FINAL TECHNICAL REPORT

Submitted to Daryll Pope and Bill Cunningham

Award #G17AC00173

Iowa Department of Natural Resources

Ambient Groundwater Quality Monitoring Program

Claire Hruby, Ph.D. - Geologist III

Iowa Department of Natural Resources
502 E. 9th St., Des Moines, Iowa 50319
ph. 515-725-8348
email: Claire.hruby@dnr.iowa.gov

Award dates: July 1, 2017 – June 30, 2018

Submitted: September 28, 2018

Overview of work

The purpose of this project was to establish the Iowa Department of Natural Resources as a new provider of water quality data to the National Groundwater Monitoring Network (NGWMN). To accomplish this objective IDNR staff worked to select 115 wells from Iowa's ambient groundwater quality monitoring network that met NGWMN criteria, categorize these wells, submit sites to the Well Registry, and establish a link to the NGWMN via the Water Quality Exchange (WQX). In addition, IDNR collaborated with staff from the Iowa Geological Survey – IIHR to link well lithology and construction data via the IGS GeoSam database.

IDNR's Ambient Groundwater Quality Monitoring Program

The Iowa Department of Natural Resources (IDNR) is a state agency that is responsible for assessing, managing, and protecting Iowa's air, water, and land resources (Environmental Services Division), management of fisheries, wildlife, forestry, and state parks, and providing recreational opportunities (Conservation & Recreation Division). The IDNR's ambient groundwater quality monitoring program is overseen by the Water Quality Monitoring and Assessment section of the Water Quality Bureau within the Environmental Services Division.

The Iowa DNR's ambient groundwater quality monitoring program's objectives are as follows:

1. To characterize the quality of groundwater by aquifer and region.
2. To evaluate long-term trends in groundwater quality.
3. To assess new or emerging issues of groundwater quality concern.

To meet these objectives, the IDNR annually monitors untreated groundwater from municipal water supply wells. The wells monitored as part of this program represent Holocene alluvial deposits and Pleistocene buried sands & gravels (Surficial aquifer system), Lower Cretaceous, Mississippian, Silurian-Devonian, Upper Carbonate Aquifer, and Cambrian-Ordovician bedrock aquifer systems. Many of the wells monitored as part of the current network were part of an original groundwater monitoring network established by a partnership between the Iowa Geological Survey (IGS) and the US Geological Survey's (USGS) Iowa Water Science Center with data collected in some wells as early as the 1960's. While initial recruitment of network participants was based on a stratified random (probabilistic) sampling design, recent additions to the network have been chosen in order to fill holes in the spatial distribution and aquifer representation rather than using any randomized procedure. All, but a few of the most recently added network wells, have been identified as representing principal aquifer systems as defined by the Ground Water Atlas of the United States by USGS staff prior to this grant process.

Since 2012, raw water samples from 137 public wells have been analyzed for several groups of contaminants, including basic water quality parameters, tritium, nutrients, nitrogen and oxygen isotopes of nitrate, dissolved metals, volatile organic compounds, radionuclides, atrazine and chloroacetanilide herbicides and their degradates, neonicotinoid pesticides, and pharmaceutical compounds. In most years, water samples are collected by the municipal water operators, themselves; however, IDNR, USGS, and/or State Hygienic Laboratory (SHL) staff collect samples in years when specialized sampling protocols are necessary, such as when samples are collected for virus or pharmaceutical analyses.

Site Selection

Figure 1 shows the 115 water quality monitoring wells selected. The criteria used to select these wells from the current active network of 137 wells were as follows:

1. Wells must have adequate lithological and construction data to make aquifer assignments and to estimate capture zones.
2. Wells must have been sampled multiple times since 2014. This criteria ensures that the well is still being actively maintained by the municipal water supply and that the current water operator is cooperative. The majority of the wells selected are active wells; however, a few wells are considered "standby" wells maintained for purposes other than drinking-water, such as fighting fires.
3. Wells must have been monitored as part of the network for a minimum of 3 years. Monitoring results are sufficient to assign subnetworks and monitoring categories or are expected to meet the 5-year criteria for assignment of categories in the near future. Some of the wells selected have been sampled as many as 11 times since 2002, and a few have been sampled as far back as the 1960's by the USGS and the Iowa Geological Survey (called the Geological Survey Bureau at the time).
4. No more than one well per aquifer per community.
5. Wide spatial distribution within the aquifer, with some preference for areas of higher aquifer use. Wells are sparse in the south-central region of the state, where most communities rely on surficial water supplies. Numbers of available wells were below the maximum recommended number of water quality sites for all aquifers, with the exception of sand and gravel aquifers – glaciated regions (N100GLCIAL). In Iowa, the groundwater quality of Pleistocene Series (112PLSC) and Holocene Alluvium (111ALVM) local aquifers are very distinct in terms of water quality and vulnerability to contamination from surface activities. In general, alluvial aquifers are highly vulnerable to surface contamination, whereas Pleistocene buried sand and gravel aquifers are confined and more likely to contain "natural" rock-derived contaminants. Most Pleistocene Series wells are confined and occur within the Des Moines Lobe landform region in north-central Iowa, while wells in Holocene Alluvium are all unconfined and more widely distributed around the state. We observed that in other neighboring states, the alluvial aquifers were classified separately and there was no maximum number of sites recommended.

Note: IDNR believes that principle national aquifers of several of the wells selected have been misclassified by USGS. We have been in touch with USGS Iowa/Illinois Water Center staff and efforts to correct these errors are ongoing. The classification of principle aquifers in ***Figure 1*** are based on IDNR classifications.

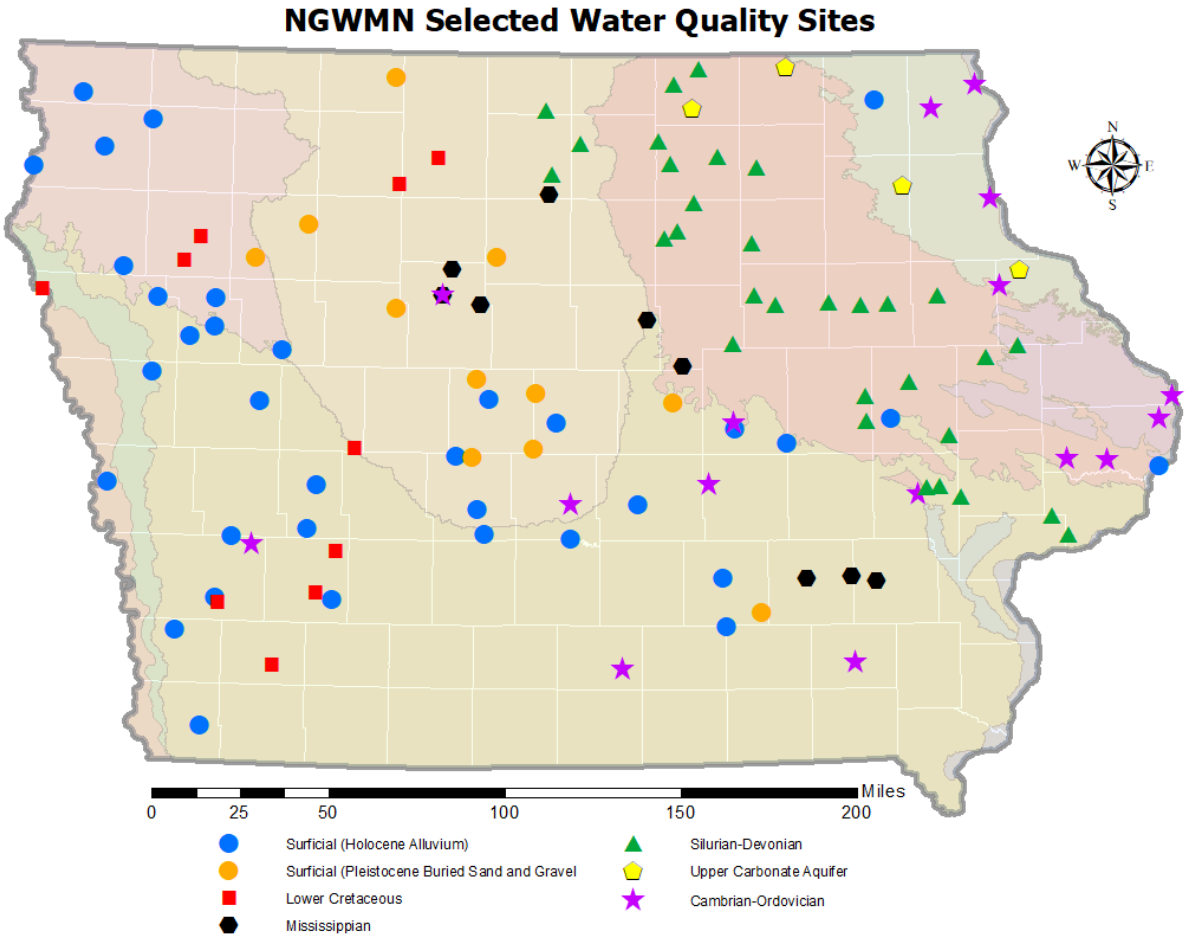

Figure 1. Sites selected for the NGWMN by principal aquifer. Holocene Alluvium and Pleistocene Buried Sand and Gravel are subsets of the Surficial aquifer system. Landform regions and county boundaries are also displayed.

Process for Assigning Subnetworks

Water quality results were used to assign **Subnetworks** as follows:

Documented changes (52 wells):

- Nitrate + nitrite as nitrogen concentrations were 2 mg/L or greater in more than 1 sample
- And/or a positive detection of any pesticide or pesticide degradate in more than 1 sample

Suspected Changes (1 well) had records of at least 2 of the following:

- Nitrate concentrations below 2 mg/L
- Pesticide or pesticide degradate detection
- Pharmaceutical detected (USGS method)
- Virus or bacteria by qPCR (USGS/USDA Laboratory for Infectious Diseases and the Environment)
- Microbial indicators detected

Background conditions (35 wells):

- No nitrate, pesticides, pharmaceuticals, or microbial contaminants detected

Unclassified (27 wells):

- Less than 5 years of data available for baseline process

IDNR has observed that the majority of anthropogenic water quality changes occur in wells with less than 100 feet (30 meters) of confining materials, and the most vulnerable wells have less than 50 feet of confining materials above the water-bearing unit. ***Figure 2*** is an example of the relationship between ambient well water quality and estimated depth of confining materials above the screened interval. Pumping rates and water levels impacts were not considered with regards to Subnetwork classification.

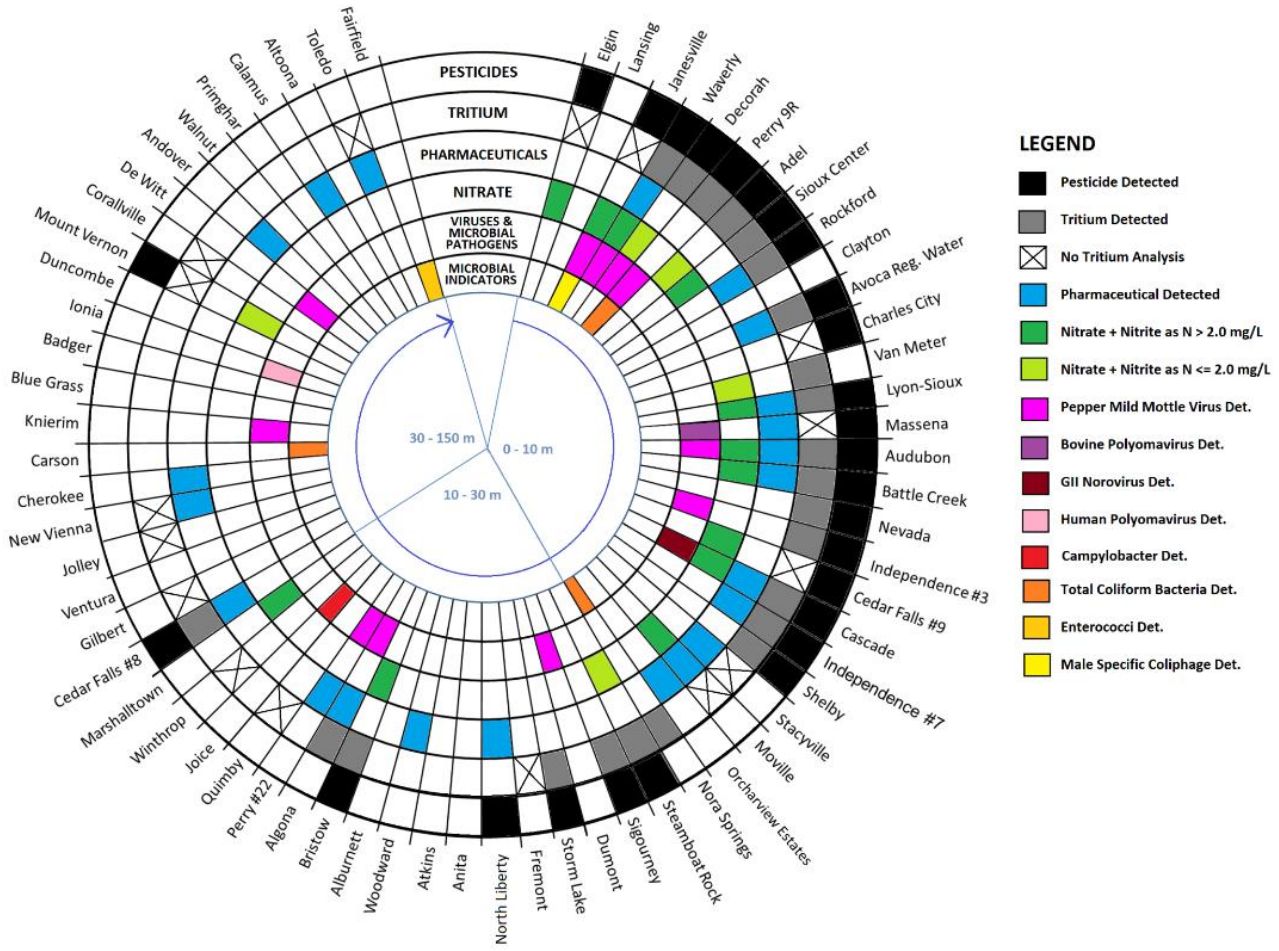

Figure 2. Results of IDNR's 2013 ambient groundwater monitoring in order of increasing confining layer thickness (clockwise).

Monitoring categories

The IDNR ambient groundwater quality monitoring program's current monitoring strategy is to sample wells identified as vulnerable to surface contamination annually, and confined wells unlikely to be influenced by surface contamination once every five years. Because we recognize estimated confining layer thickness at the well is not a perfect method for assessing vulnerability, we also include a small subset of wells from the low vulnerability category representing the various aquifers in the annual monitoring scheme. This strategy mirrors the suggested water-quality monitoring frequencies described in the Framework Document Table 4.5.2.1 for water quality, with a few exceptions.

Trend wells (58 wells) have been monitored at least once prior to the year 2000, annually from 2002-2006, and at least 2 times since 2012, and will continue to be monitored annually for the foreseeable future. Most (49) of the trend wells have estimated confining layer thicknesses at or below 50 feet thick, indicating that these wells are highly susceptible to anthropogenic contamination. All, but 4, have shown some indication of anthropogenic effects. These wells also have highly cooperative and trained water operators willing to collect samples, which makes them good candidates for annual sampling.

Surveillance wells (57 wells) have been monitored at least 3 times in the past 15 years, and plans are to continue sampling once every 5 years. In general these are confined wells with low (<200 ft/day) hydraulic conductivities. A few of these wells fall into the "unconfined" or "confined/high conductivity" categories shown in Table 4.5.2.1.

Twelve (12) wells assigned as Surveillance wells draw water from confined regions of the Cambrian-Ordovician wells, which have estimated hydraulic conductivity between 10^{-5} ft/day – 20 ft/day; therefore, they fall below the 200 ft/day threshold outlined in Table 4.5.2.1 for more frequent sampling. Two (2) wells represent the unconfined region of the Cambrian-Ordovician aquifer. These wells have shown no indication of anthropogenic contamination, but will be considered for more frequent (annual) monitoring if resources are available.

Three (3) wells in this category represent the Upper Carbonate Aquifer. These wells show no evidence of anthropogenic water quality changes after data from 7 sampling events was reviewed. More frequent monitoring may be considered in the future.

Fifteen (15) wells in the Surveillance category represent the Silurian-Devonian aquifer system. Of these, 9 are confined wells screened primarily in the deeper Silurian strata which has reported hydraulic conductivities below 135 ft/day. The remaining 6 draw water from Devonian strata, which have reported conductivities ranging from 0.1 to 225 ft/day. As additional information about recharge rates, hydraulic conductivity, and water quality of these wells becomes available, these wells could be reclassified to the Trend category and added to the annual sampling

program if resources are available. The Silurian-Devonian wells currently listed in the Trend category are considered more vulnerable to anthropogenic effects given the presence of karst and/or as evidenced by historical water quality records.

Six (6) wells in the Surveillance category represent locations where the Mississippian aquifer is confined. Hydraulic conductivities at each well have not been determined; however, the Mississippian aquifer has been shown to range from 0.14 – 1,510 ft/day, so it is possible that some of these wells would fall into the confined/high conductivity category in Table 4.5.2.1, which has a suggested monitoring frequency of 2 years. If resources are available, IDNR will consider sampling these wells more regularly.

Hydraulic conductivity of the Lower Cretaceous (Dakota) aquifer in western Iowa range from 22 – 81 ft/day; therefore, the 9 Lower Cretaceous wells in this category also meet the standards of Table 4.5.2.1.

All 10 surveillance wells in the Pleistocene buried sand and gravel subset of the Glacial Aquifer represent confined conditions with hydraulic conductivities of 100 ft/day or less.

Sampling Techniques

For basic chemical constituents, Iowa DNR and our partner water supply operators refer to collection techniques outlined in the USGS National Field Manual for the Collection of Water-Quality Data for collection of groundwater samples for water supply wells:

https://water.usgs.gov/owq/FieldManual/chapter4/pdf/Chap4_v2.pdf

Modifications of USGS protocol are necessary in some instances. Thus, the following steps are also required:

1. In-lieu of measured purge volumes, all wells are required to be pumped a minimum of 30 minutes.
2. Phone contact is established with all water operators each year to ensure willingness to sample, correct shipping locations, explain any variations to sampling protocols, and update the status of wells.
3. Well tag ID's are installed on most water supply wells and all forms include reference to both the local well number and the Tag ID number.
4. All laboratory instructions for specific bottles, fill instructions, holding, transport, and shipping are followed.
5. Pre-printed labels are used whenever possible to avoid mislabeling.
6. Only certified water operators and trained agency staff are permitted to sample.
7. Complete all chain-of-custody paperwork.

Quality Assurance Processes

Field: Duplicate samples are collected at 10% of sites, and 2-3 blanks are collected per sampling season. Published SOP's for data collection are followed at all times, including use of protective gear, "clean-hands/dirty-hands" protocols, and limited exposure to pharmaceuticals or personal care products when appropriate.

Laboratory: Laboratory QA/QC protocols, including standards and controls, spiked samples, lab blanks, and laboratory duplicate analyses are documented by individual laboratories.

Database: Analytical results submitted to the EQuIS database are checked against laboratory reports to ensure accurate data migration has occurred. Look-up tables are used when possible to promote standardized data entry.

Reporting: Publications are reviewed internally by a review team prior to publication. Reports formulated in cooperation with IGS, USGS, EPA, and other collaborators follow review processes as required by these organizations.

Minimum Data Elements

All Minimum Data requirements required to be submitted via the **Well Registry**, including location information, accuracy, aquifer codes, site type, confinement status, and well depth were uploaded. National aquifer codes used during the initial upload are based on previous USGS classification efforts. IDNR believes some (<10) of these sites have been miscoded and is working with IGS and USGS staff to agree on final classifications. Any changes will be corrected in the well registry.

Lithologic (L) and well construction (C) data are provided via the Iowa Geological Survey's GeoSam database. Linkage to GeoSam was established using web services provided under a separate grant. All sites chosen for the network have well logs available and many have chip samples stored at the Geological Survey's Oakdale facility. However, detailed lithologic descriptions have not been created for all sites. Continued joint efforts between the IDNR and the IGS is ongoing to complete lithologic descriptions. Well screen and well casing details are also not available for all sites. Given that the USGS has used these wells for monitoring for several decades, we are confident that they are currently the best representation of Iowa's ambient groundwater quality that is available to us at this time. If other agencies or resources become available to improve our knowledge of these details or to install dedicated monitoring wells, we will certainly be willing to modify our well selection in the future.

Water quality data are linked via the WQX portal, thus no web service development was necessary.

Water quality analytes

Analyte lists for each monitoring category are as follows:

Trend wells:

The following parameters have been consistently reported for network wells in past years:

- pH
- Specific conductance
- Temperature
- Nitrite + nitrite as nitrogen
- Ammonia
- Chloride
- Total dissolved solids

Additional efforts will be made to record the following details at the time of sampling:

- Ground-water level (every effort will be made to collect these data; however, limitations of staff time, accessibility, and water operation may limit our ability to gather this information)
- Pumping rate
- Pumping time

Surveillance:

- Bromide
- Sodium
- Calcium
- Magnesium
- Potassium
- Sulfate
- Alkalinity
- Orthophosphate
- Dissolved oxygen
- Oxygen reduction potential
- Iron
- Manganese

In FY2017 Iowa DNR collected samples from our network for Polonium-210 and Lead-210 analyses, neonicotinoid pesticides, and isotopes of nitrogen and oxygen in nitrate. We anticipate

that every year will include supplemental groups of parameters. Special studies of this sort may include, but are not limited to, the following:

- Radionuclides
- Total organic carbon
- Synthetic Organics
- Volatile Organic Compounds
- Pharmaceuticals
- Pesticides
- Trace metals
- Emerging Contaminants
- Microbial indicators
- Microbial pathogens and/or indicators using qPCR
- Nitrogen and Oxygen isotopes of nitrate

List of accredited laboratories

IDNR relies entirely on the **State Hygienic Laboratory of Iowa in Coralville, Iowa**, for analyses of parameters listed under Trend and Surveillance monitoring. Special projects in past years have relied on the following:

1. Laboratory for Infectious Disease and the Environment – Marshalltown, WI (M. Borchardt, pathogens)
2. Water Sciences Laboratory – University of Nebraska-Lincoln (D. Snow, nitrate isotopes)
3. USGS Laboratories in Denver (E. Furlong, pharmaceuticals) and Sacramento (M. Hladik, neonicotinoids)

Additional considerations:

One reason that IDNR was interested in pursuing this grant was because of our desire to link water quality monitoring data collected by the USGS at the wells submitted to the NGWMN. Given problems with multiple site ID's, this desire has yet to be fulfilled. We hope that in the near future it will be possible to link USGS data (currently housed in NWIS) to these sites in Iowa.

IDNR greatly appreciated the opportunity to become a new provider to this network. We hope to continue to work collaboratively with the Iowa Geological Survey and the US Geological Survey staff to maintain and grow our ability to assess the health and sustainability of Iowa's groundwater resources in years to come.