoephedrine	quinine	raloxifene	ranitidine	sertraline
Joice #1	3/26/2013 12:45												
Jolley #1	3/25/2013 14:40	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Knierim #1	3/25/2013 13:40	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Lansing #4	4/9/2013 14:35	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Lyon-Sioux RWS-3	4/2/2013 13:43	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Marshalltown #5	4/15/2013 14:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Massena #6	3/13/2013 13:45	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Mount Vernon #9	3/18/2013 16:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Mount Vernon #9 (field rep)	3/18/2013 16:05	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Moville #5	4/1/2013 16:10	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Nevada #8	4/16/2013 14:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Nevada #8 (blank)	4/16/2013 14:20	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
New Venna #4	3/19/2013 16:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Nora Springs #4	4/23/2013 12:05	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Orchardview Est. #1	3/4/2013 12:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Perry #22	3/4/2013 15:25	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Perry #9R	3/6/2013 15:15	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Perry #9R (RS)	6/18/2013 11:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Primghar #8	4/3/2013 13:30	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Quimby #3	4/9/2013 12:55	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Riverview Estates #1	3/4/2013 14:40	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Rockford #2	4/23/2013 13:05	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Shelby #6A	4/22/2013 14:30	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Sigourney #02-5	4/15/2013 17:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Sioux Center #13	4/2/2013 12:42	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Stacyville #3	4/24/2013 13:40	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Steamboat Rock #1	4/1/2013 14:35	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Storm Lake #18	4/8/2013 13:35	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Toledo #2	3/12/2013 15:10	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Van Meter #3	3/5/2013 15:10												
Van Meter #3 (RS)	6/18/2013 9:00	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Van Meter #3 (RS) (field rep)	6/18/2013 9:05	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Ventura #1	3/26/2013 13:15												
Walnut #2	3/18/2013 14:30	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Waverly #6	4/2/2013 13:05	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Waverly #6 (RS)	6/12/2013 10:30	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Winthrop #3*	4/17/2013 12:06	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Winthrop #3 (blank)*	4/17/2013 12:11	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2
Woodward St. Hos. #2	3/6/2013 13:25	<188	<3.07	<150	<168	<50	<17.2	<26.3	<11.1	<79.9	<9.72	<192	<16.2

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

*USGS pharmaceutical analyses were run on a frozen field replicate

APPENDIX B

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L) sitagliptin	sulfadimethoxine	sulfamethizole	tamoxifen	temazepam	theophylline	tiotropium	triamterene	trimethoprim	valacyclovir	venlafaxine	verapamil
Adel #3	3/5/2013 14:10												
Alburnett #3	3/18/2013 14:00	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Algona #8	3/26/2013 14:15	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Algona #8 (field rep)	3/26/2013 14:20	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Altoona #3	4/23/2013 14:30												
Andover #1	4/29/2013 12:15	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Anita #4	3/13/2013 14:40												
Atkins #3	3/12/2013 12:45	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Audubon #13	3/12/2013 14:15	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Audubon #13 (field rep)	3/12/2013 14:20	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Avoca Reg. Water #19	3/19/2013 15:15	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Badger #3	3/26/2013 12:50	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Battle Creek #3	4/9/2013 13:00	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Blue Grass #1a	3/20/2013 13:15	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Bristow #2	4/22/2013 15:10	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Calamus 2007	3/11/2013 15:40	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Carson #7	3/19/2013 13:45	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Cascade #4	3/13/2013 14:00	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Cedar Falls #8	3/27/2013 13:45	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Cedar Falls #9	3/27/2013 16:00												
Cedar Falls #9 (RS)	6/12/2013 14:00	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Charles City #8	3/25/2013 14:45	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Cherokee #10	4/8/2013 12:30	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Clayton #1	4/10/2013 13:50	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Coralville #10	5/1/2013 13:15												
De Witt #7	3/11/2013 15:00	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Decorah #7	4/9/2013 13:35	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Decorah #7 (field rep)	4/9/2013 13:40	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Dumont #2	4/22/2013 15:35	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Duncombe #4	3/27/2013 12:55	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Elgin #2	4/10/2013 13:15	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Fairfield #6	4/3/2013 13:15	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Fremont #2-88	4/15/2013 15:20	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Gilbert #3	4/16/2013 15:30	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Independence #3	5/8/2013 12:30	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Independence #7	4/8/2013 13:30	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Independence #7 (RS)	6/11/2013 12:50	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Ionia #2	3/25/2013 16:15	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Janesville #3	4/2/2013 14:40	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5

RS = samples obtained during the June resampling period

field rep = field replicate

Well/Sample Name	Sample Date-Time	Undetected Pharmaceuticals (ng/L)											
		sitagliptin	sulfadimethoxine	sulfamethizole	tamoxifen	temazepam	theophylline	tiotropium	triamterene	trimethoprim	valacyclovir	venlafaxine	verapamil
Joice #1	3/26/2013 12:45												
Jolley #1	3/25/2013 14:40	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Knierim #1	3/25/2013 13:40	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Lansing #4	4/9/2013 14:35	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Lyon-Sioux RWS-3	4/2/2013 13:43	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Marshalltown #5	4/15/2013 14:15	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Massena #6	3/13/2013 13:45	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Mount Vernon #9	3/18/2013 16:00	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Mount Vernon #9 (field rep)	3/18/2013 16:05	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Moville #5	4/1/2013 16:10	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Nevada #8	4/16/2013 14:15	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Nevada #8 (blank)	4/16/2013 14:20	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
New Venna #4	3/19/2013 16:00	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Nora Springs #4	4/23/2013 12:05	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Orchardview Est. #1	3/4/2013 12:00	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Perry #22	3/4/2013 15:25	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Perry #9R	3/6/2013 15:15	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Perry #9R (RS)	6/18/2013 11:00	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Primghar #8	4/3/2013 13:30	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Quimby #3	4/9/2013 12:55	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Riverview Estates #1	3/4/2013 14:40	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Rockford #2	4/23/2013 13:05	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Shelby #6A	4/22/2013 14:30	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Sigourney #02-5	4/15/2013 17:00	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Sioux Center #13	4/2/2013 12:42	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Stacyville #3	4/24/2013 13:40	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Steamboat Rock #1	4/1/2013 14:35	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Storm Lake #18	4/8/2013 13:35	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Toledo #2	3/12/2013 15:10	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Van Meter #3	3/5/2013 15:10												
Van Meter #3 (RS)	6/18/2013 9:00	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Van Meter #3 (RS) (field rep)	6/18/2013 9:05	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Ventura #1	3/26/2013 13:15												
Walnut #2	3/18/2013 14:30	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Waverly #6	4/2/2013 13:05	<97.3	<65.5	<104	UTA	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Waverly #6 (RS)	6/12/2013 10:30	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Winthrop #3*	4/17/2013 12:06	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Winthrop #3 (blank)*	4/17/2013 12:11	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5
Woodward St. Hos. #2	3/6/2013 13:25	<97.3	<65.5	<104	<52.4	<18.4	<41.5	<43.1	<5.25	<19	<163	<4.48	<15.5

blank = field blank

RS = samples obtained during the June resampling period

field rep = field replicate

*USGS pharmaceutical analyses were run on a frozen field replicate

APPENDIX C

Matrix Recovery Results for Analyses by qPCR

Samples	Poliovirus Sabin 3		Campylobacter		Giardia lamblia	
	Concentration (genomic copies)	% Recovery	Concentration (genomic copies)	% Recovery	Concentration (genomic copies)	% Recovery
Decorah #7 spiked sample	9.37E+06	102	1.44E+06	105	5.42E+03	72
Decorah #7 positive control	9.14E+06		1.37E+06		7.54E+03	
Elgin #2 spiked sample	1.35E+07	85	4.09E+05	76	2.93E+03	47
Elgin #2 positive control	1.58E+07		5.38E+05		6.24E+03	
Independence #7 spiked sample	6.22E+05	13	3.99E+05	32	1.64E+03	66
Independence #7 positive control	4.70E+06		1.25E+06		2.48E+03	
Lansing #4 spiked sample	1.80E+06	29	1.00E+05	23	1.11E+03	22
Lansing #4 positive control	6.21E+06		4.27E+05		5.10E+03	