IIHR 2016 Water Monitoring Report

Larry Weber, Ph.D., Director

Christopher Jones, Ph.D., Research Engineer

Caroline Davis, Ph.D., Assistant Research Scientist

IIHR – Hydroscience and Engineering
College of Engineering
The University of Iowa
Iowa City, Iowa 52242-1585

March 21, 2017

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Executive Summary

From the Stanley Building situated on the banks of the Iowa River at the University of Iowa, IIHR Hydroscience and Engineering seeks to be a research leader in hydraulics, hydrology, water quantity and water quality, and to educate students to be future leaders in these areas. The education IIHR provides, combined with hands-on engineering practice, attracts a vibrant international mix of students with a rich variety of interests.

Recent directors of the institute have encouraged IIHR's further development, incorporating the strengths of the past into an expanding and complex mix of research, education, and public service. Today's blend of applied and theoretical studies, both of which have been enriched by computerized collection and analysis of data and by numerical modeling techniques, has set the stage for a great diversity of projects ranging from model studies of specific hydraulic structures to computational fluid dynamics investigations of complex flow mechanisms.

The floods of 2008 catalyzed the creation of IIHR's Iowa Flood Center, the nation's first academic center devoted to the study and research of floods. State appropriations, in combination with various grants and contracts, support IFC's efforts to improve flood monitoring and prediction capabilities in Iowa.

In 2012 the Flood Center extended efforts beyond water quantity issues into the pressing issue of Iowa water quality. A modest equipment purchase began the creation of what may be the largest real-time, continuous water quality monitoring network in the U.S. The timing was fortuitous, because around this time a coalition of Iowa stakeholders developed the Iowa Nutrient Reduction Strategy (INRS), a science and technology-based approach to assess and reduce nutrients delivered to Iowa waterways. The Iowa Nutrient Research Center (INRC) supports this effort with research and science-based information. Iowa's strategy was one of the first, and other states have looked to it as a guide for their own efforts.

The INRC has created a very productive collaborative team, with overlapping and complementary sets of knowledge. The IIHR continuous monitoring network, far larger than its beginnings in 2012, is the backbone of the University's effort to support INRS. The near real-time sensor data is collected in-situ in Iowa's rivers and streams, and the data is relayed back to the Institute every 15 minutes. Water quality parameters commonly measured include nitrate concentration, turbidity, temperature, specific conductance, pH, and dissolved oxygen concentration.

Researchers at IIHR have also developed an easy-to-use web platform, the Iowa Water-Quality Information System (IWQIS), to disseminate the sensor data, similar to the Iowa Flood Center's Iowa Flood Information System. IWQIS displays near real-time data on nitrate and other water quality variables from in-stream sensors across Iowa in a user-friendly, Google Maps interface. This information makes it possible for interested Iowans to use a science-based approach when making decisions that affect water quality. Water quality data from several USGS and USDA monitoring sites is collected by IIHR and also displayed in IWQIS. All archived IIHR water quality is made available to upon request.

This report is a summary of data collected from 2012 to 2016, with a special focus on 2016 nitrate data. The report is the second annual report, issued for public consumption in the first quarter of each year. This year's report includes a statewide Nitrate-N load calculation along with Iowa's proportionate contribution to nitrate loading in the Mississippi River Basin.

Larry Weber, Ph.D.
Director
March 1, 2017

Part One:

The IIHR Water Monitoring Network

I. Overview

A. Iowa Water Quality History

Prior to European settlement in the 19th century, Iowa was covered with prairies, oak savannahs, wetlands and forests. Much of the landscape was internally drained, meaning that rainfall and snowmelt drained to small depressional areas, rather than stream networks. Groundwater-fed streams meandered across the landscape and likely ran shallow and clear, carrying low levels of sediment and nutrients. Rivers easily spilled out into the flood plain after heavy rains, and river banks re-vegetated during drought, reducing streambank erosion.

Over several decades, the native prairie was broken and cultivated for corn, oats and alfalfa, and a few other minor crops. Soil erosion was intense in the first years following a field's cultivation.

From the period of 1880 to 1920, many of Iowa's wettest areas were drained using pervious clay pipes. This was most common in the recently-glaciated area of north-central Iowa known as the Des Moines Lobe. Many new streams were constructed in ditches to drain water externally to the river network. Many existing streams were straightened to facilitate crop production.

The post-World War II era brought new developments to agriculture. The emergence of chemical fertilizers, soybeans, and continued drainage of the landscape with plastic drainage tiles helped Iowa become a world leader in crop and livestock production.

The loss of the native ecosystems, stream straightening and incision, artificial drainage, and discharges from industries and municipalities degraded water quality. Although the decline in water quality probably subsided in the early 1980s, Iowa's streams still carry more nutrients and sediment than most people find acceptable.

B. Iowa Landforms

To the untrained eye, Iowa's landscape may look uniform. The homogeneity of the corn and soybean landscape masks significant landscape differences that exist across the state. There are seven major landforms in Iowa, all shaped by glacial, wind, river and marine environments of the geologic past.

Stream water quality is greatly affected by the landform. For example, the streams flowing through the shallow limestone rock layers of northeast Iowa can be quite clear and cold. Rivers and streams of the artificially drained area of north central Iowa contain high levels of nutrients. Southern Iowa streams are muddier as the Loess soils of this area are easily eroded. Descriptions of Iowa Landforms follow, along with a map showing their location.

In western Iowa's **Loess Hills**, thick deposits of wind-blown silt (loess) form a unique landscape feature. The Loess was carried around by Missouri River floods and ground down by glaciers, especially from about 28,000 to 12,000 years ago. The formation is only about 15 miles wide, but runs about 200 miles north to south. The soil is fertile but easily erodible.

The **Des Moines Lobe** was formed during a brief period of glaciation in Iowa, from 15,000 to 12,000 years ago. The melted glacier left behind a poorly drained landscape of wetlands and potholes, with abundant clay and peat soils. Curved bands of ridges and knobby hills contribute to a gently rolling landscape. The Des Moines Lobe is part of the Prairie Pothole Region that extends from the city of Des Moines north and west to into Alberta. Most of the potholes have been drained with ditching and underground tile lines to make way for agriculture. Agriculture also created many streams here that did not exist prior to European settlement.

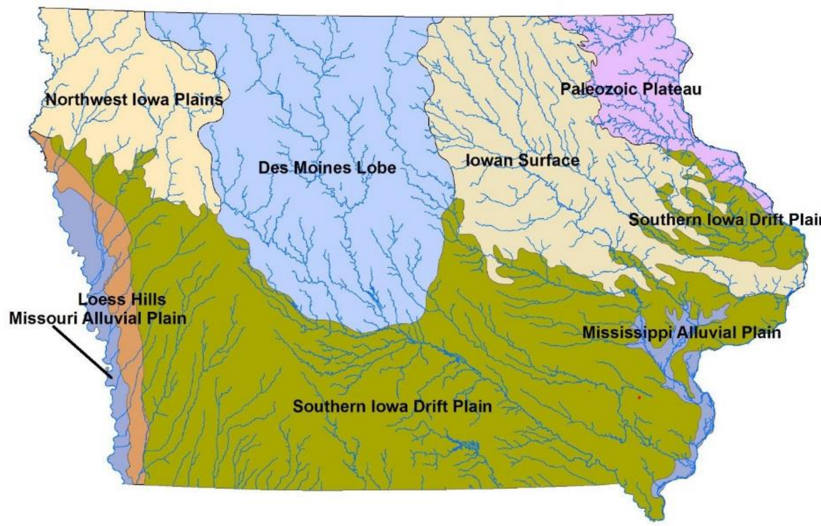


Figure 1: Iowa Landforms

The **Southern Iowa Drift Plain** (SIDP) was formed by glaciers that extended south to the Missouri River 500,000 years ago. Nature has had a lot of time to erode and carve away at the Loess soils here, a process that was sped up by early settlers. The hilly landscape is fertile but easily eroded.

Long, gently rolling slopes and low relief characterize the **Iowan Surface** of Northeast Iowa. This area was a prehistoric tundra when the Wisconsin glacier covered the Des Moines Lobe area 15,000 years ago. Drainage is well developed but slow because of the low relief. Thus, many of the farmed fields are artificially drained with tile to enhance crop production. A mantle of silt and sand dominates, likely deposited by persistent northwesterly winds blowing off the Wisconsin glacier. Some soils may have formed under forest, rather than prairie.

The **Northwest Iowa Plains** are similar to the Iowan Surface, but unlike the Iowan Surface, this area probably never had trees. Loess soils dominate because of its proximity to the Missouri and Big Sioux Rivers. This is the highest and driest area of Iowa, but still wet enough to require artificial drainage in many areas to enhance crop production.

The **Paleozoic Plateau** of Northeast Iowa is easily recognizable as “different”, even to the most untrained of eyes. This region is part of the four-state (IA, MN, IL, WI) Driftless Area, which remained unglaciated during the last glacial advance over Iowa. Narrow valleys are carved into the sedimentary rock of the Paleozoic Age. Dissolving limestone helped create a landscape of caves, springs, and sinkholes. Groundwater wells in this area are easily contaminated by surface activities.

The Mississippi and Missouri River **Alluvial Plains** seem disproportionately wide relative to the river itself. This is because they were originally formed by the huge floods that resulted from melting glaciers. Sloughs and oxbow lakes mark disconnected sections of the river channel. Levees and artificial drainage enable crop production, although the sandy soils can sometimes require irrigation during drier years. Smaller versions of these alluvial plains can be found along some interior rivers.

C. Iowa Nutrient Reduction Strategy

In response to the public's desire for improved water quality, a coalition of Iowa stakeholders developed the Iowa Nutrient Reduction Strategy (INRS) in 2011, a science and technology-based approach to assess and reduce nutrients delivered to Iowa waterways. The Iowa Nutrient Research Center (INRC) supports this effort with research and science-based information. Iowa's strategy was one of the first, and other states have looked to it as a guide for their own efforts.

The INRC provides science-based information on water quality for Iowans. INRC research evaluates the performance of current and emerging nutrient management practices, and provides recommendations on how to best implement these practices. This information benefits all Iowans, from farmers to urban dwellers, who depend on water for life and livelihood.

The INRC has created a very productive collaborative team, with overlapping and complementary sets of knowledge. For example, Iowa State University has more than 150 years of experience and credibility in farming practices and agricultural science. IIHR— Hydroscience & Engineering (IIHR) at the University of Iowa has been an acknowledged worldwide leader in hydrology and fluids-related research for nearly a century. The combination sets up a powerful force for progress.

D. IIHR Water Quality Monitoring

In support of the Iowa Nutrient Reduction Strategy, and the backbone of the water-quality research at IIHR, is a network of water-quality monitoring sites throughout Iowa. Expanding from an initial 7 IIHR sites in 2012, the combined network (IIHR, USGS, USDA) is expected to surpass 80 water quality monitoring sites when fully deployed in 2017.

The water quality monitoring stations, designed and constructed by IIHR engineers and researchers, employs the use of continuous in-situ sensors that provide near real-time data, on parameters such as nitrate concentration, turbidity, temperature, specific conductance, pH, and dissolved oxygen concentration.

Researchers at IIHR have also developed an easy-to-use web platform, the Iowa Water-Quality Information System (IWQIS), to disseminate the sensor data, similar to the Iowa Flood Center's Iowa Flood Information System (IFIS). IWQIS displays the near real-time water quality data from in-stream sensors across the state of Iowa in a user-friendly, Google Maps interface. This new interface makes it possible for all interested Iowans to view statewide water quality conditions, and to use a science-based approach when making decisions that affect water quality. Water quality data from several USGS and USDA-ARS monitoring sites is harvested by IIHR and also displayed in IWQIS. All archived IIHR water quality is made available upon request.

Real-time monitoring by IIHR predates the INRC. The monitoring program was an off-shoot of the Lucille A. Carver Mississippi River Environmental Research Station (LACMRERS). LACMRERS was a dream of its founding director, Tatsuaki Nakato, and IIHR's former director, V.C. Patel. They obtained a generous grant of $1.2 million from the Roy J. Carver Charitable Trust, which represented the bulk of the building costs. LACMRERS opened in 2002.

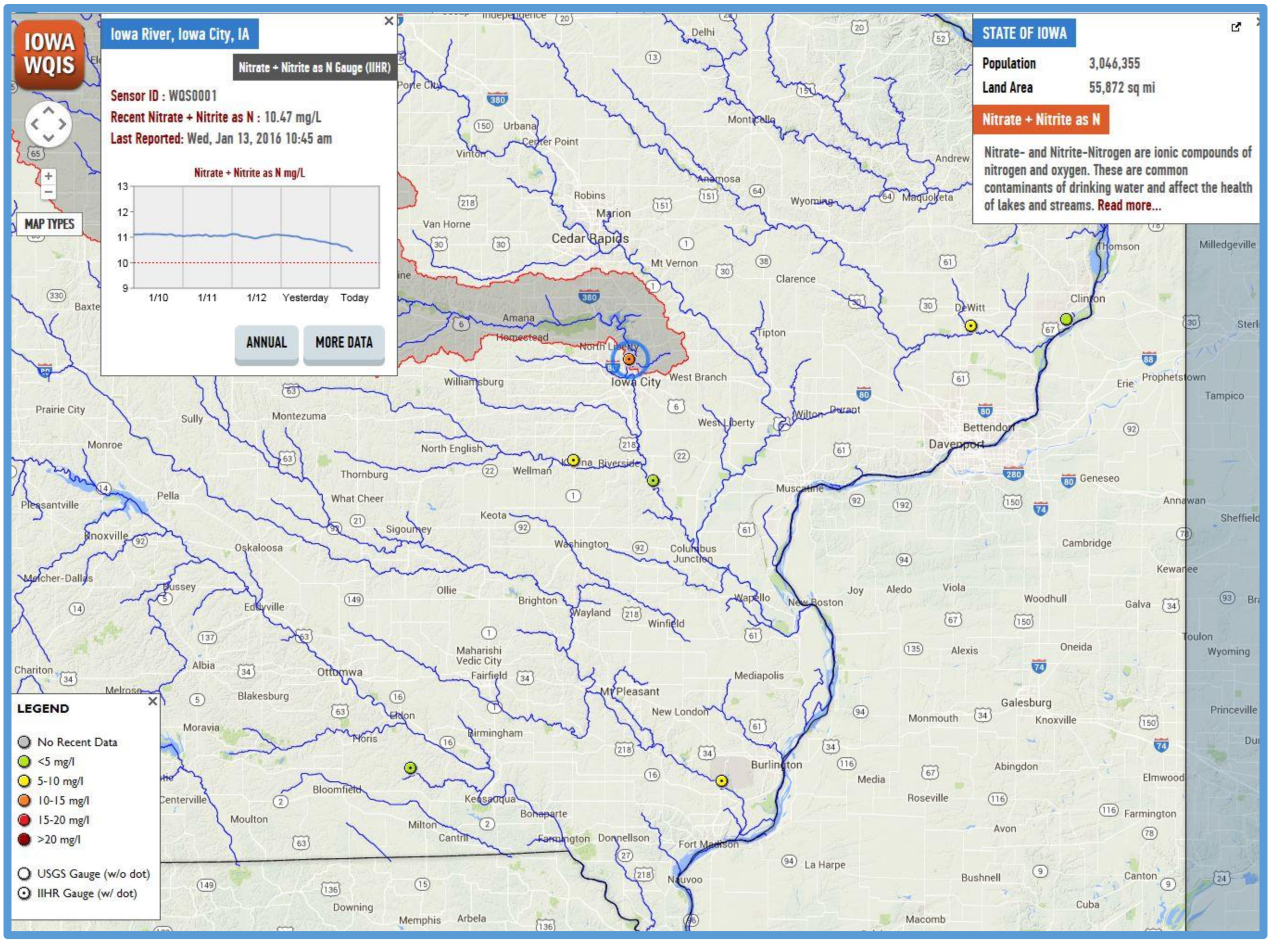


Figure 2: Screenshot from the IWQIS website illustrating nitrate concentration in the Iowa River at Iowa City

In 2008, a second major contribution from the Carver Trust brought its support of LACMRERS to a total of more than $2 million, allowing IIHR to equip the laboratory with a multi-beam echo sounder, state-of-the art water quality sensors and data loggers, sediment laboratory equipment, and other equipment for large-river research. From this second contribution, a few nitrate sensors were deployed along and in the Mississippi River, in Clear Creek in Johnson County, and for short-term research projects. Four sites were monitored in Lake Odessa (SE Iowa) in 2011-2012 to assess nitrogen processing.

The current program of real-time stream monitoring of interior streams began in 2012. That year seven nitrate sensors were deployed at sites in the Lower Iowa River Watershed. In 2013, three additional stream sites were added. Also in 2013, equipment was purchased with funding from the Housing and Urban Development (HUD) (one sensor deployed on Otter Creek in NE Iowa) and additional devices were funded by IIHR to monitor a constructed wetland in NE Iowa and the Skunk River at Augusta.

Twelve stream sites were added in 2014 with funding from HUD and INRC. This enlarged the network to 22. This expanded to 28 sites in 2015 with funding from HUD, INRC, the City of Dubuque, and Iowa Department of Natural Resources (IDNR). Continued funding from INRC, plus integration of sensors from the Agricultural Research Service (ARS) and Coe College, enlarged the network to a total of 56 sites in 2016. Harvest of data from the USGS sites into the IWQIS network made data available for 70 sites throughout Iowa.

The objectives of IIHR water quality monitoring are three-fold:

- Inform the water quality discussion in Iowa with credible, science-based data.
- Quantify nitrogen loads transported from Iowa watersheds, which will help track progress toward water quality objectives outlined in the INRS.
- Use accumulated data to conduct original research on water quality, hydrology, and land use effects on Iowa's ground and surface waters.

E. Staff

The monitoring network and IWQIS are operated and maintained by several IIHR scientific staff members. These include:

- Jason McCurdy, Research Assistant: Jason-mccurdy@uiowa.edu
- Thomas Stoeffler, Research Assistant: thomas-stoeffler@uiowa.edu
- Samuel Debionne, Engineer: samuel-debionne@uiowa.edu
- James Niemeier, Ph.D., Assistant Research Scientist: james-niemeier@uiowa.edu.
- Ibrahim Demir, Ph.D. Assistant Research Engineer: ibrahim-demir@uiowa.edu
- Caroline Davis, Ph.D., Assistant Research Scientist: caroline-davis@uiowa.edu
- Christopher Jones, Ph.D., Research Engineer: christopher-s-jones@uiowa.edu
- Larry Weber, Ph.D., Professor and IIHR Director: larry-weber@uiowa.edu

II. Monitored Parameters

A. Nitrate- and Nitrite-Nitrogen (NO_x) are ionic compounds of nitrogen and oxygen. These are common contaminants of drinking water and affect the health of lakes and streams. Many nitrogen compounds naturally exist in lakes, streams and groundwater, including nitrate and nitrite. Nitrate is a negative ion consisting of one nitrogen atom and three oxygen atoms. It is an essential plant nutrient. Because it is a relatively stable form of nitrogen, and because it is very water soluble, it is the most common form of nitrogen entering the stream network from farmed fields. It is also present in municipal wastewater discharge, leakage from septic tanks, and runoff from manure. Nitrate and nitrite (one nitrogen with two oxygen atoms) in drinking water pose an acute health risk for infants less than 6 months of age. The infant's digestive system has not developed a mature assemblage of microorganisms, and as a result, nitrate and nitrite compete with hemoglobin for oxygen in the bloodstream. This condition is known as methemoglobinemia (blue baby syndrome). Very few methemoglobinemia cases caused by contaminated drinking water have been reported in the United States since 1960. Incidence was higher prior then. Drinking water nitrate and nitrite are measured "as nitrogen" in the U.S., with a limit set at 10 parts per million (mg/L) for nitrate-nitrogen and 1 mg/L for nitrite-nitrogen.

Elevated NO_x in streams and lakes can upset the natural balance, leading to harmful algae blooms and poor diversity of organisms. Prior to European settlement, NO_x levels in Iowa streams were likely less than 2 mg/L. Nitrite usually is not stable in the environment, especially in streams, where it is quickly converted to nitrate. In Iowa, about 80-90% of NO_x originates from non-point sources (mostly row crop and animal agriculture) with the balance coming from wastewater treatment discharges, septic tanks, and natural sources.

Nitrate-nitrite nitrogen (NO_x-N) is measured using the Nitratax sc plus sensor (Hach Co.) with a path length 2 or 5 mm, depending on the model. The device works on the principle of ultraviolet (UV) light absorption. Both forms of NO_x-N absorb UV. As the concentration increases, absorption of UV also increases. A built-in photometer measures the primary beam, while a second beam of UV light provides a reference standard. The optic windows of the device are automatically cleaned at a defined interval using a wiper. NO_x-N is quantified in the range of 0.1-50 mg/L in 0.1 mg/L increments. Figure 3 illustrates the Nitratax sensor.

Figure 3: Nitratax Plus SC

B. Turbidity. Sediment particles obstruct the transmittance of light through water and impart a property known as turbidity. Turbid water is cloudy water. Turbidity is measured in Nephelometric Turbidity Units (NTUs). Clear water like drinking water has a turbidity less than 1 NTU. Muddy floodwaters can have turbidity greater than 1000 NTU. A few rivers are naturally muddy. The Missouri River, for example, was very muddy prior to dam construction and channelization, and its aquatic life was adapted to that condition. Most Iowa streams, however, likely ran clear (less than 10 NTU) before the prairie was broken. Excess cloudiness reduces diversity of fish and other organisms in our lakes and streams.

Figure 4: DTS-12 Turbidimeter

Turbidity is measured using a DTS-12 turbidity sensor (Figure 4) from Forest Technology Systems. A continuous beam of light is transmitted through the water being measured. Suspended (not dissolved) solid particles “scatter” the light beam. The scattered light is measured at a 90 degree angle to the transmitted beam. The scattered light is then converted to standardized NTU. The DTS-12 also measures temperature. It can measure turbidity in the range of 0-1600 NTU at an accuracy of +2% + 0.2 NTU at <400 NTU and +4% at >400 NTU. Precision is 0.01 NTU.

C. Temperature. Extremes of temperature, especially excess heat, are harmful to aquatic life and can lead to fish kills and other negative consequences. Because natural vegetation along the stream bank (riparian area) has been altered, many Iowa streams do not have shady areas and suffer from heat stress.

Temperature is measured using an electronic thermometer contained within the Hydrolab DS5X multiparameter water quality sonde (Ott Hydromet). Multiple measurement probes are contained with the sonde (Figure 5). Temperature is measured from -5 to 50C at an accuracy of + 0.10 and precision of 0.01C with an electronic thermometer. Temperature measurements are made interchangeably in degree Celsius or Fahrenheit, but are shown on IWQIS in Fahrenheit. Conversions between Celsius and Fahrenheit scale are shown in Table 1 below.

Degrees Celsius	Degrees Fahrenheit
0	32
10	50
20	68
30	86

Table 1: Celsius-Fahrenheit conversions

D. **Specific Conductance (SC)** is created by the positive and negative ions of dissolved salts. Ions enable water to conduct electricity. Water with high SC is salty and harmful to freshwater organisms. SC greater than about 1000 microsiemens (µS) would likely be stressful to aquatic life. Excess SC can be caused by stormwater runoff (road salts), wastewater discharges, and manure runoff.

High-conductivity (high levels of salts or ions) water transmits electricity much better than water without ions. To measure conductivity, a current is induced across two electrodes. The amount of electricity that is conducted from one electrode to the other is converted to conductivity. An SC probe is contained within the Hydrolab HL4 and is measured inside a temperature range of -5 to 50C with temperature compensation. Range of SC measurement is 0-100 milliSiemens per centimeter (mS/cm) with an accuracy of ±0.5% of reading + 0.001 mS/cm and a precision of 0.001 mS/cm.

E. **pH** is the measure of acidity or alkalinity in the water. A pH of 7 is exactly neutral; lower than 7 is acid, higher than 7 is basic (alkaline). Most Iowa waters are slightly to moderately alkaline (7.5-8.5) in their natural condition. pH tends to be slightly higher in the summer. In a lake or stream plagued by algae, pH levels can vary greatly between daytime and nighttime. This stresses the other organisms.

pH is measured using an ion-selective electrode contained within the Hydrolab DS5x at an accuracy of ±0.2 and precision of 0.01 unit. pH is a logarithmic conversion of hydrogen ion concentration. The electrode allows passage of hydrogen ions, and only hydrogen ions, from the measured water to the electrode itself, where a voltage is measured and converted to the pH scale.

F. **Dissolved oxygen (DO)** is needed by fish and other aquatic life. Decomposition of organic material from wastewater discharges or manure consumes DO. Ammonia and nitrite-nitrogen also consume oxygen. Algae blooms affect DO levels by giving off oxygen in the day but consuming it at night. When DO drops below 4-5 parts per million, fish begin to die. Fish like carp and

Figure 5: Hydrolab HL4

bullhead can tolerate much lower DO levels than desirable species like smallmouth bass and walleye.

Dissolved oxygen (DO) is measured using the principle of luminescence quenching by oxygen in a sensor contained within the Hydrolab DS5x. Measurement range is 0-60 mg/L, although natural waters rarely exceed 20 mg/L. Accuracy is +0.1 mg/L at DO < 8, +0.2 mg/L at DO > 8. Precision is 0.01 mg/L.

III. IIHR Water Monitoring Network Sites

A. Equipment Deployment

Nearly all monitoring sites are interior streams. Equipment is deployed such that sensors are immersed in flowing water. Care is taken to deploy the sensors in spots where the risk of damage due to river debris and vandalism is low. Most sensors are removed in late fall to prevent ice damage. Although each site deployment is unique to the specific site conditions, IIHR researchers and technicians have developed an easy-to-install package system for instrument power, control, and data transmission that facilitates simple and rapid deployment of equipment.

The sensors themselves reside within PVC pipe, perforated so that the flowing stream can continuously bathe the sensor with fresh water. Solar panels, deep cycle batteries, and data loggers are situated on the adjacent stream bank. Data is conveyed back to IIHR in Iowa City via cell modem. Figure 6 illustrates a typical deployment.

Figure 6: Typical deployment of sensor equipment at IIHR monitoring site

B. Site Selection

Sites are selected based on a number of factors:

- Some sensing equipment is/was funded specifically for a research proposal or project in a selected watershed.
- Major interior river sites are selected based on their strategic importance for nutrient load estimations, including proximity to USGS water discharge measurement locations.
- Significance of the stream for recreation, municipal water supply, or other designated uses.
- Suitability of the site for sensor equipment, i.e. security, water depth, etc.
- Requests from outside stakeholders.

The number and location of IIHR monitoring sites can vary depending upon research needs, equipment maintenance, and other factors. Figure 7 below and the map shown in Table 2 illustrate sites monitored in 2016. Water quality data along with additional information about each site can be found later in this report.

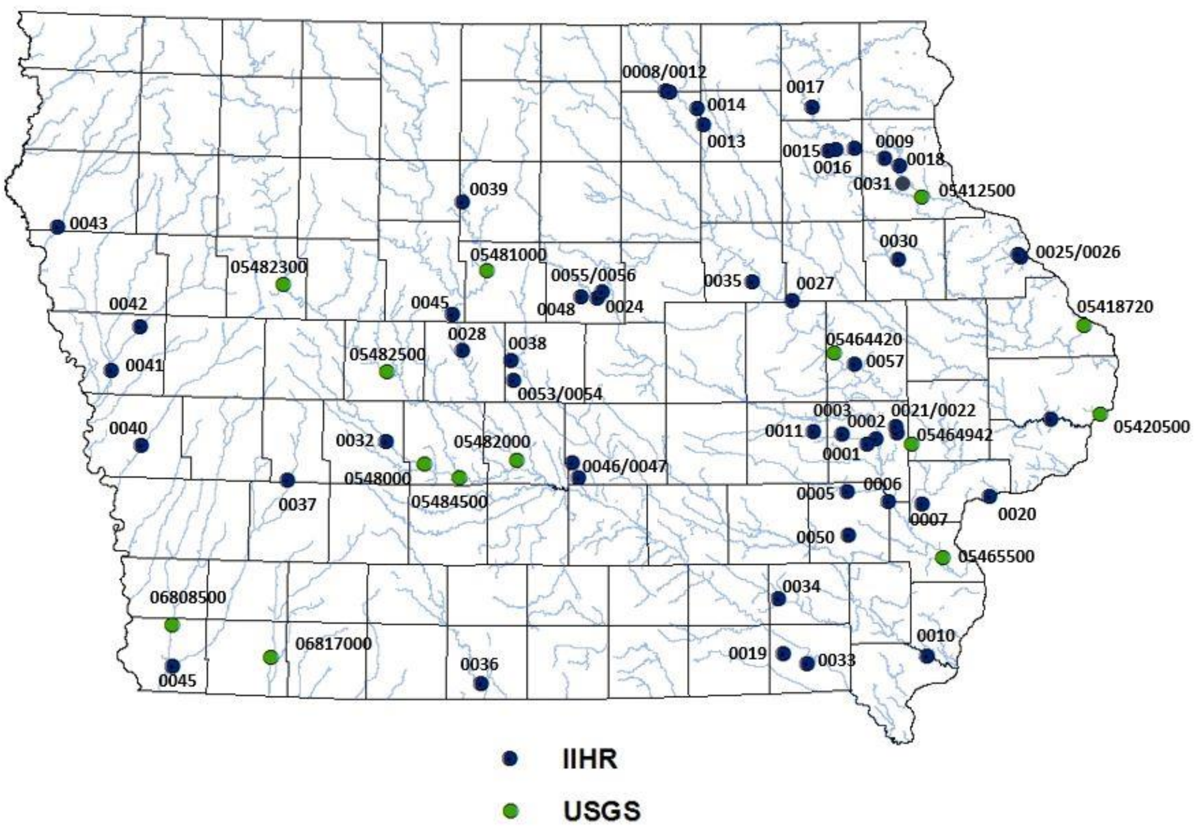


Figure 7: 2016 Sensor Deployments

Code	Name	Years Monitored
WQS0001	Iowa River at Iowa City	2012-2016
WQS0002	Clear Creek at Coralville	2012-2016
WQS0003	Clear Creek near Oxford	2012-2016
WQS0005	English River near Kalona	2012-2016
WQS0006	Iowa River near Lone Tree	2012-2016
WQS0007	Cedar River near Conesville	2012-2016
WQS0008	Slough Creek CREP Wetland outlet near Orchard	2013-2016
WQS0009	Otter Creek at Elgin	2013-2016
WQS0010	Skunk River at Augusta	2013-2016
WQS0011	Clear Creek near Homestead	2014-2016
WQS0012	Slough Creek CREP Wetland inlet near Orchard	2014-2016
WQS0013	Beaver Creek near Bassett	2014-2016
WQS0014	Beaver Creek near Colwell	2014-2016
WQS0015	Otter Creek near Elgin	2014-2016
WQS0016	Otter Creek near West Union	2014-2016
WQS0017	Brockcamp Creek near Ft. Atkinson	2014-2016
WQS0018	Roberts Creek near Elkader	2014-2016
WQS0019	S. Chequest Creek near Douds	2014-2016
WQS0020	Mississippi River near Fairport	2014-2016
WQS0021	Rapid Creek near Iowa City	2014-2016
WQS0022	Rapid Creek tributary near Iowa City	2014-2016
WQS0023	Wapsipinicon River near DeWitt	2015-2016
WQS0024	South Fork of the Iowa River near New Providence	2015-2016
WQS0025	South Fork of Catfish Creek near Dubuque	2015-2016
WQS0026	Middle Fork of Catfish Creek at Dubuque	2015-2016
WQS0027	Lime Creek near Brandon	2015-2016
WQS0028	Des Moines River near Boone	2015-2016
WQS0029	Alluvial Well near WQS00028	2015-2016
WQS0030	Spring at Manchester Fish Hatchery near Manchester	2015-2016
WQS0031	Big Spring near Elkader	2015-2016
WQS0032	Middle Raccoon River near Panora	2016
WQS0033	Des Moines River near Keosauqua	2016
WQS0034	Cedar Creek near Batavia	2016
WQS0035	Miller Creek near LaPorte City	2016
WQS0036	Thompson Fork near Davis City	2016
WQS0037	East Nishnabotna River near Brayton	2016
WQS0038	Squaw Creek near Ames	2016
WQS0039	Boone River near Goldfield	2016
WQS0040	Boyer River near Logan	2016
WQS0041	Little Sioux River near Turin	2016
WQS0042	Maple River near Mapleton	2016
WQS0043	Floyd River near James	2016
WQS0044	East Nishnabotna near Riverton	2016
WQS0045	Des Moines River near Stratford	2016
WQS0046	Walnut Creek near Prairie City	2016
WQS0047	Walnut Creek near Prairie City	2016
WQS0048	Tipton Creek near Hubbard	2016
WQS0049	Chequest Creek Douds	2016
WQS0050	West Fork Crooked Creek near Washington	2016
WQS0051	Beaver Creek near Eldora	2016
WQS0052	Stormwater tile, McLoud Run near Cedar Rapids	2016
WQS0053	Walnut Creek near Kelley	2016

Table 2: IIHR 2016 monitoring sites.

IV. Maintenance and Quality Control

Sensor output is monitored daily via IWQIS and an IWQIS Administrative Panel at the University of Iowa's Oakdale campus. When non-sensical data or obvious malfunction is indicated, staff visit the site. Many times the problem can be resolved on site. If not, the equipment is retrieved and returned to Oakdale, where repairs are made if possible. If IIHR staff are unable to make repairs, the device is sent to the manufacturer for repairs. It is important to recognize that this equipment is exposed to harsh conditions very much unlike traditional measurement conditions found in a laboratory. Thus, equipment does malfunction from time to time, and at a higher frequency than lab measurement equipment. Downtime creates gaps in data during the monitoring season. Service contracts are maintained with the manufacturers for the most critical equipment, so that data gaps are kept to a minimum.

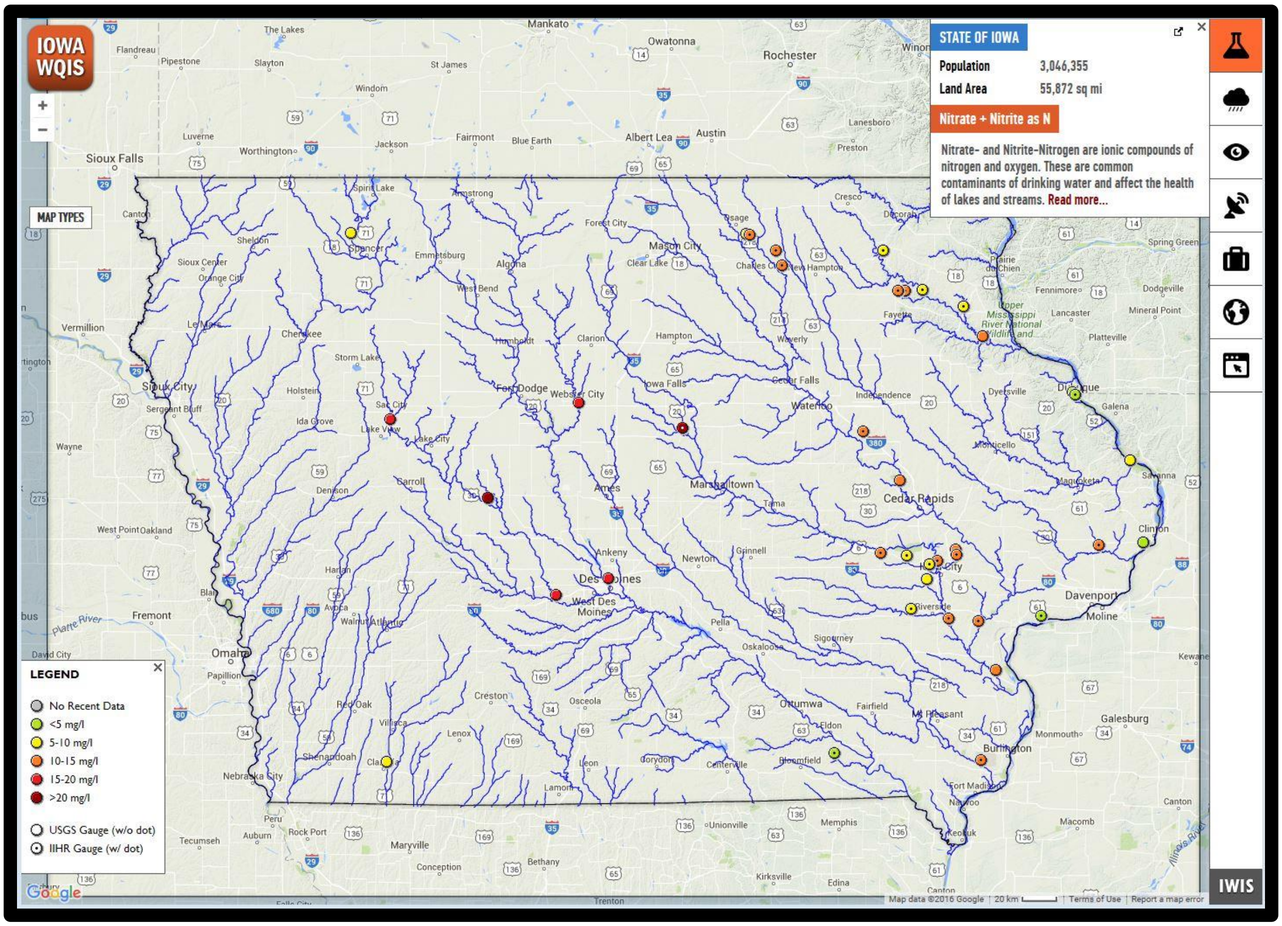
All equipment is checked, calibrated, and maintained according to the manufacturers' recommendations. Equipment is checked with known concentration solutions at the Oakdale facility. Because of keen interest from the public, and because many research projects focus on it, special attention is given to the Nitratax units and NO_x measurements. Each nitratax site is visited at least once every six weeks. Instrument components are checked at each visit, and a grab water sample is collected from the stream, with the date and time noted. This sample is then analyzed by the State Hygienic Laboratory and the result compared to the Nitratax result at the time of sampling. If problems are indicated, the Nitratax unit is calibrated and/or serviced. These comparative results are archived and accessed when necessary.

Other notes on data:

- Although the monitoring season can vary from year to year and site to site based on weather and maintenance considerations, the monitoring "season" is considered to April through October. Some data is reported outside this window. Quality Control examination of all data was conducted from March deployment (variable date from year to year) through fall retrieval for monitoring years 2012-2016 using all available data/information for each site, including IIHR field site notes, discharge and gage height, weather/precipitation conditions, system health variables (e.g., battery voltage), and acceptable limits/thresholds for each measured parameter.
- Temporal plots in the appendix figures show both approved data (red color) and raw or omitted data (gray color). Omitted data was not otherwise used in this report for calculations or for monthly statistics.
- Data was filtered to a 15 minute data interval, and matched to USGS discharge data where available.
- N Load and Yield calculations were carried out using an integral of the 15 minute data (N concentration and Q) for each month.

Part Two:

Water and Climate Data



V. Climate

A. Overview.

Land use has dramatically changed Iowa stream hydrology and water quality over the past 175 years. Urbanization, along with conversion of the native prairies, wetlands and savannahs to agricultural land has increased loads of nutrients, sediment, and synthetic chemicals in Iowa waterways. However, large-scale conversion of uncropped land to cropped land mostly ended in the 1970s. Since that time, land use change in Iowa has been minimal. The exception to this is around urban centers like Des Moines-Ames and Cedar Rapids-Iowa City where agricultural land has been developed for housing and commercial uses.

Thus most of Iowa has seen a relatively stable land use condition over the past 25 years, especially in the most intensely farmed areas like the Des Moines Lobe. The amount of land idled in the USDA's Conservation Reserve Program (CRP) does change from year to year, but these acres have always been a relatively small percentage of the total.

Because the total amount of cropped area has changed relatively little in recent decades, land use effects on water quality have been relatively static. Even so, water quality can change dramatically from year to year, this because of Iowa's dynamic weather. This is not to say weather "causes" water quality to be good or bad, only that year-to-year variations are mostly driven by it in a largely unchanging landscape.

Iowa has an extreme and dynamic climate characteristic of a mid-continental location. In fact, Iowa (especially the northern half) has some of the most extreme climate on earth. Precipitation especially can be highly variable from year to year. Pollutant loadings tend to be higher in wet years, although high river flows can dilute the concentrations of contaminants. Movement of contaminants such as nitrate into the stream network tends to be far lower in dry years. However, the warm, stagnant water resulting from a drought may be favorable for nuisance and harmful algae blooms.

The narrative that follows summarizes Iowa climate from 2012-2015, the period of record here for IIHR monitoring data.

B. 2012

This year finished as one of the most extreme years in the Iowa climate record. Statewide, it was the second warmest year ever next to 1931, with many locations, including Des Moines, experiencing their hottest year. Warmth in March was especially remarkable, with the statewide average temperature almost 17 degrees (F) above normal. In terms of deviation from average, March 2012 was the second most abnormal month ever in the record (a frigid February 1936 is first). Perhaps even more remarkable, March was warmer than April in some locations.

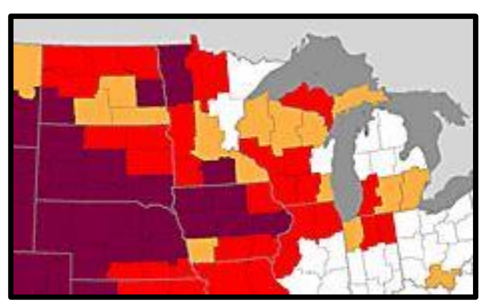


Figure 8: Map showing extreme drought conditions (darkest red) in September 2012

The warm spring of 2012 was followed by one of the worst droughts in Iowa history. Statewide annual precipitation was more than 8 inches below normal. This coupled with extreme July heat and low soil moisture conditions carrying over from 2011 to produce severe drought nearly statewide.

C. 2013

More extreme weather followed the 2012 drought. A statewide average of 13.6 inches of rain fell during April and May, more than double the average and two inches more than the previous record for the two months combined. Many Iowa farmers were unable to plant crops because of wet fields. Nitrate levels in many Iowa streams were higher than had ever been measured. Following a normal June, the weather turned extreme again. Less rain fell from July to December than fell in April and May. Average temperatures for the year ended up about 2 degrees F below normal, with December being the most abnormal month (six degrees colder than normal).

D. 2014

Weather in 2014 was most notable for the severe winter (Dec 2013-Feb 2014). Statewide the winter was the 4th-coldest after 1936, 1979, and 1978. The eastern 1/3 of Iowa was especially cold, reflecting the persistent "polar vortex" that affected the entire eastern U.S.

The year was wet, nearly eight inches above normal for precipitation. June was especially wet with a statewide average rainfall exceeding 10 inches. Historic floods hit Northwest Iowa during this time.

E. 2015

The big weather story in 2015 was precipitation. The first three months were extremely dry, especially March. After a normal April, the skies opened and rainfall from May through September was far above average. A few stations, especially in the west and south, experienced their wettest year ever. Bedford, IA near the Missouri border received an amazing 63 inches of rain in 2015. Many cities near the Missouri-Mississippi divide saw rainfall exceeding 50 inches.

Statewide annual temperatures were 1.1 degrees above normal, but extreme heat was rare. The year was the second consecutive without a 100 degree day anywhere in the state.

The graphs that follow illustrate temperature and precipitation in each of Iowa's nine climate zones. The water quality narrative that follows will refer to these zones when discussing weather effects on water quality data.

F. 2016

Temperatures were above normal in all nine Iowa climate regions during 2016. Statewide 2016 was 2.5 degrees (F) above normal and the 5th warmest year ever. Above normal days outnumbered below normal days 245 to 121. However, extreme heat was rare with only one 100 degree day reported (Little Sioux, June 11). Extreme cold was also relatively rare, with an average of 14 days reported with low temperatures less than zero, four fewer days than normal. The coldest temperature reported was -29 at Rock Rapids (December 18).

Precipitation however, was quite variable. Northern Iowa saw very wet conditions with the year ending well above normal in all three of the northern climate regions. Record rainfalls in August and September in north central and northeast Iowa led to major flooding in the Turkey, Wapsipinicon, Shell Rock, and Cedar River Watersheds. Several north central and northeast Iowa cities experienced their wettest year ever, led by Charles City with 58.6 inches. Decorah received 8.5 inches of rain on August 23 while Nora Springs received 10.6 inches on September 22.

Conditions were drier to south. All three Central Iowa climate regions, along with the Southwest Iowa climate region, saw slightly above normal precipitation. The South Central and Southeast Iowa climate regions were much drier with some areas experiencing mild to moderate drought throughout the summer. For the year, these two climate regions finished below normal for total precipitation. Some areas of southern Iowa experienced their driest year since 1988.

Figure 9: Iowa's climate zones correspond to crop district designations.

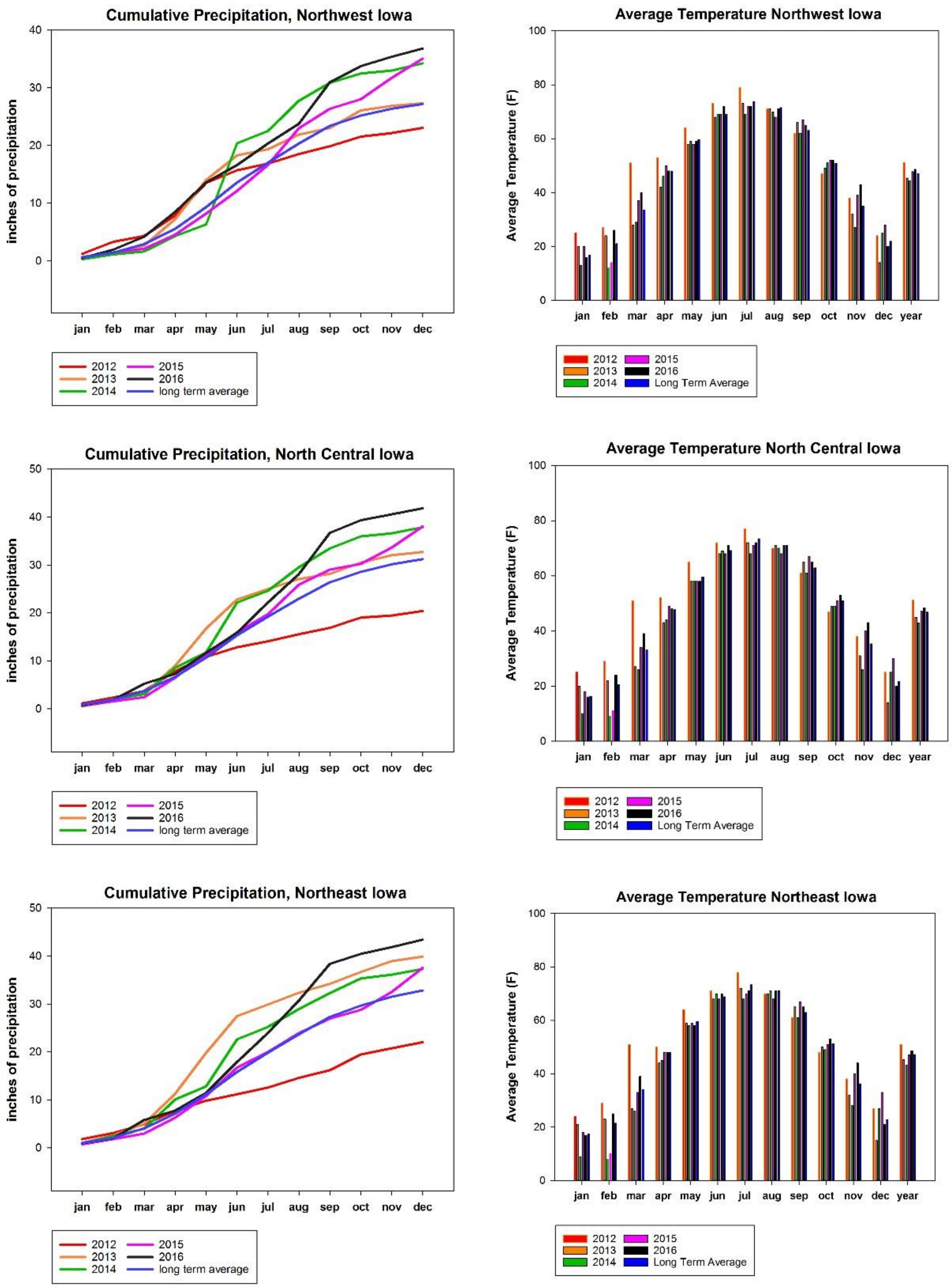


Figure 10: Precipitation and Temperature for Northern Iowa Regions, 2012-2016

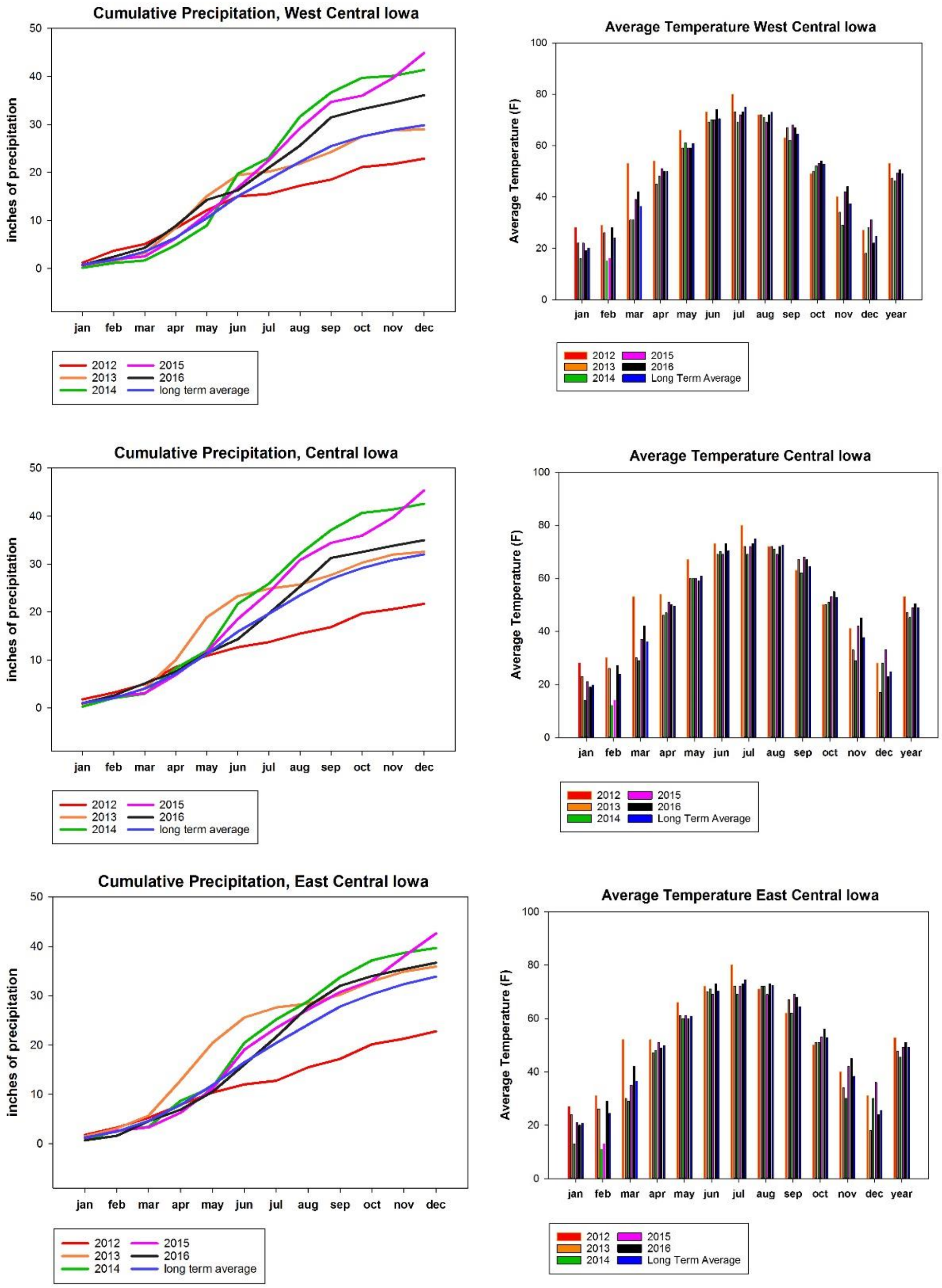


Figure 11: Precipitation and Temperature for Central Iowa Regions, 2012-16

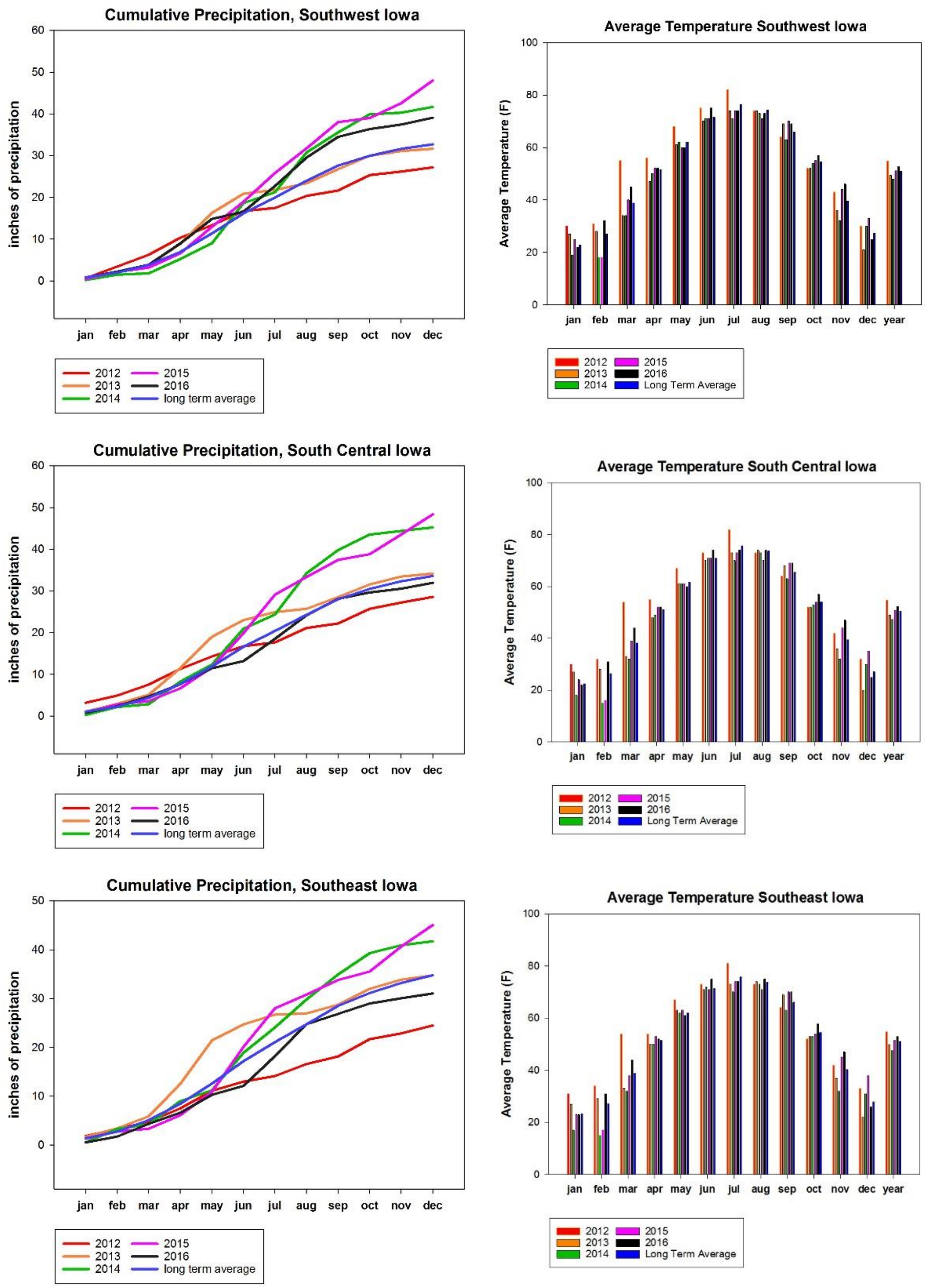


Figure 12: Precipitation and Temperature for Southern Iowa Regions, 2012-16

VI. Water Quality

A. Data reported

The pages that follow illustrate nitrate data collected at each IIHR monitoring site from 2012 (or when data collection began) through 2016. Data for other parameters, including turbidity, specific conductance, temperature, dissolved oxygen, and pH is also available in an appendix for some sites, but is not presented in this narrative report. People may request the nitrate and other data in Excel format by contacting:

Christopher S. Jones
332 Trowbridge Hall, University of Iowa
Iowa City, IA 52242
319-335-0589
Christopher-s-jones@uiowa.edu

B. Definitions

Some important water quality definitions for interpreting the data include:

1. **Concentration**, measured in milligrams per liter (mg/L), which is equivalent to parts per million. Concentration is the mass of a contaminant per unit volume of water. Nitrate and nitrite are reported "as nitrogen". Nitrate and nitrite ions contain both nitrogen and oxygen atoms. It is common to convert their concentration to nitrogen as a way to standardize reporting. The maximum amount of nitrogen in the nitrate-nitrite form allowed in municipal drinking water is 10 mg/L.
2. **Load.** Load is the total mass of a contaminant that passes a given point on a stream within a defined period of time. For the purposes of this report, the point on the stream is the location of the nitrate sensor. The period of time is usually the total amount measured April through October, unless otherwise noted. Load is a product of concentration and river discharge. Usually the river discharge used is that measured by the nearby USGS discharge gauge, unless otherwise noted. Load is reported in pounds of nitrogen present in the form of nitrate and nitrite. Comparing load from year to year is illustrative of climatic and other factors that cause variability in water quality.
3. **Yield.** Yield is the amount of nitrogen transported in the river, per unit area of watershed draining to the measurement site. Yield is reported here as pounds nitrogen per acre. Yield is especially useful for comparing nitrogen loss between different watersheds. It is calculated by dividing the load by the total land area upstream of the sensor.

C. Figures and Graphs

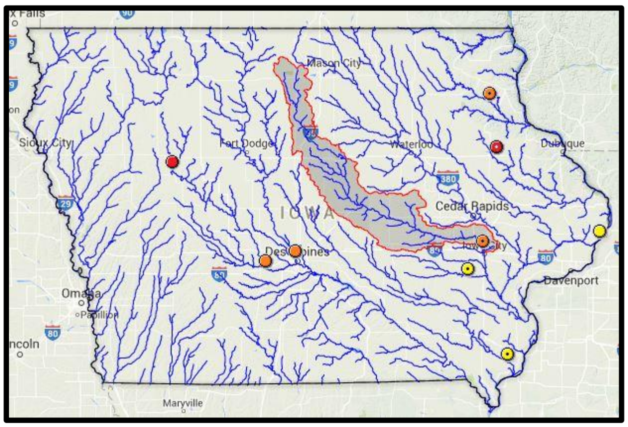
Data is collected every 15 minutes for each water quality sensor parameter. Space limits how this immense amount of data can be presented. Here we present data for the individual sites in time series graphs and summary tables. The reader may notice sudden drops in nitrate concentrations in the time series graphs. These drops are caused by rain events. Since rain and overland runoff contain low levels of nitrate, compared to tile water and groundwater, stream nitrate drops during and immediately after rainstorms. These changes tend to be more dramatic and of a shorter duration in small streams.

D. Individual Site Summaries

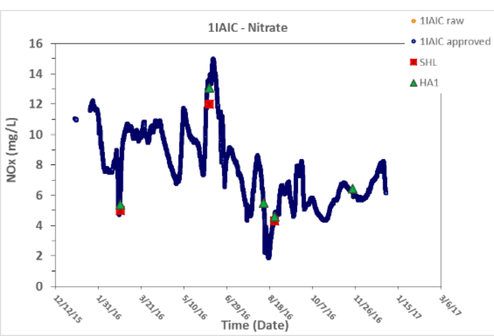
The pages that follow contain time series graphs, watershed maps, and site summaries for the IIHR sensor locations. Following the individual report summaries, data tables summarize year-to-year and site-to-site comparisons, along with a narrative summary of 2016 nitrate data.

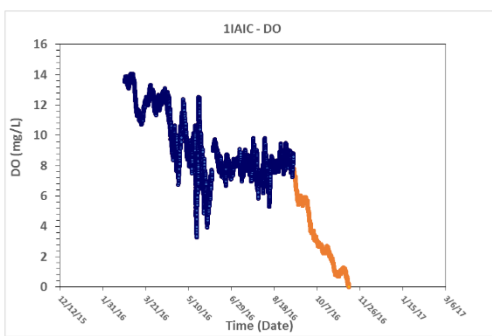
1. Site WQS0001 Iowa River at Iowa City

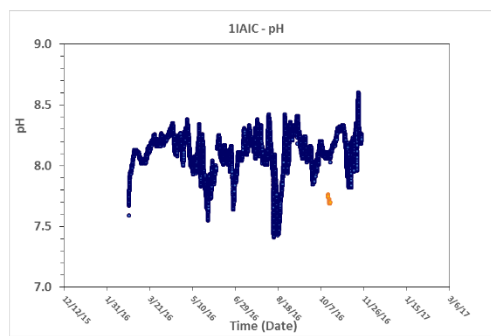
Site No.	WQS0001
Name	**Iowa River near Iowa City, Iowa**
Location	Left bank of Iowa River, 210 ft downstream of Dubuque Street bridge (41.6938, -91.5481)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature, specific conductance, pH, dissolved oxygen
Period of Record	August 2012 – December 2016
Drainage Area	3147 sq mi
Funding Sources	IIHR, INRC
Co-located Measurement	2.6 mi downstream from USGS 05453520 (stage, discharge) 260 ft downstream of DNR Ambient Monitoring Site (Storet ID 10520002)
Purpose & Significance	This site provides nitrogen-N load estimations for the drainage area above Coralville Dam, including the Coralville Reservoir; contributing in part to statewide N-loading estimates related to the Iowa Nutrient Reduction Strategy. Data from this site is used to inform decisions at the Iowa City water treatment plant regarding water-supply use (e.g., Craig Meecham, Senior Treatment Plant Operator, Iowa City Water Division, City of Iowa City). Discharge at this site is dominantly controlled by US Army Corps of Engineers regulation of Coralville Lake levels and associated flow from the dam.

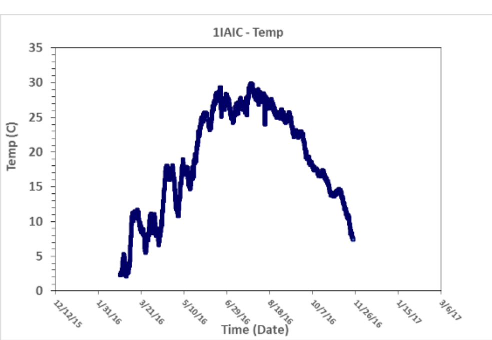


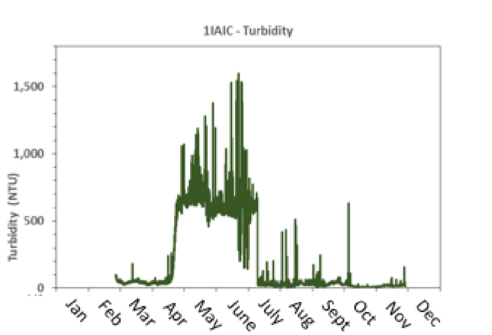
Discussion: This site receives water primarily from the Des Moines Lobe and the Southern Iowa Drift Plain, with very small areas of the Iowan Surface also contributing. The headwaters of the Iowa River are drained extensively by field tiles and county tile mains. This contributes to a large load and yield of nitrate delivered by the stream. High nitrate concentrations along with discharges characteristic of a large river make the Iowa one of the biggest contributors to Mississippi River Basin nitrate loads.

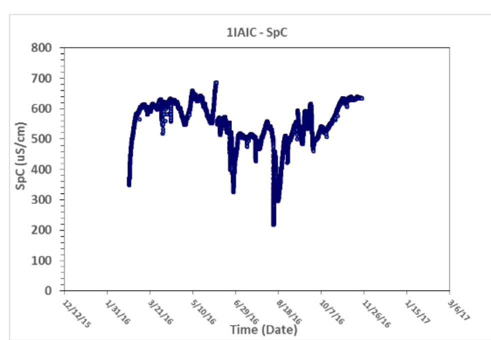






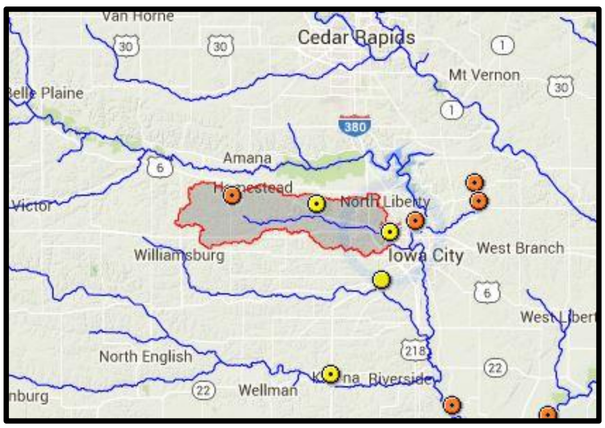




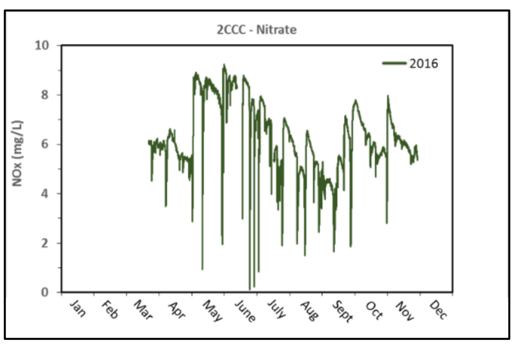


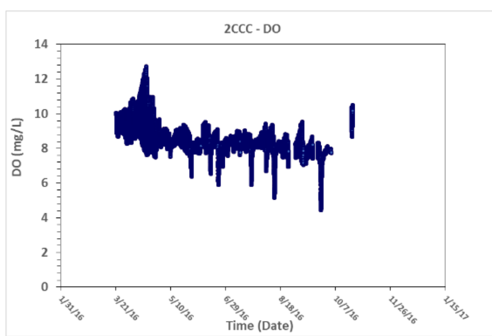
2. Site WQS0002 Clear Creek at Coralville

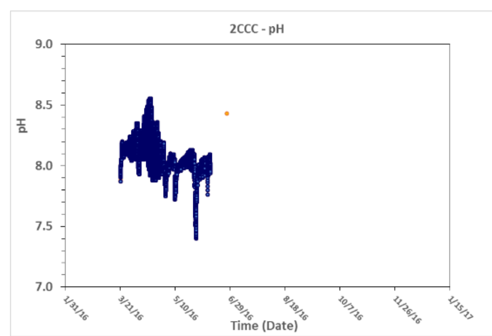
Site No.	WQS0002
Name	Clear Creek at Coralville, Iowa
Location	Left bank of Clear Creek, 16 ft upstream of Camp Cardinal Blvd bridge (41.6765, -91.5983)
WQ Parameters	Nitrate + nitrite as N, temperature, specific conductance, pH, dissolved oxygen
Period of Record	May 2012 – November 2016
Drainage Area	98 sq mi
Funding Sources	IIHR, INRC, EPSCoR
Co-located Measurement	USGS 05454300 (stage, discharge) CZO/EPSCoR project-related YSI EXO water quality sonde deployed in-situ and water sampling of storm events by isco water sampler.
Purpose & Significance	The Clear Creek watershed is a small (HUC10) tributary of the Lower Iowa river watershed that is highly utilized by U of I researchers due to its close proximity to the U of I campus. Current research projects, including funding from the Critical Zone Observatory Intensively Managed Landscapes (CZO-IML) grant (A. Bettis, T. Papanicolaou) and EPSCoR (A. Bettis, A. Ward), provide additional data and resources for WQS data integration and analysis. The WQS0002 site is the most downstream USGS gage station on Clear Creek, prior to Clear Creek entering the Iowa River. This site is one of three sites within the nested Clear Creek watershed.

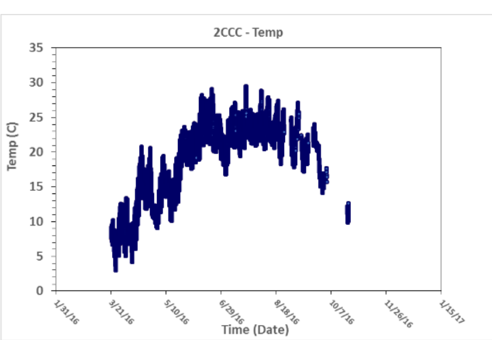


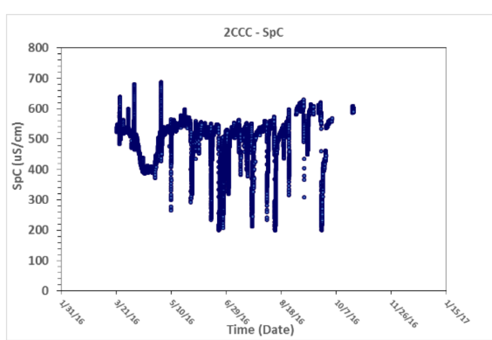
This Clear Creek site (vs the other two) is interesting in that it has a large urban component. The nitrate concentration in streams such as this typically drops as it flows through the urban area, while specific conductance increases due to street and storm sewer runoff (road salts).

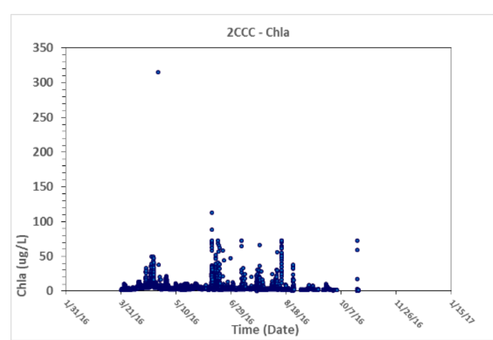






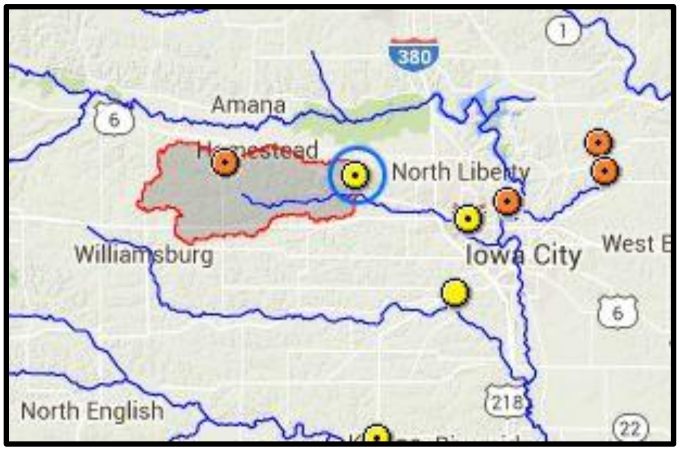




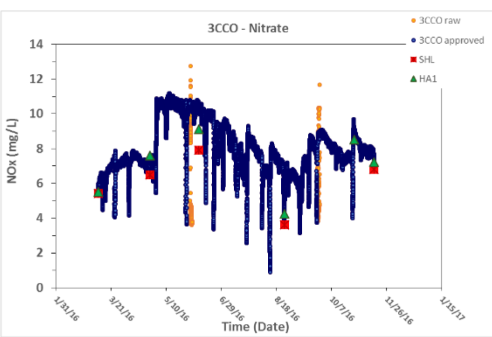


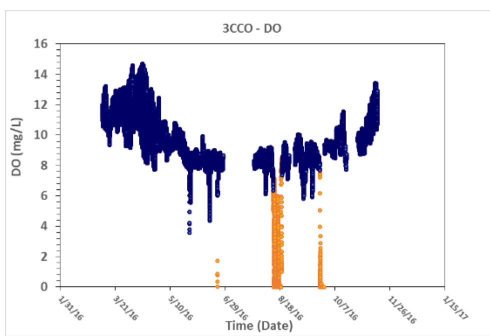
3. Site WQS0003 Clear Creek near Oxford

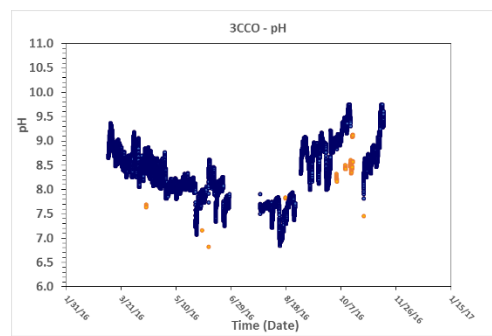
Site No.	WQS0003
Name	**Clear Creek near Oxford, Iowa**
Location	Left bank of Clear Creek, 10 ft upstream of Eagle Ave NW bridge (41.7182, -91.7403)
WQ Parameters	Nitrate + nitrite as N, temperature, specific conductance, pH, dissolved oxygen
Period of Record	May 2012 – November 2016
Drainage Area	61 sq mi
Funding Sources	IIHR, INRC, EPSCoR
Co-located Measurement	USGS 05454220 (stage, discharge) CZO/EPSCoR project-related YSI EXO water quality sonde deployed in-situ and water sampling of storm events by isco water sampler.
Purpose & Significance	The Clear Creek watershed is a small (HUC10) tributary of the Lower Iowa river watershed that is highly utilized by U of I researchers due to its close proximity to the U of I campus. Current research projects, including funding from the Critical Zone Observatory Intensively Managed Landscapes (CZO-IML) grant (A. Bettis, T. Papanicolaou) and EPSCoR (A. Bettis, A. Ward), provide additional data and resources for WQS data integration and analysis. The WQS0003 site is the most upstream USGS gage station on Clear Creek, above the Coralville station. This site is one of three sites within the nested Clear Creek watershed.

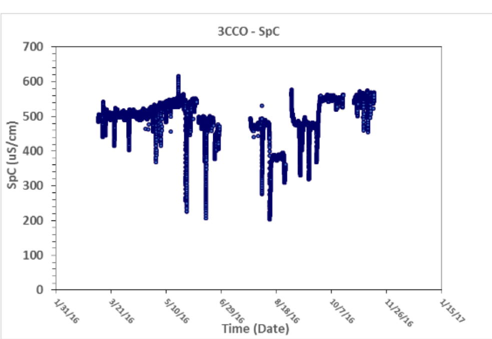


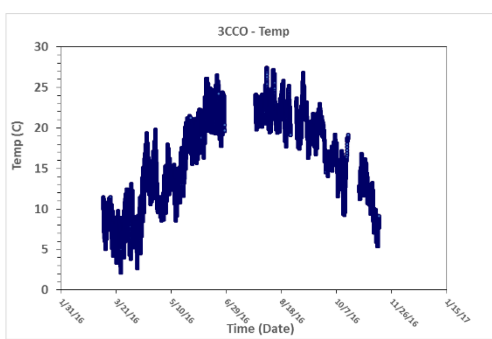
Water quality in Clear Creek at Oxford is largely driven by agricultural land use upstream from the site. Nitrate levels tend to be higher than those at Coralville, where low-nitrate urban runoff dilutes levels from the upstream areas.





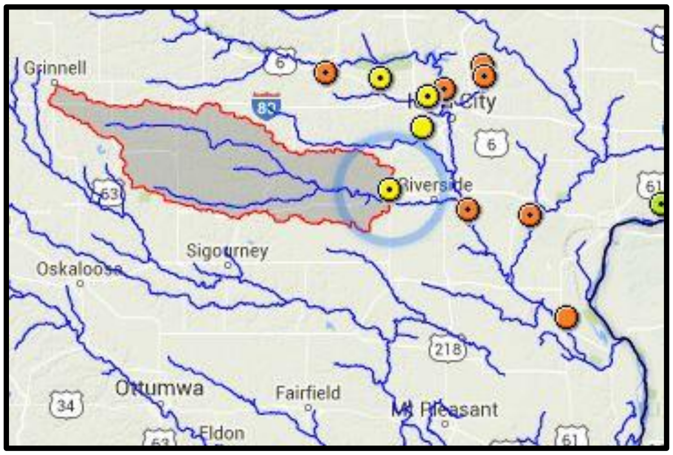




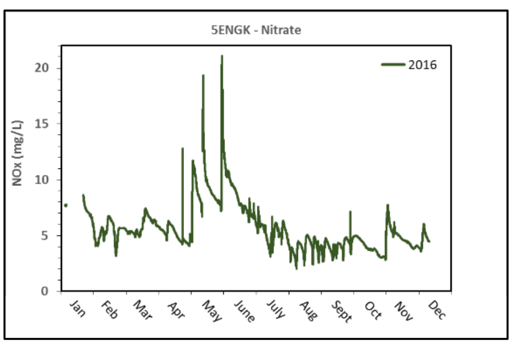


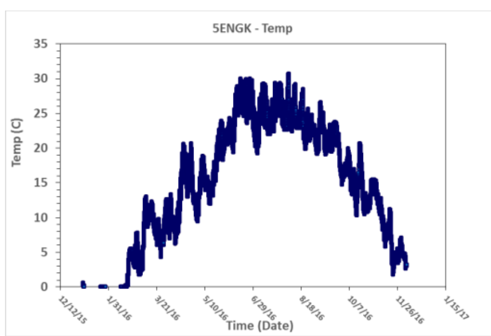
4. Site WQS0005 English River near Kalona

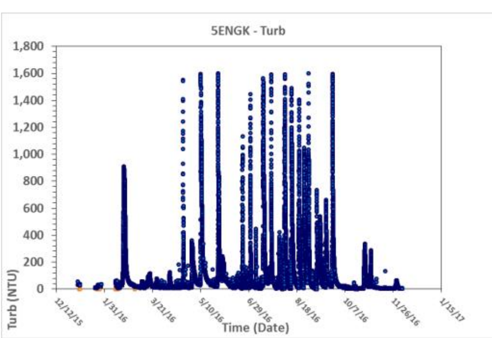
Site No.	WQS0005
Name	English River near Kalona, Iowa
Location	Left bank of English River, 5 ft downstream of Hwy 1 bridge (41.4694, -91.7144)
WQ Parameters	Nitrate + nitrite as N, temperature, turbidity
Period of Record	May 2012 – December 2016
Drainage Area	576 sq mi
Funding Sources	IIHR, INRC
Co-located Measurement	USGS 05455500 (stage, discharge) 11 mi upstream of DNR Ambient Monitoring Site (Storet ID 10920001)
Purpose & Significance	The English River is a large tributary of the Iowa River, characteristic of an agricultural watershed in the Southern Iowa Drift Plain. This site is an important location for IFC flood research and reporting, and is part of ongoing research activities at IIHR. As of the 2016 monitoring season, this site will be a Water Quality Initiative (WQI) project area funded through the Iowa Nutrient Reduction Strategy. In addition, nitrate measurements at this site contribute in part to statewide N-loading estimates.



Discussion: The English River is the second largest tributary of the Iowa River (the Cedar River is the largest). The watershed of the English River, however, yields a significantly smaller amount of nitrogen on a per acre basis. Again this is a reflection of landform, so important when discussing Iowa water quality. The English River watershed lies entirely within the Southern Iowa Drift Plain. There is less artificial drainage here, and the soils have smaller amounts of nitrogen-containing organic matter. This is manifested in lower stream nitrate levels when compared to Des Moines Lobe and Iowan Surface streams. That said, the English River can still have remarkably high nitrate levels at times.

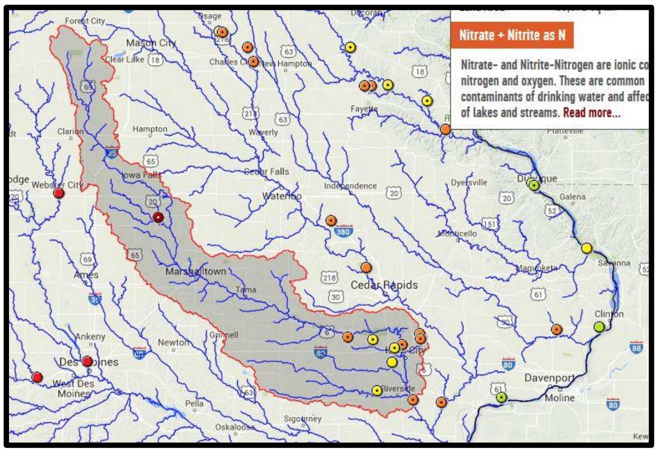






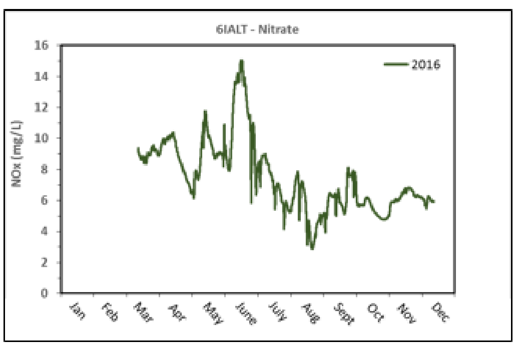
5. Site WQS0006 Iowa River near Lone Tree

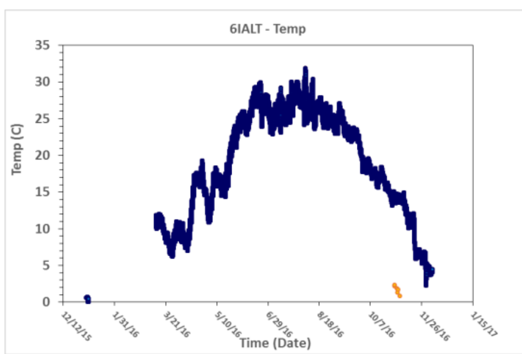
Site No.	WQS0006
Name	Iowa River near Lone Tree, Iowa
Location	Left bank of Iowa River, 17 ft downstream of Tri-County Bridge Rd bridge (41.4238, -91.4787)
WQ Parameters	Nitrate + nitrite as N, temperature, turbidity
Period of Record	June 2012 – December 2016
Drainage Area	4293 sq mi
Funding Sources	IIHR, INRC
Co-located Measurement	USGS 05455700 (stage, discharge) DNR Ambient Monitoring Site (Storet ID 10580002)
Purpose & Significance	The Iowa River near Lone Tree WQS site is a significant location for strategic load calculation to quantify the Iowa River watershed's contribution of N-loading to the Mississippi River. This site is located immediately upstream of the confluence with the Cedar River.

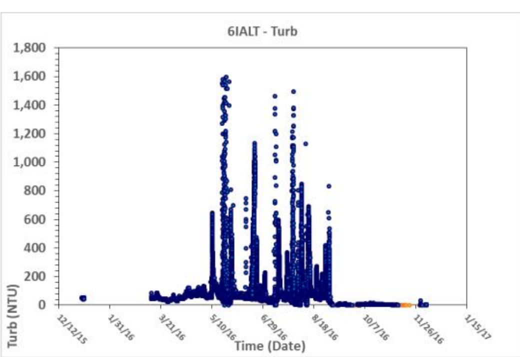


Discussion: This is the last gauging station on the Iowa upstream from the Cedar River confluence. Nitrate concentrations and yields are slightly lower here than the Iowa River-Iowa City location. This illustrates a dilution effect resulting from the English River, which has lower nitrate levels characteristic of the Southern Iowa Drift Plain.

This site will be strategically important in the coming years as scientists quantify N loads from Iowa's major watersheds. Comparing the Iowa River watershed with the adjacent Skunk and Cedar River Watersheds will inform the discussion about farming practices and potential conservation practices. Concentration and per acre yields seem to be higher in the Cedar and lower in the Skunk, when compared to the Iowa River.

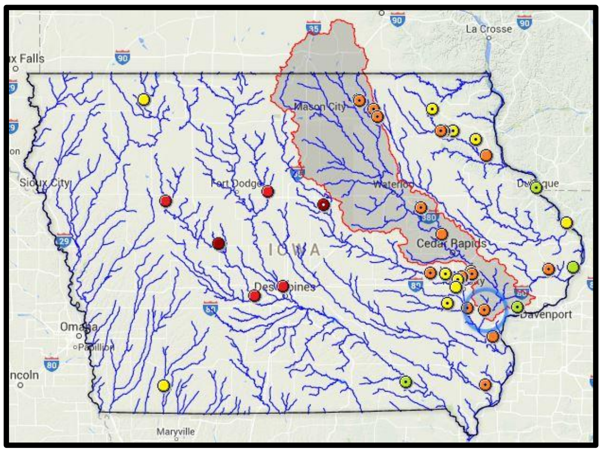






6. WQS0007 Cedar River near Conesville

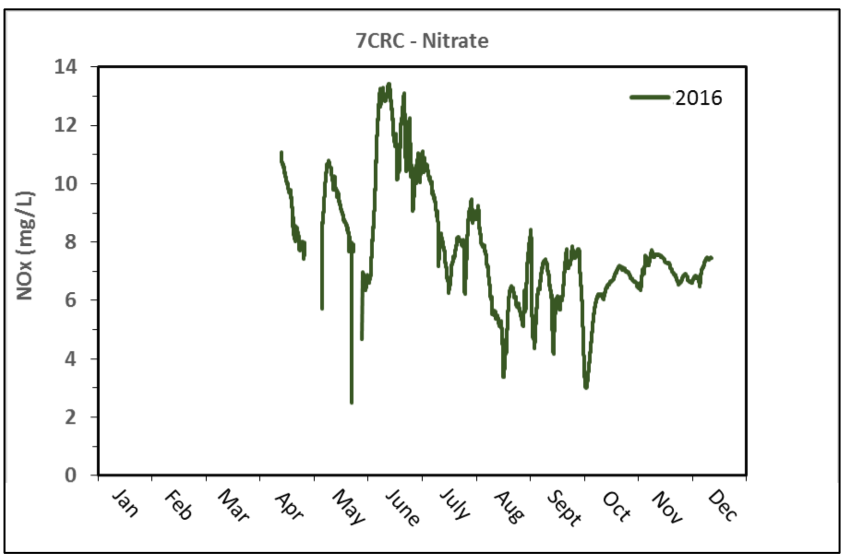
Site No.	WQS0007
Name	**Cedar River near Conesville, Iowa**
Location	Right bank of Cedar River, 15 ft upstream of 231st St bridge (41.4097, 91.2904)
WQ Parameters	Nitrate + nitrite as N
Period of Record	June 2012 – December 2016
Drainage Area	7787 sq mi
Funding Sources	IIHR, INRC
Co-located Measurement	USGS 05465000 (stage, discharge) DNR Ambient Monitoring Site (Storet ID 10700001)
Purpose & Significance	This site is a significant location for strategic load calculation to quantify the Cedar River watershed's contribution of N-loading to the Mississippi River. This site is located immediately upstream of the confluence with the Iowa River. In conjunction with nitrate concentration measurements at the USGS gage (Cedar River, Palo), the N load contribution of the Middle and Lower Cedar River watersheds can be estimated.



Discussion: Receiving water from both Minnesota and Iowa, the Cedar River watershed is Iowa's second largest (Des Moines River watershed is the biggest). At almost 8000 square miles, it is bigger than a few states. Although it is bigger than the receiving Iowa River, it is considered an Iowa River tributary due to the hydrology and geomorphology of the confluence. The Cedar drains primarily the Iowan Surface, with small parts of the Southern Iowa Driftplain and the Mississippi Alluvial Plain contributing.

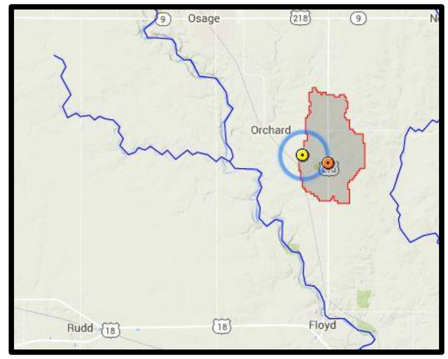
Many recent conservation efforts have focused on the Cedar River. Its importance as municipal water supply for Cedar Rapids and its large N contributions to the Mississippi Basin merit this attention.

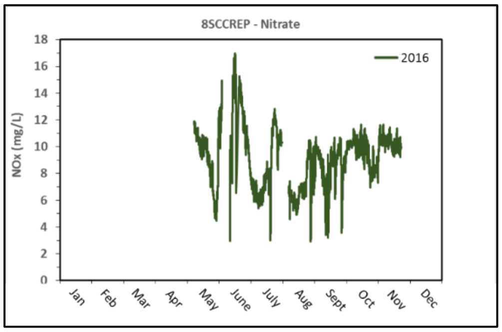
This site will be particularly important in the coming years as scientists estimate N loads from Iowa's largest watersheds, and how this relates to the state's Nutrient Reduction Strategy.

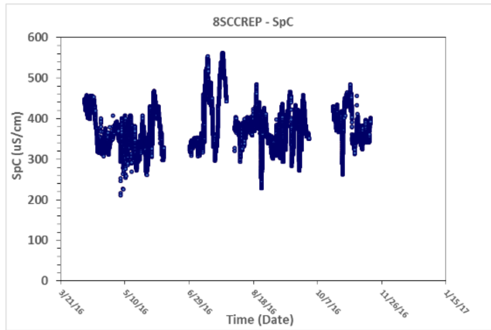


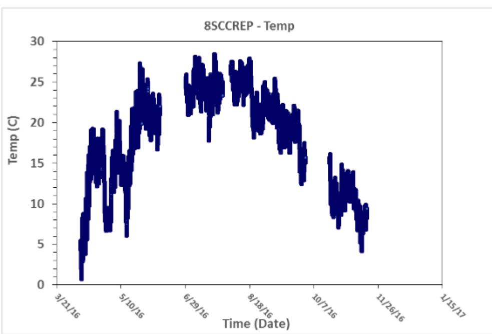
7. WQS0008 Slough Creek CREP Wetland outlet near Orchard

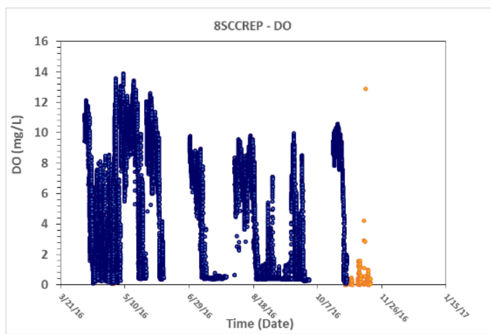
Site No.	WQS0008
Name	**Slough Creek CREP wetland near Orchard, Iowa**
Location	Left bank of Slough Creek, 240 ft downstream of CREP wetland weir (43.2100, -92.7502)
WQ Parameters	Nitrate + nitrite as N, temperature, specific conductance, pH, dissolved oxygen
Period of Record	May 2013 – November 2016
Drainage Area	6 sq mi
Funding Sources	IIHR, INRC
Co-located Measurement	550 ft upstream of DNR Ambient Monitoring Site (Storet ID 15340015)
Purpose & Significance	This site monitors the outflow of water from the weir of the CREP wetland on Slough Creek. The CREP wetland sites are important for demonstrating the effectiveness of constructed wetlands for the purpose of reducing nitrate loads to the Cedar and Mississippi Rivers, which is a key intent of the Iowa Nutrient Reduction Strategy.

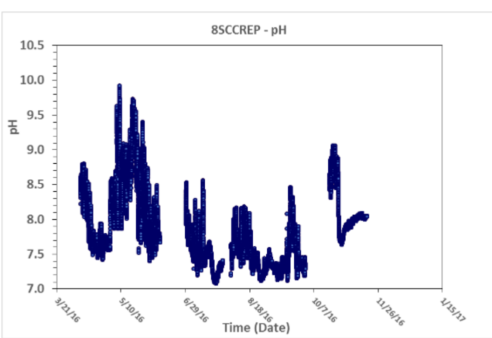


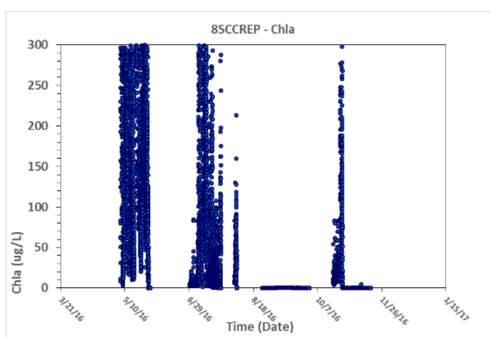












Discussion: A 24-acre constructed wetland was completed at this site in 2012. The wetland is positioned along Slough Creek which drains to a Cedar River tributary, Spring Creek. Lowering nitrate levels in the Cedar is critical because of the downstream municipal water supply in Cedar Rapids.

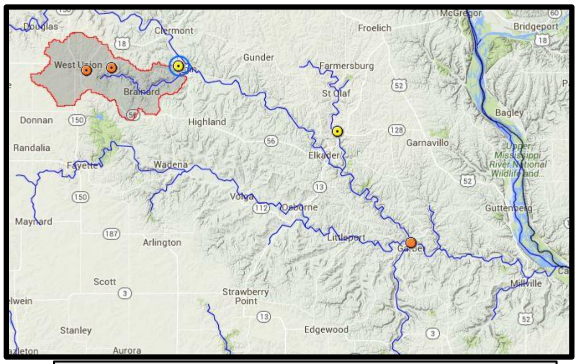
Researchers at IIHR have been studying water quality and nutrient processing in the wetland since 2013. Work has shown modest declines in the nitrate traveling through the wetland, especially after about June 1.

Nitrate in the water entering the wetland can exceed 20 parts per million (ppm), more than twice the safe limit for drinking water. As the water warms in late spring, however, this aquatic vegetation and other life in the wetland begins to process nitrate and sequester it as organic material, or convert it to harmless nitrogen gas which is released to the atmosphere. By the end of the summer, nitrate levels in the water leaving the wetland are less than 2 ppm.

The wetland also provides critical habitat for birds, reptiles, amphibians, and certain fishes. Birds present include pelicans and trumpeter swans.

8. WQS0009 Otter Creek at Elgin

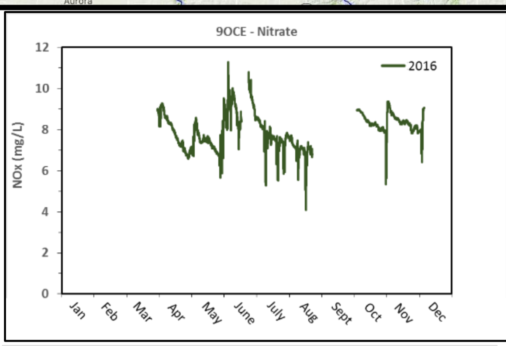
Site No.	WQS0009
Name	Otter Creek at Elgin, Iowa
Location	Right bank of Otter Creek, 5 ft upstream of Cedar Rd bridge (42.9500, -91.7538)
WQ Parameters	Nitrate + nitrite as N, temperature, specific conductance, pH, dissolved oxygen
Period of Record	June 2013 – November 2016
Drainage Area	46 sq mi
Funding Sources	INRC, HUD
Co-located Measurement	USGS 05411900 (stage, discharge)
Purpose & Significance	Otter Creek is a tributary of the Turkey River in NE Iowa. This site is one of three nested sites within the Otter Creek watershed operated by IIHR in 2016 and initially funded by HUD through the Iowa Watersheds Project.

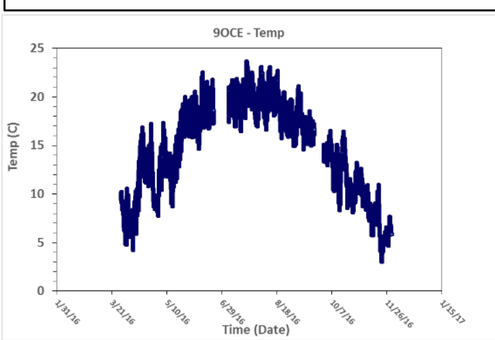


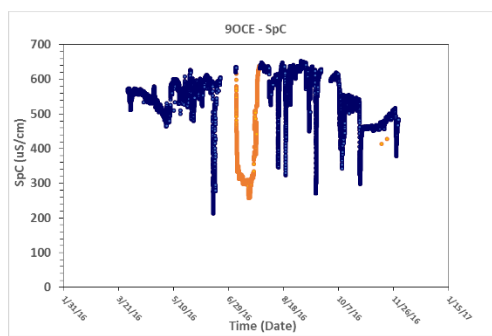
Discussion: Currently IIHR researchers developed a hydrograph separation model that uses nitrate concentrations from three Otter Creek sites to examine the contributions of tile drainage, groundwater and surface/storm flow to the stream. Otter Creek is a tributary of the Turkey River, and major Iowa interior stream.

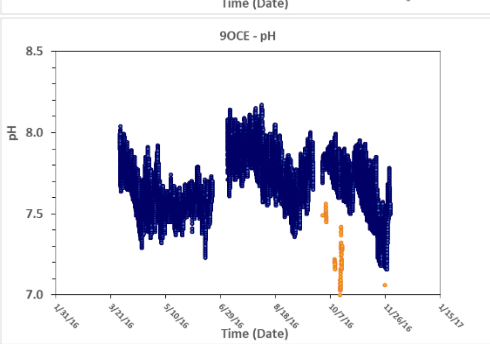
This site is near the confluence of the Turkey. Being the furthest-downstream site of the three Otter Cr sensors, it has the lowest nitrate concentration, which is typical, as high nitrate water from the headwaters (tile drainage) is diluted by lower nitrate groundwater throughout the stream course.

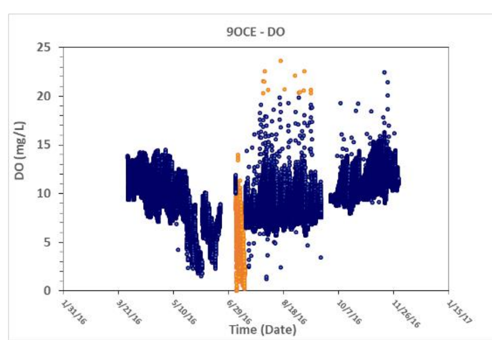
This site is the only one of the three with a flow gauge and load calculations.





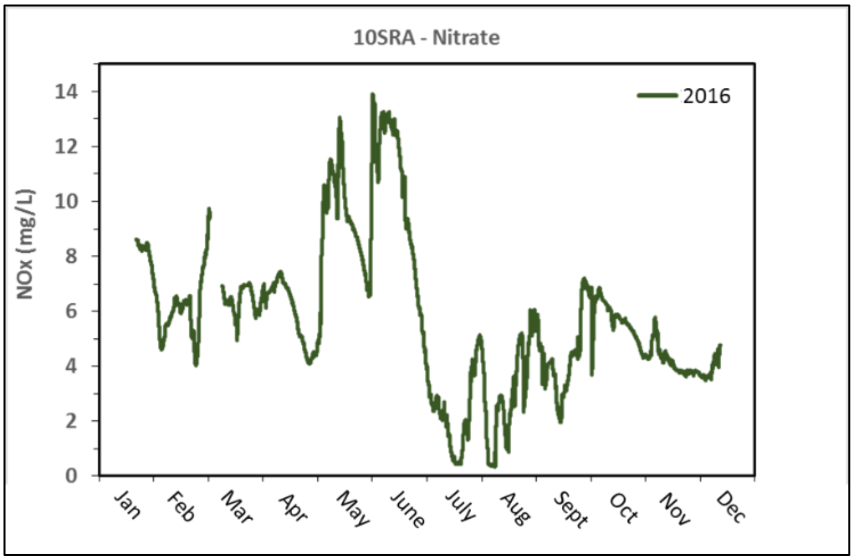


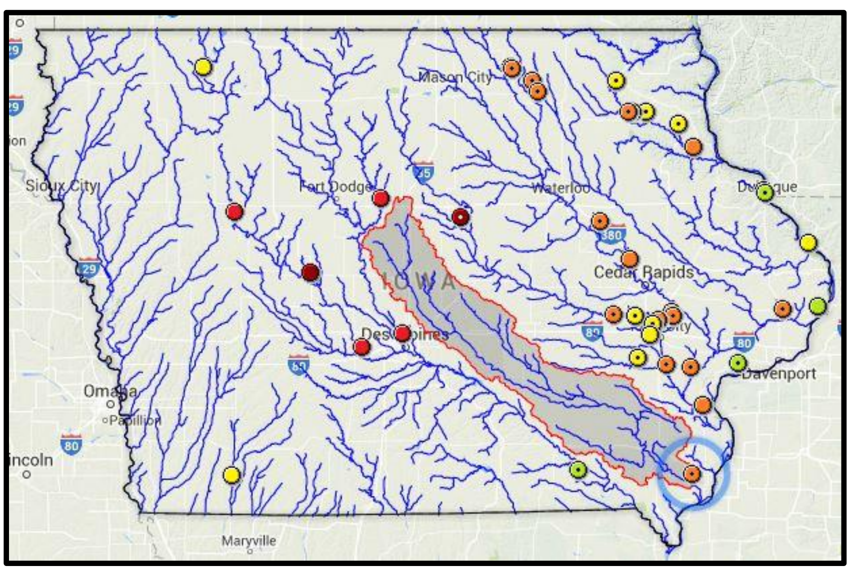




9. WQS0010 Skunk River at Augusta

Site No.	**WQS0010**
Name	**Skunk River at Augusta, Iowa**
Location	Right bank of Skunk River, upstream of Perkins Rd bridge (40.7530, -91.2754)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature
Period of Record	July 2013 – December 2016
Drainage Area	4312 sq mi
Funding Sources	IIHR, INRC
Co-located Measurement	USGS 05474000 (stage, discharge)
Purpose & Significance	This site is located near the mouth of the Skunk River before its confluence with the Mississippi River, and is a crucial load calculation site for the Iowa Nutrient Reduction Strategy. There are several Water Quality Initiative projects funded through the Iowa Nutrient Reduction Strategy upstream of this site, along with several medium-large point source discharges.





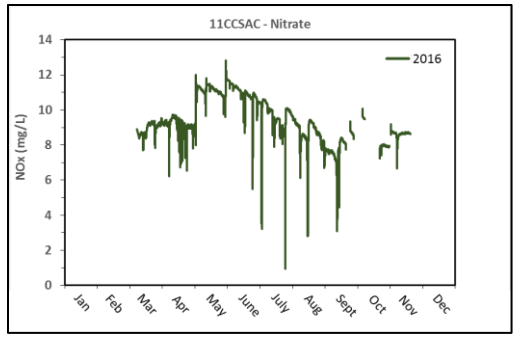
Discussion: The Skunk River is a major interior stream and its watershed occupies about 8% of Iowa's area. The two major branches (South and North) are independent, parallel rivers until they combine southeast of Sigourney.

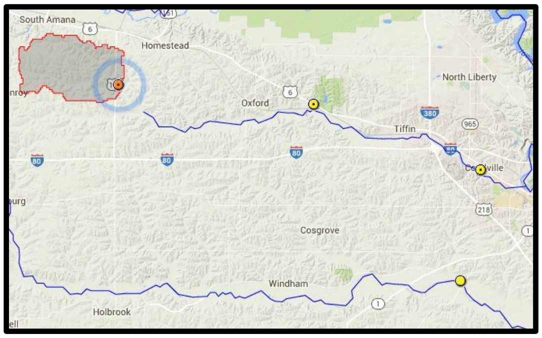
The Skunk River is a study in contrasts. The Des Moines Lobe headwaters, despite very high nitrate concentrations, offer an excellent cool water fishery for smallmouth bass. Between Ames and Colfax, the stream has been straightened and loses most of its biological integrity. Downstream of Colfax, it is characteristic of turbid, Southern Iowa Drift Plain Streams.

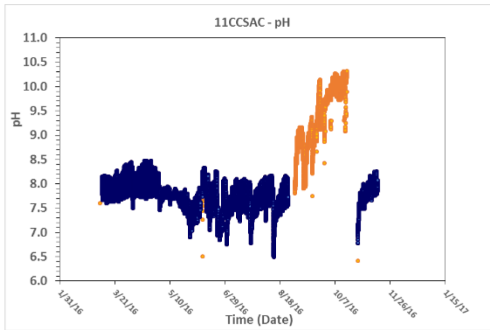
Nitrate concentrations can approach 14 mg/L at the mouth, quite high for a watershed of this size. The Skunk River is also interesting in that it is one of the few major rivers in Iowa where water quality is quite dependent on point-source pollution, at least during certain times of the year. This site near the Mississippi confluence will be important when assessing load reductions that may result from Iowa's Nutrient Reduction Strategy.

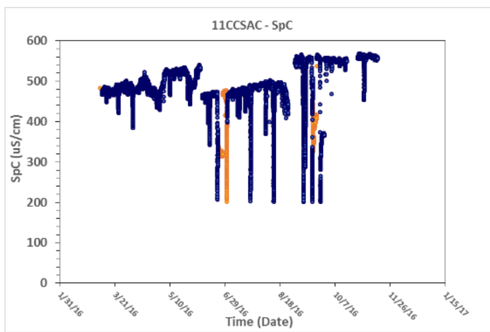
10. WQS0011 Clear Creek near Homestead

Site No.	WQS0011
Name	Clear Creek near Homestead, Iowa
Location	Right bank of Clear Creek, downstream of 190th St bridge (41.7305, -91.9071)
WQ Parameters	Nitrate + nitrite as N, temperature, pH, specific conductance, dissolved oxygen
Period of Record	April 2014 – November 2016
Drainage Area	10 sq mi
Funding Sources	INRC, EPSCoR
Co-located Measurement	IFC CLRCRK03 (stage) CZO/EPSCoR project-related YSI EXO water quality sonde deployed in-situ and water sampling of storm events by isco water sampler.
Purpose & Significance	The Clear Creek watershed is a small (HUC10) tributary of the Lower Iowa river watershed that is highly utilized by U of I researchers due to its close proximity to the U of I campus. Current research projects, including funding from the Critical Zone Observatory Intensively Managed Landscapes (CZO-IML) grant (A. Bettis, T. Papanicolaou) and EPSCoR (A. Bettis, A. Ward), provide additional data and resources for WQS data integration and analysis. The WQS0011 site is one of three sites within the nested Clear Creek watershed, and is the most upstream site on Clear Creek, above the Oxford station.



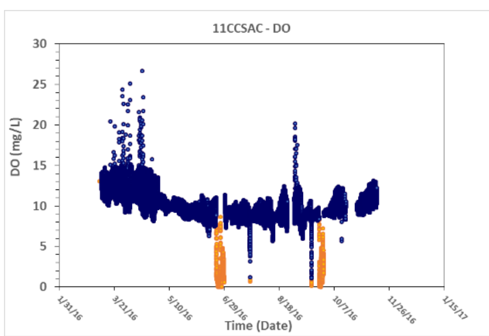


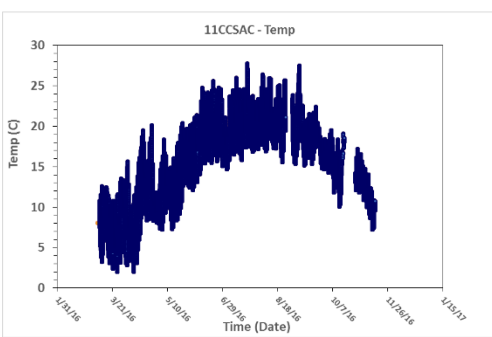


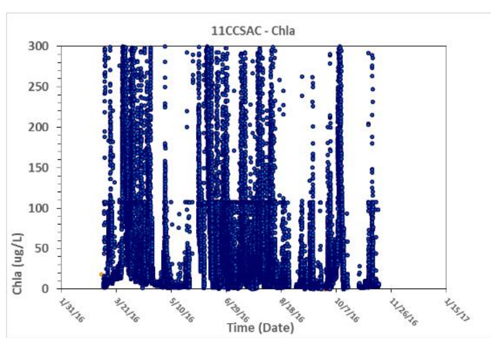


Discussion: Clear Creek is studied closely by IIHR researchers because of its proximity to Iowa City, it is an important tributary of the Iowa River, and it has both an urban and rural component. The headwaters are intensely cropped with corn and soybeans and the lower sections are highly developed within the city of Coralville.

This site has the highest nitrate concentrations of the three the Clear Creek nitrate sensors, with values at times exceeding 16 mg/L.

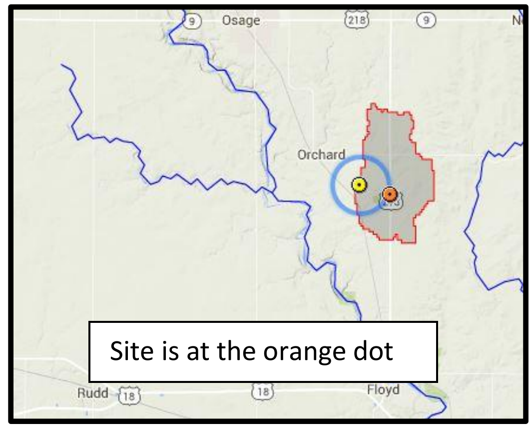


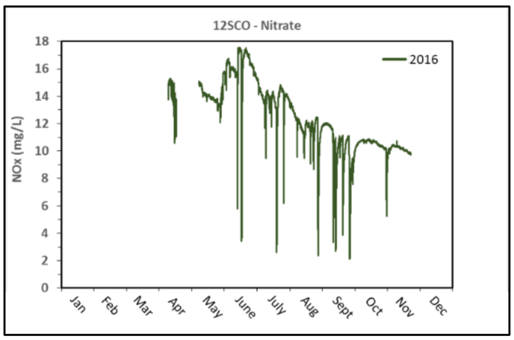


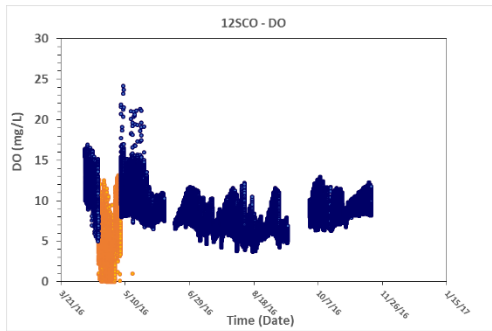


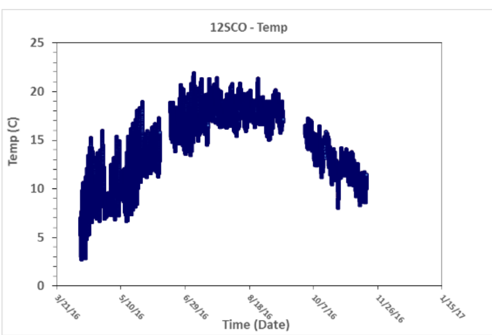
11. WQS0012 Slough Creek Wetland Inlet near Orchard

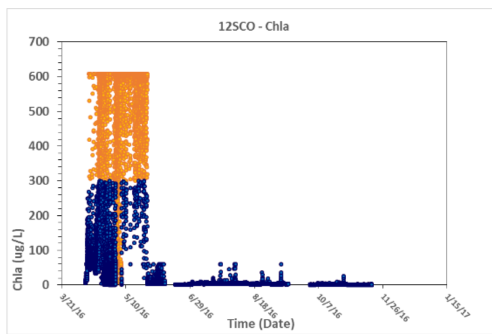
Site No.	**WQS0012**
Name	**Slough Creek near Orchard, Iowa**
Location	Right bank of Slough Creek, 5 ft upstream of Hwy 218 bridge (43.2063, -92.7322)
WQ Parameters	Nitrate + nitrite as N, temperature, pH, specific conductance, dissolved oxygen
Period of Record	May 2014 – November 2016
Drainage Area	5 sq mi
Funding Sources	INRC
Co-located Measurement	IFC SLOUGHCR01 (stage) DNR Ambient Monitoring Site (Storet ID 15340014)
Purpose & Significance	This site monitors the inflow of water to the CREP wetland on Slough Creek. The CREP wetland sites are important for demonstrating the effectiveness of constructed wetlands for the purpose of reducing nitrate loads to the Cedar and Mississippi Rivers.

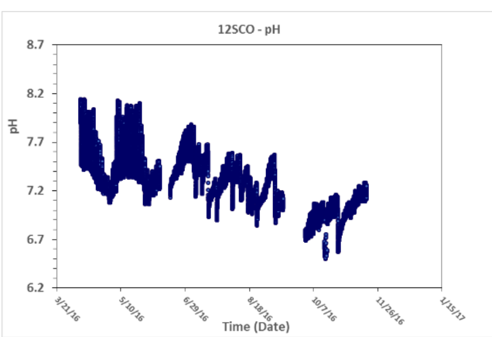


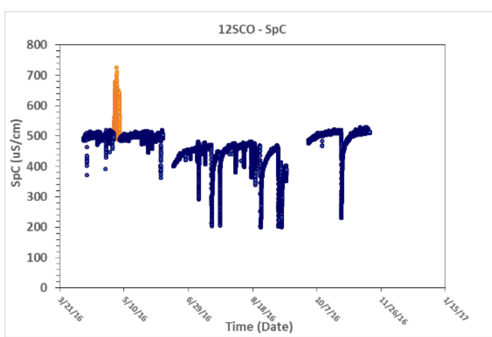












Discussion: A 24-acre constructed wetland was completed at this site in 2012. The wetland is positioned along Slough Creek which drains to a Cedar River tributary, Spring Creek. Lowering nitrate levels in the Cedar is critical because of the downstream municipal water supply in Cedar Rapids.

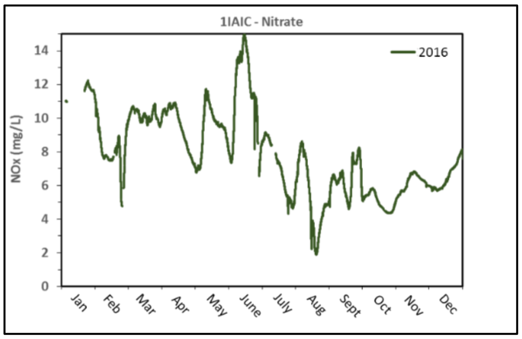
Researchers at IIHR have been studying water quality and nutrient processing in the wetland since 2013. Work has shown modest declines in the nitrate traveling through the wetland, especially after about June 1.

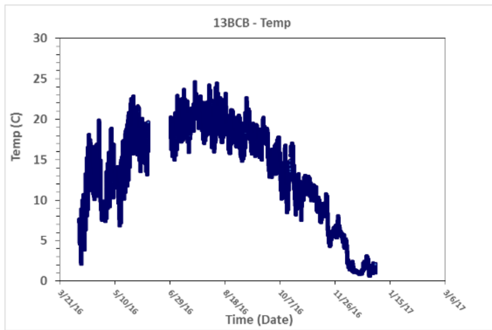
Nitrate in the water entering the wetland can exceed 20 parts per million (ppm), more than twice the safe limit for drinking water. As the water warms in late spring, however, this aquatic vegetation and other life in the wetland begins to process nitrate and sequester it as organic material, or convert it to harmless nitrogen gas which is released to the atmosphere. By the end of the summer, nitrate levels in the water leaving the wetland are less than 2 ppm.

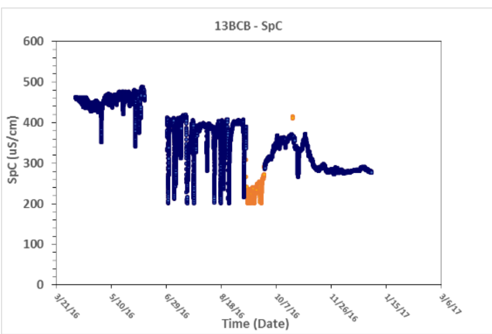
The wetland also provides critical habitat for birds, reptiles, amphibians, and certain fishes. Birds present include pelicans and trumpeter swans.

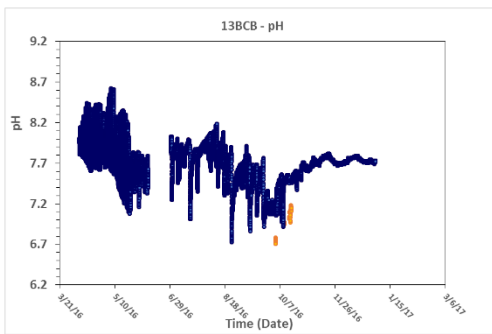
12. WQS0013 Beaver Creek near Basset

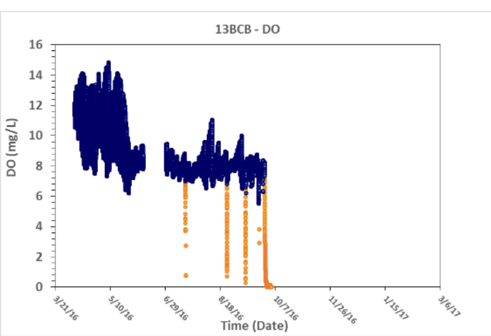
Site No.	**WQS0013**
Name	**Beaver Creek near Bassett, Iowa**
Location	Right bank of Beaver Creek, upstream of Hwy 18 bridge (43.0668, -92.5283)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature, specific conductance, pH, dissolved oxygen
Period of Record	April 2014 - present
Drainage Area	17 sq mi
Funding Sources	HUD
Co-located Measurement	IFC BEAVER01 (stage)
Purpose & Significance	Beaver Creek is a tributary of the Little Cedar and Cedar River in northeast Iowa. This site is one of two water quality monitoring sites within the Beaver Creek watershed that are currently being operated by IIHR and are funded by HUD through the Iowa Watersheds Project. This site is part of a dense network of monitoring equipment that has been deployed to track watershed conditions associated with the construction of small-scale flood mitigation projects. Research evaluates the use of water quality measurements to deduce groundwater, stormwater, and tile water contributions to the stream.

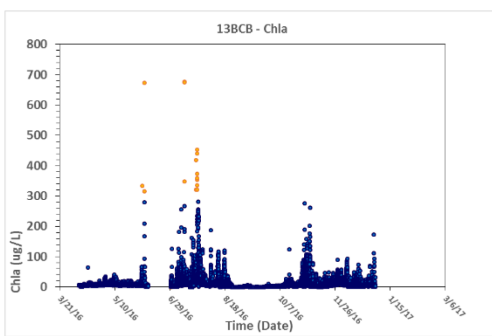


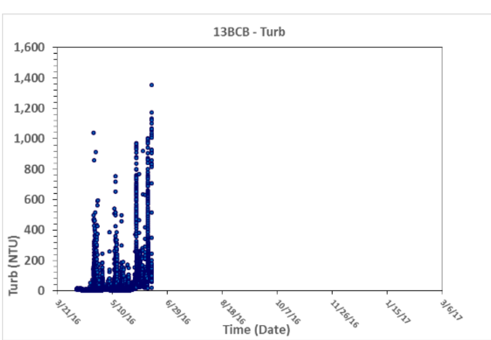












Discussion: Beaver Creek is a small tributary of the Cedar River. The watershed is the site of multiple IIHR research projects associated with both water quality and flooding. The data from the Beaver Creek nitrate sensors are interesting in that the downstream site has a higher nitrate concentration than the upstream site, which is atypical of Iowa watersheds. Intriguingly, there is a constructed CREP wetland upstream of the Colwell site (WQS0014) that may be producing this effect by lowering nitrate concentrations in the headwaters.

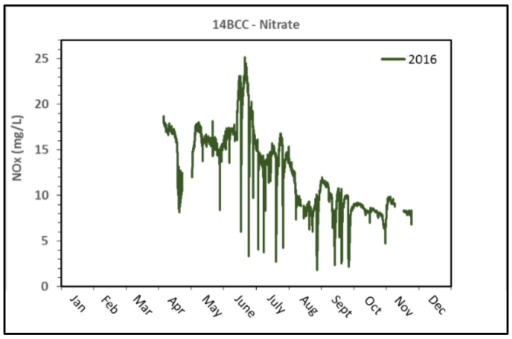
Six more CREP wetlands are planned for the watershed in the coming years which potentially could lower nitrate concentrations further.

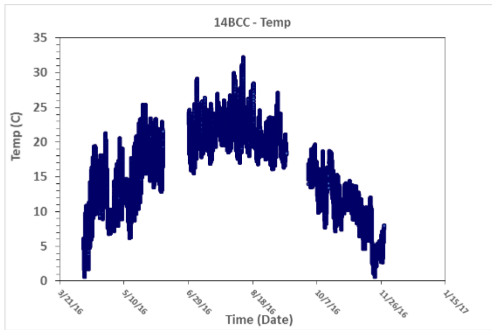
There are no significant point source inputs in the Beaver Creek watershed.

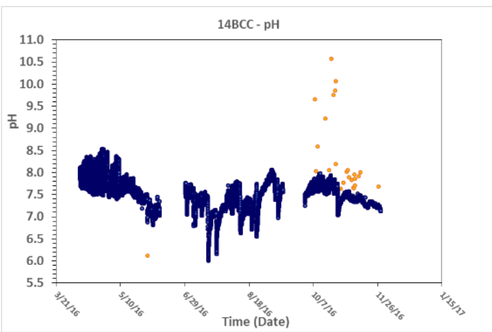
Reducing nitrate concentrations in Cedar River tributaries is important because of the downstream municipal water supply at Cedar Rapids.

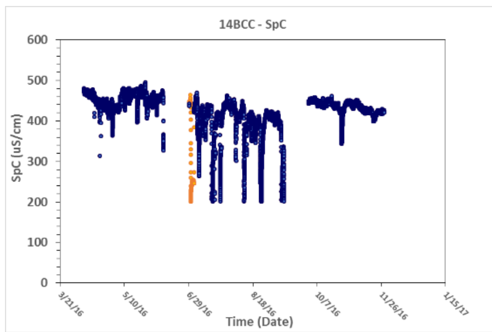
13. WQS0014 Beaver Creek near Colwell

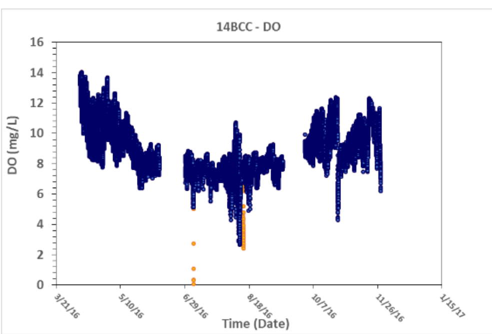
Site No.	**WQS0014**
Name	**Beaver Creek near Colwell, Iowa**
Location	Left bank of Beaver Creek, upstream of 155th St bridge (43.1341, -92.5675)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature, specific conductance, pH, dissolved oxygen
Period of Record	April 2014 – November 2016
Drainage Area	7 sq mi
Funding Sources	HUD
Co-located Measurement	IFC BEAVER03 (stage)
Purpose & Significance	Beaver Creek is a tributary of the Little Cedar and Cedar River in northeast Iowa. This site is one of two water quality monitoring sites within the Beaver Creek watershed operated by IIHR in 2016 and originally funded by HUD through the Iowa Watersheds Project. This site is part of a dense network of monitoring equipment that has been deployed to track watershed conditions associated with the construction of small-scale flood mitigation projects.

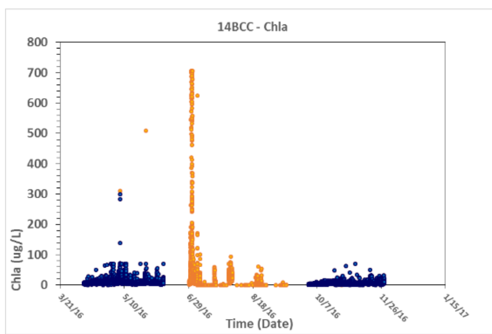


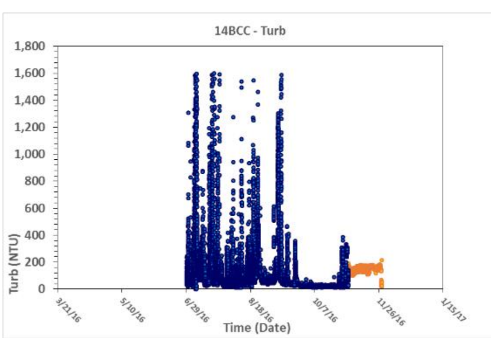












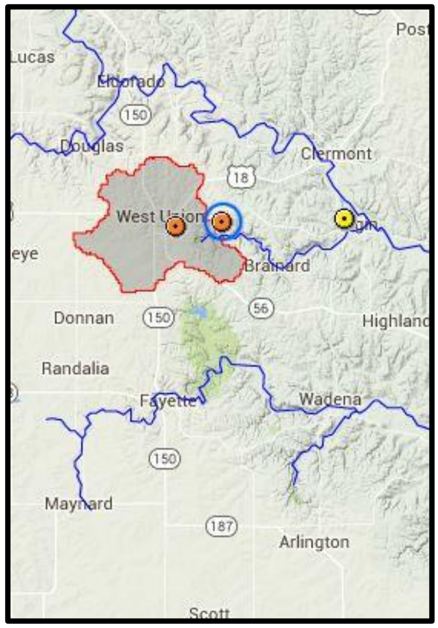
Discussion: Beaver Creek is a small tributary of the Cedar River. The watershed is the site of multiple IIHR research projects associated with both water quality and flooding. The data from the Beaver Creek nitrate sensors is interesting in that the upstream (Colwell) site has a lower nitrate concentration than the downstream site, which is atypical of Iowa watersheds. Intriguingly, there is a constructed CREP wetland upstream of the Colwell site (WQS0014) that may be producing this effect by lowering nitrate concentrations in the headwaters.

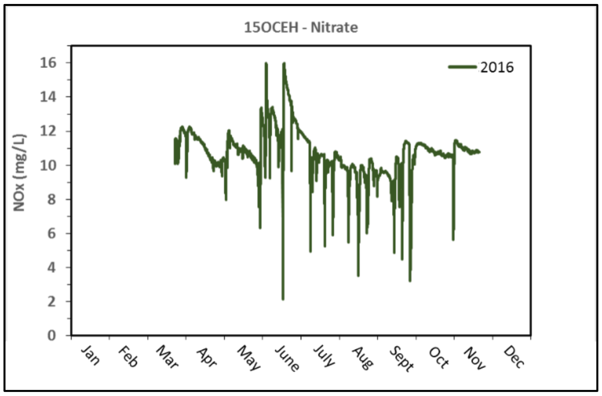
Six more CREP wetlands are planned for the watershed in the coming years which potentially could lower nitrate concentrations further.

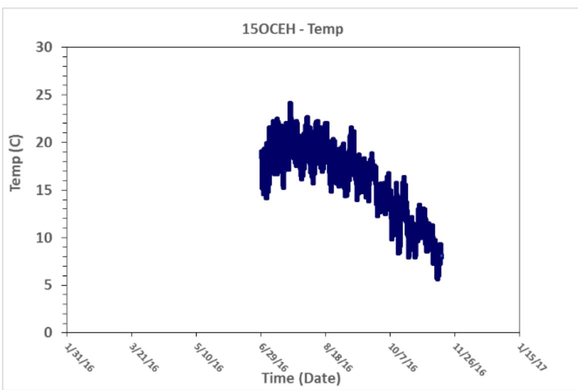
CREP Wetlands: The Conservation Reserve Enhancement Program (CREP) is a state/federal initiative to develop wetlands which are strategically located using computer technology and designed to remove nitrate from tile-drainage water from cropland. Removal of nitrate from these waters helps protect drinking water supplies and reduce hypoxia in the Gulf of Mexico. The program is implemented in cooperation with the USDA Farm Service Agency (FSA) and is available in 37 Soil and Water Conservation Districts (SWCD) in the tile-drained region of Northern Iowa.

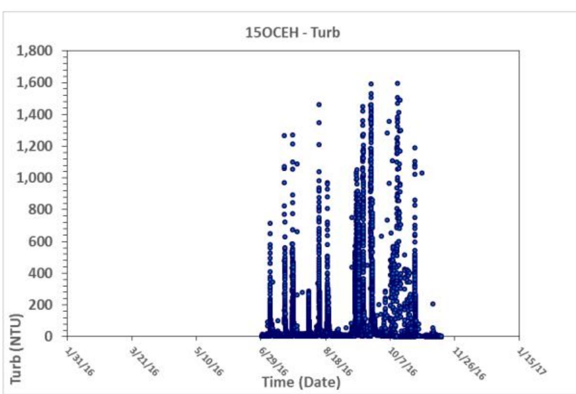
14. WQS0015 Otter Creek near Hornet Road at Elgin

Site No.	**WQS0015**
Name	**Otter Creek at Hornet Rd near Elgin, Iowa**
Location	Left bank of Otter Creek, 30 ft downstream of Hornet Rd bridge (42.9500, -91.7538)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature
Period of Record	April 2014 – November 2016
Drainage Area	26 sq mi
Funding Sources	INRC, HUD
Co-located Measurement	IFC OTTRCRK03 (stage)
Purpose & Significance	Otter Creek is a tributary of the Turkey River in NE Iowa. This site is one of three nested sites within the Otter Creek watershed operated by IIHR in 2016 and initially funded by HUD through the Iowa Watersheds Project. Site discontinued November 2016.









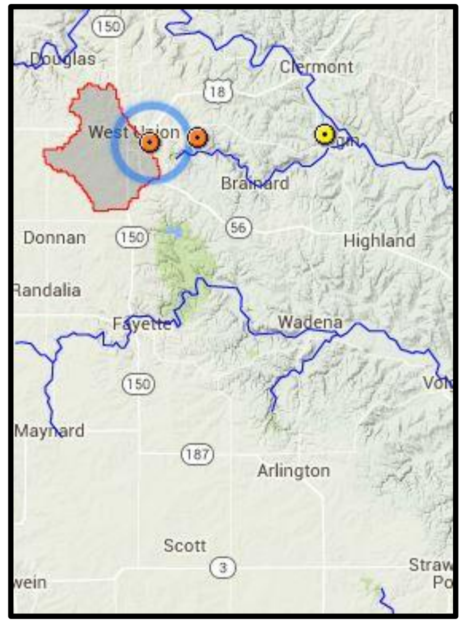
Discussion: Currently IIHR researchers developed a hydrograph separation model that uses nitrate concentrations from three Otter Creek sites to examine the contributions of tile drainage, groundwater and surface/storm flow to the stream. Otter Creek is a tributary of the Turkey River, a major Iowa interior stream.

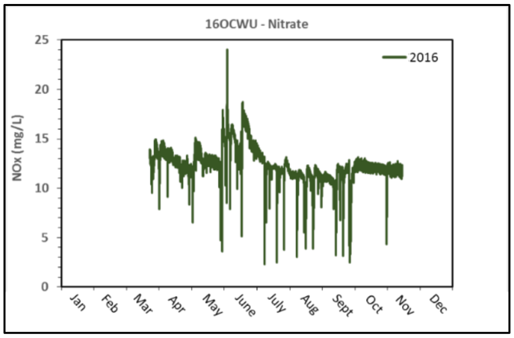
This site is about midway between the headwaters and the stream's confluence with the Turkey. There is no flow gauge.

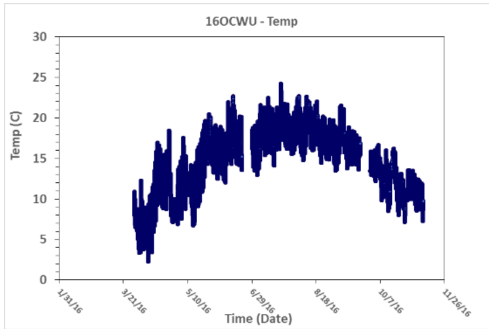
Nitrate concentrations follow a typical pattern of decline from the headwaters downstream. Nitrate levels here are midway between those at the upstream site and those downstream at the mouth. This likely reflects dilution of headwater tile flow with lower nitrate groundwater as the stream progresses downstream.

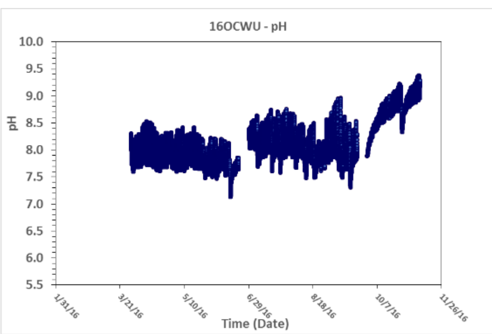
15. WQS0016 Otter Creek near West Union

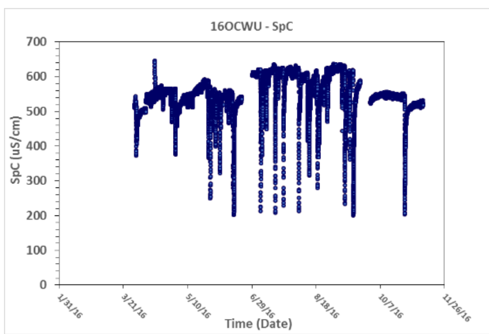
Site No.	WQS0016
Name	Otter Creek near West Union, Iowa
Location	Left bank of Otter Creek, 10 ft upstream of Echo Valley Rd bridge (42.9472, -91.7950)
WQ Parameters	Nitrate + nitrite as N, temperature, specific conductance, pH, dissolved oxygen
Period of Record	April 2014 – November 2016
Drainage Area	15 sq mi
Funding Sources	INRC, HUD
Co-located Measurement	IFC OTTRCRK04 (stage)
Purpose & Significance	Otter Creek is a tributary of the Turkey River in NE Iowa. This site is one of three nested sites within the Otter Creek watershed operated by IIHR in 2016 and initially funded by HUD through the Iowa Watersheds Project.

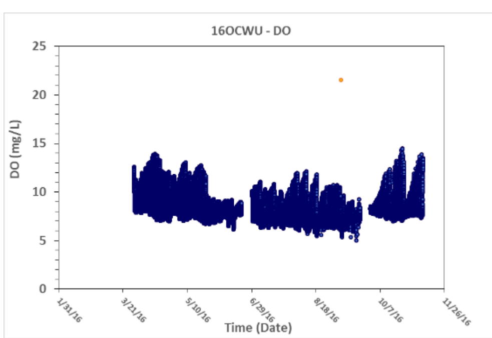












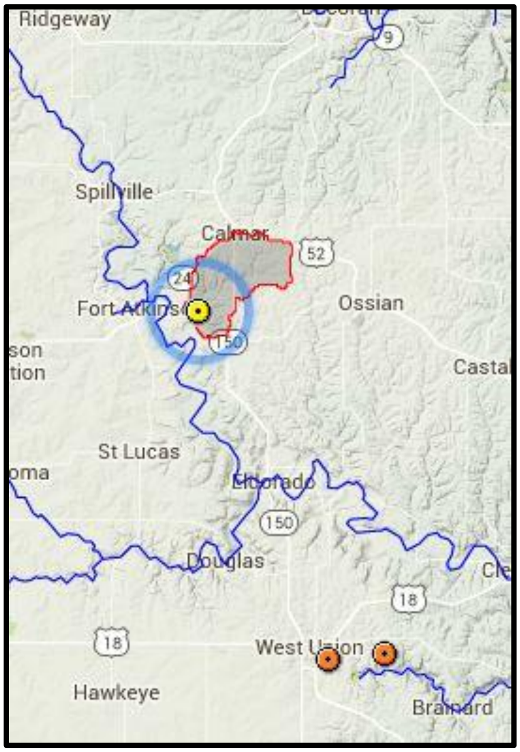
Discussion: Currently IIHR researchers developed a hydrograph separation model that uses nitrate concentrations from three Otter Creek sites to examine the contributions of tile drainage, groundwater and surface/storm flow to the stream. Otter Creek is a tributary of the Turkey River, and major Iowa interior stream.

This site is near the headwaters and the city of West Union, which may provide an urban component to the water quality observed in this stream.

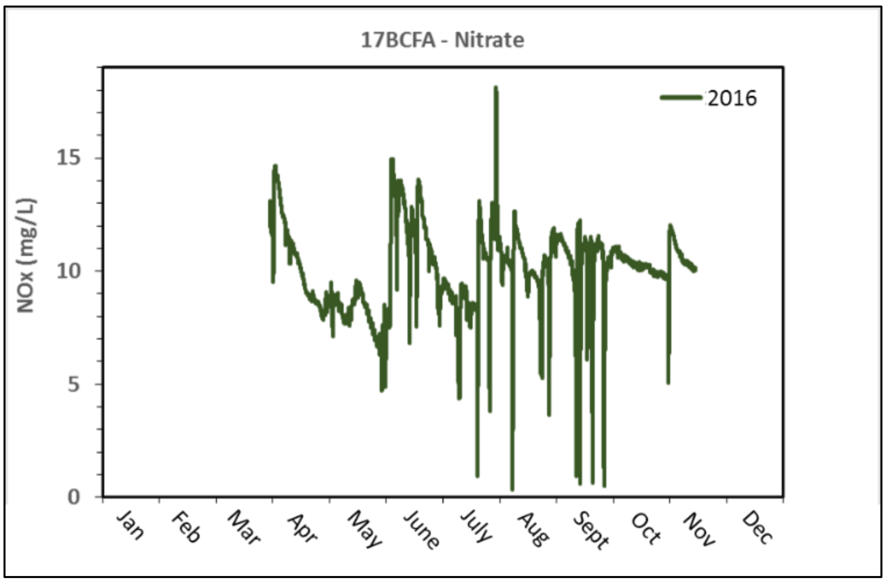
Nitrate concentrations follow a typical pattern of decline from the headwaters downstream. Nitrate levels here are higher than either of the two downstream sites. This likely reflects dilution of headwater tile flow with lower nitrate groundwater as the stream progresses downstream.

16. WQS0017 Brockamp (Bohemian) Creek near Ft. Atkinson

Site No.	WQS0017
Name	Bohemian Creek near Fort Atkinson, Iowa
Location	Right bank of Bohemian Creek, 50 ft downstream of CR-B32 bridge (43.1335, -91.8893)
WQ Parameters	Nitrate + nitrite as N
Period of Record	May 2014 – November 2016
Drainage Area	8 sq mi
Funding Sources	INRC
Co-located Measurement	IFC BRCKCMP01 (stage)
Purpose & Significance	Bohemian Creek is a tributary of the Turkey River in NE Iowa, downstream of the town of Calmar, and is a WQI watershed. Site discontinued November 2016.

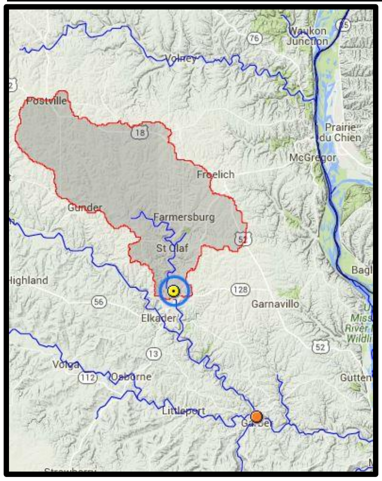


Discussion: This Winnishiek County stream is one of the few IIHR sites located within the Paleozoic Plateau (Driftless) Region of Iowa. Artificial drainage is usually not as necessary here as in other farmed areas of Iowa, and nitrate levels can be lower as a result. Still, concentrations here exceed 13 mg/L, far higher than most water quality objectives for Iowa waters.



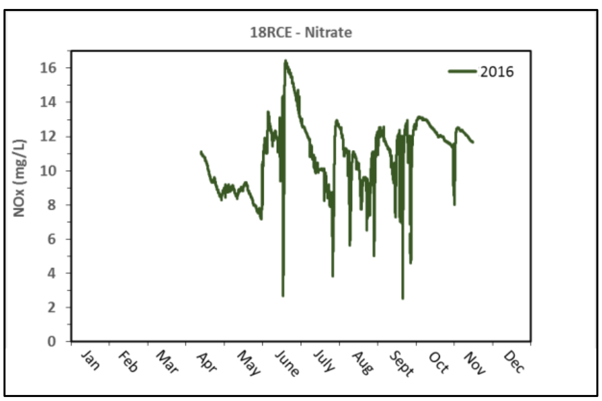
17. WQS0018 Roberts Creek near Elkader

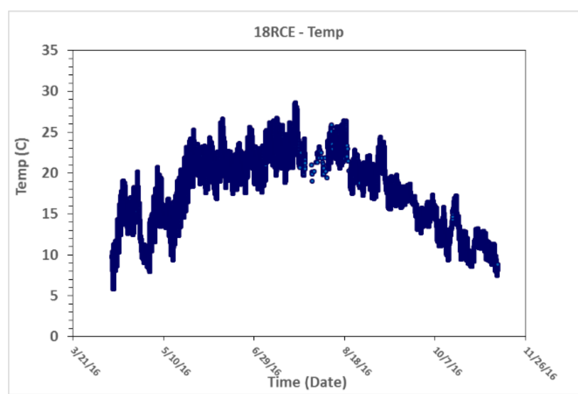
Site No.	WQS0018
Name	Roberts Creek near Elkader, Iowa
Location	Right bank of Roberts Creek, downstream of Hwy 13 bridge (42.8742, -91.3826)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature
Period of Record	May 2014 – November 2016
Drainage Area	116 sq mi
Funding Sources	INRC
Co-located Measurement	IFC RBRTSCR01 (stage)
Purpose & Significance	Roberts Creek is a tributary of the Turkey River in NE Iowa, and is a WQI watershed. Site discontinued November 2016.

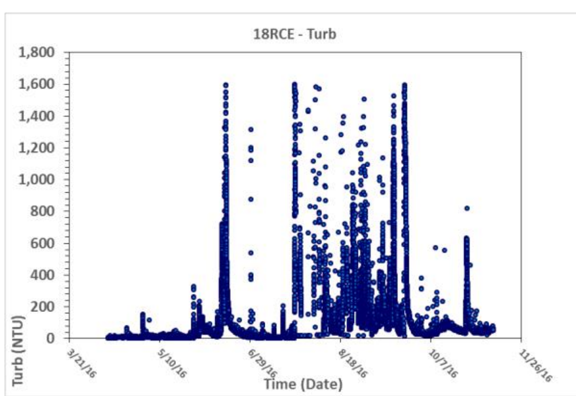


Discussion: Like WQS0017, this is another stream located within the Paleozoic Plateau (Driftless) Region of Iowa and the Turkey River Watershed. The Turkey Basin has been the focus of several IIHR research projects. Much of stream nitrate in this area originates from groundwater, and not necessarily tile water. The porous Karst materials found in the subsurface allow nitrate to infiltrate rapidly to shallow aquifers in the area. Water quality in this stream impact that in Big Spring (WQS0031) even though they are not in the same watershed.

Karst topography is a landscape formed from the dissolution of soluble rocks such as limestone, dolomite, and gypsum. It is characterized by underground drainage systems with sinkholes and caves. Karst is common in the Paleozoic Plateau (Driftless) Region of Northeast Iowa. Groundwater in this area is very vulnerable to contamination from surface activities. Rock outcroppings, deep and narrow valleys, and cool water streams are all characteristic of this Iowa region, the most unique geographic region in the state.

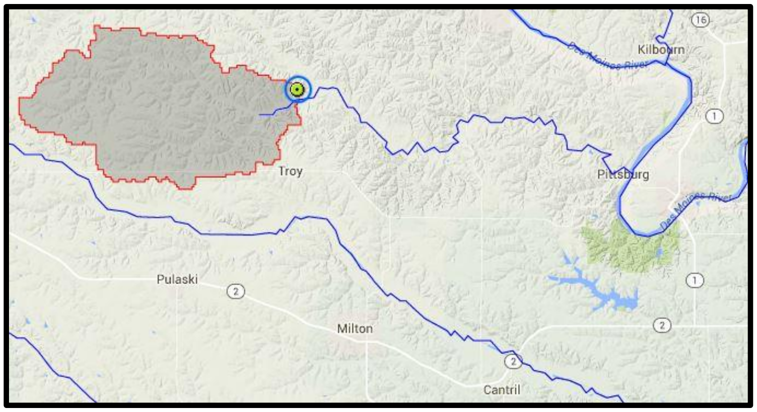




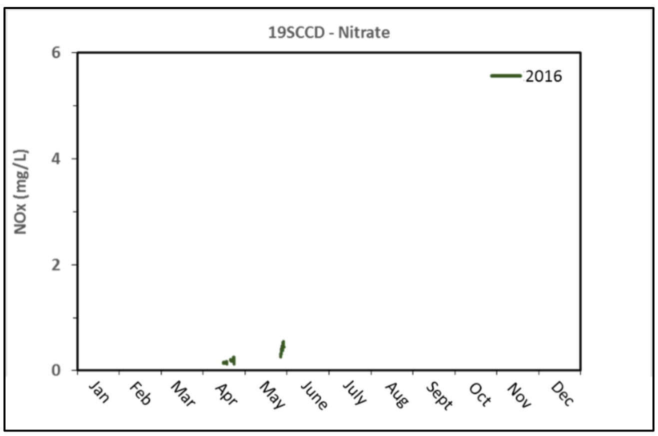


18. WQS0019 South Chequest Creek near Douds

Site No.	WQS0019
Name	South Chequest Creek near Douds, Iowa
Location	Left bank of S Chequest Creek, downstream of Yak Blvd bridge (40.7828, -92.1978)
WQ Parameters	Nitrate + nitrite as N
Period of Record	April 2014 – May 2016
Drainage Area	31 sq mi
Funding Sources	INRC, HUD
Co-located Measurement	IFC SCHQSTCR01 (stage)
Purpose & Significance	South Chequest creek is a tributary of the Des Moines River in SE Iowa. Originally funded by HUD through the Iowa Watersheds Project, this site was relocated downstream in 2016 to Chequest Creek (WQS0049) due to frequent sedimentation of sensor which adversely affected data quality.

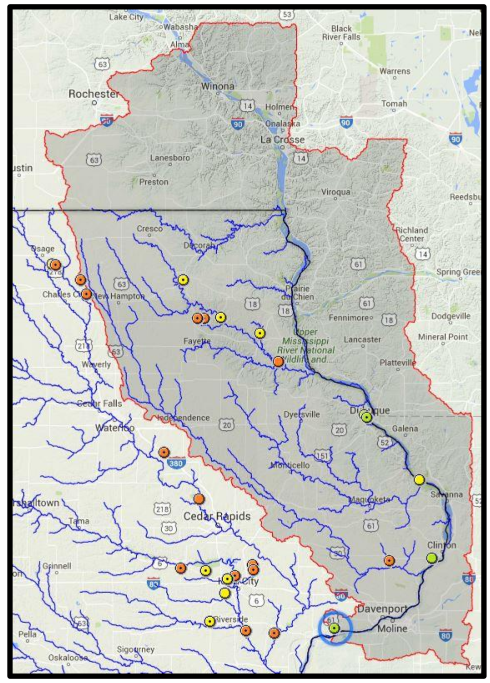


Discussion: The watershed of this small lower Des Moines River tributary is the site of numerous IIHR research efforts focusing on flooding. Nitrate concentrations are typically low relative to the rest of Iowa, although a reading of 14.5 mg/L was registered in 2014. This does not appear to have been an anomalous result and may have been the result of a release of some form into creek. This stream is fairly characteristic of Southern Iowa Drift Plain streams.



19. WQS0020 Mississippi River at Fairport

Site No.	WQS0020
Name	**Mississippi River Pool 16 near Fairport, Iowa**
Location	Right bank of Mississippi River, at Iowa DNR Fairport Fish Hatchery (41.4362, -90.8978)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature, specific conductance, pH, dissolved oxygen
Period of Record	July 2014 – November 2016
Drainage Area	99300 sq mi
Funding Sources	IIHR, INRC
Co-located Measurement	19.3mi downstream of Lock & Dam 15, US Army Corps of Engineers (Rock Island District)
Purpose & Significance	This site is located along Pool 16 of the Mississippi River near the Lucille A. Carver Mississippi Riverside Environmental Research Station operated by IIHR.

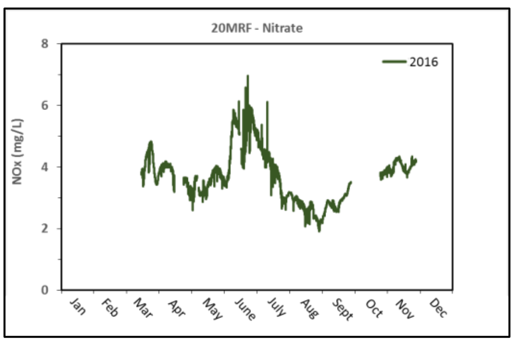


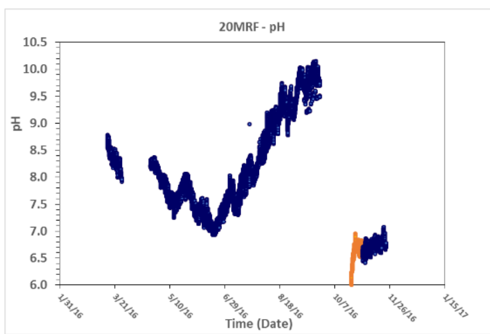
Discussion: This is the only IIHR "Big River" water quality monitoring location. The nitrate sensor is located at the Lucille A. Carver Environmental Research Station near Muscatine.

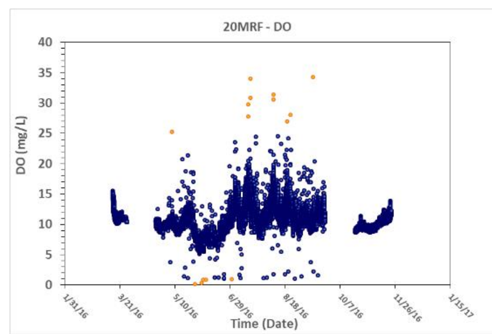
Water quality in the two big rivers (Mississippi and Missouri) tends to be substantially different than interior streams. Because of the enormous upstream watershed area, water quality changes much more slowly. The area upstream of this sensor (not completely shown in the map) is almost twice Iowa's size.

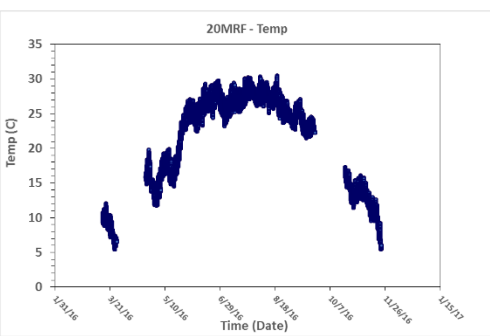
Nitrate concentrations are far lower than interior streams. This is because the high nitrate from streams like the Skunk and Turkey River is diluted by groundwater and lower nitrate concentrations from streams to the north of Iowa.

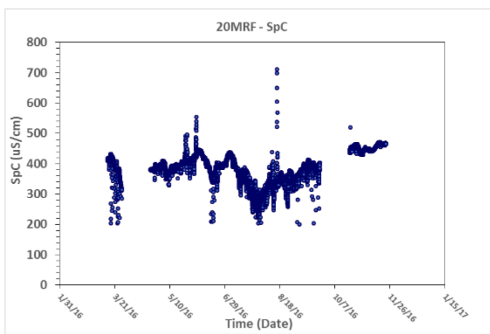
Nonetheless, even a comparatively small nitrate concentration about 2 mg/L delivers an enormous nitrate load (total mass of a pollutant) because the flow in Mississippi are so large compared to interior streams.

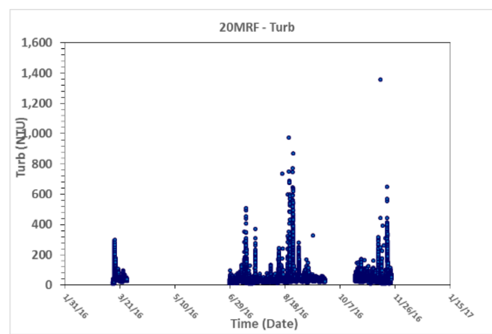








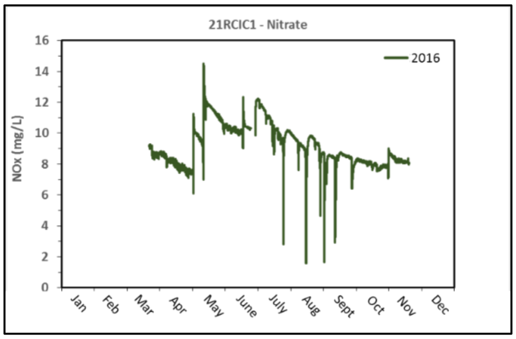


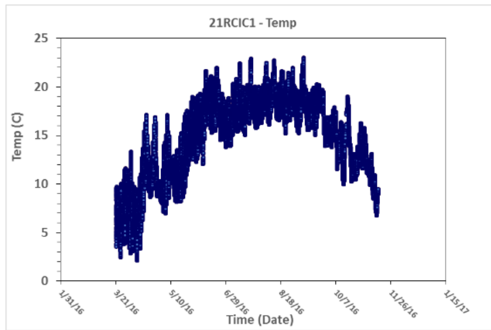


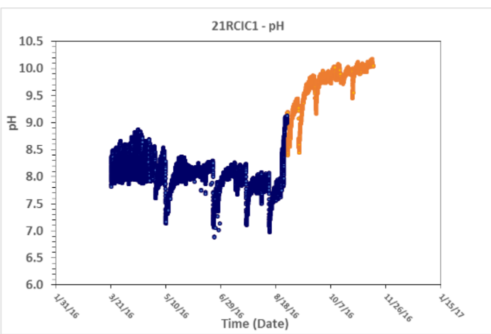
The lock and dam system on the Mississippi, and the huge reservoir dams on the Missouri, both affect water quality, mainly by settling solid materials. This has contributed to wetland erosion along the Louisiana coast. Levees on both rivers divorce the river from its flood plain. This removes the ability of backwater areas to process nutrients, effectively increasing nitrate and phosphorous concentrations in the river. Managing these rivers for navigation, flood control, water quality, and biodiversity is an enormous and challenging task for the country.

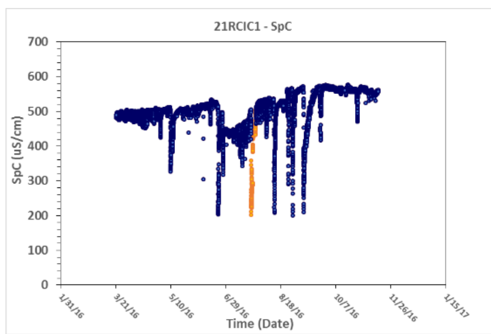
20. WQS0021 Rapid Creek near Iowa City

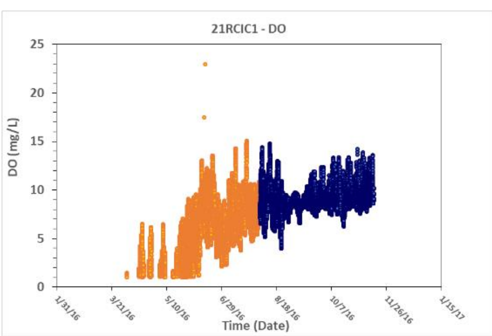
Site No.	WQS0021
Name	Rapid Creek near Iowa City, Iowa
Location	Left bank of Rapid Creek, 20ft downstream of Rapid Creek Rd NE bridge (41.7217, -91.4262)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature, specific conductance, pH, dissolved oxygen
Period of Record	September 2014 – November 2016
Drainage Area	6 sq mi
Funding Sources	INRC, INRC-Rapid Creek
Co-located Measurement	IFC RAPIDCR01 (stage)
Purpose & Significance	Rapid Creek is a tributary of the Iowa River north of Iowa City. This site is located on the East Branch of Rapid Creek and is part of a paired watershed study of stacked best management practices funded by the INRC.

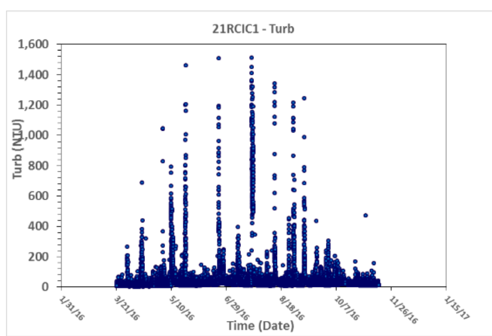










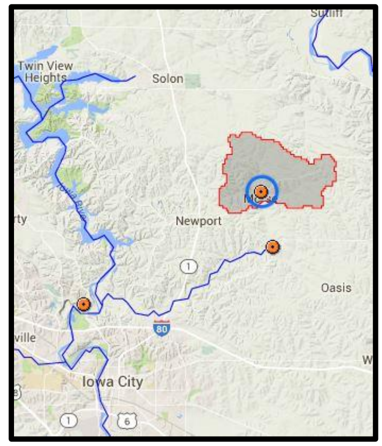


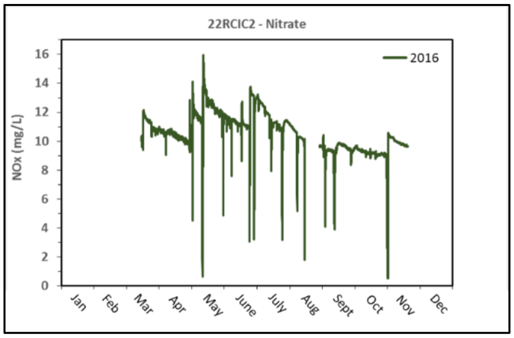
Discussion: This small watershed on the outskirts of Iowa City is the site of a paired watershed study. In this type of study, two or more similar watershed are studied for a period of time to assess how conservation practices manifest themselves in stream water quality. Presumably weather is affecting all the basins nearly equally.

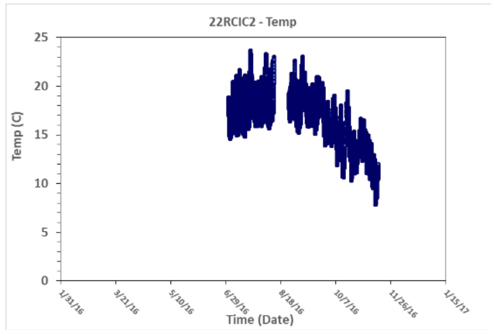
Practices are not implemented in a "control" watershed, while practices are implemented in one or more "treatment" watersheds. Such practices might include cover crops, buffers, reduced tillage and others. This watershed is the control watershed of the study; WQS0022 is the treatment watershed. The study is ongoing, but thus far it appears the nitrate concentration has declined more in the control watershed.

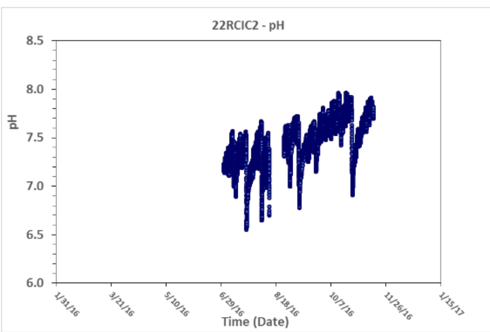
21. WQS0022 Rapid Creek tributary near Iowa City

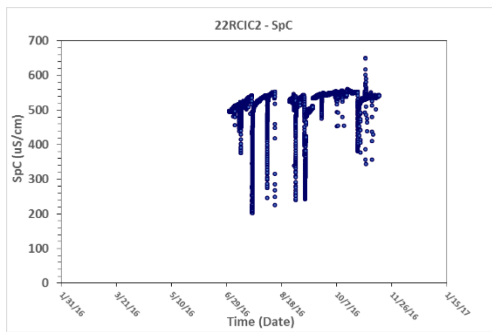
Site No.	**WQS0022**
Name	**Rapid Creek tributary near Iowa City, Iowa**
Location	Left bank of Rapid Creek, 10ft upstream of Putnam St NE bridge (41.7483, -91.4338)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature, specific conductance, pH
Period of Record	September 2014 – November 2016
Drainage Area	3 sq mi
Funding Sources	INRC, INRC-Rapid Creek
Co-located Measurement	IFC RAPIDTRB01 (stage)
Purpose & Significance	Rapid Creek is a tributary of the Iowa River north of Iowa City. This site is located on a tributary of Rapid Creek and is part of a paired watershed study of stacked best management practices funded by the INRC.

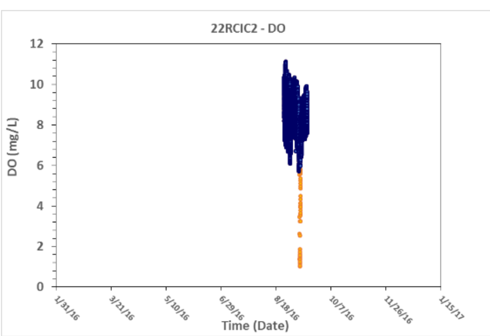


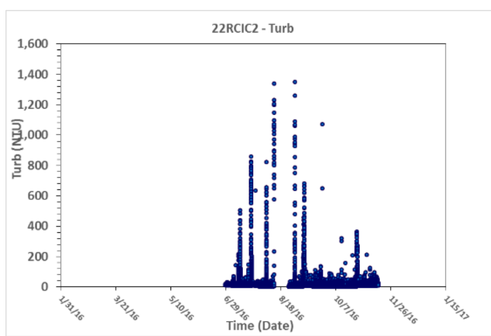










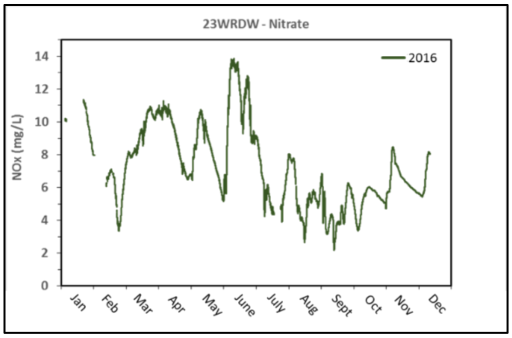


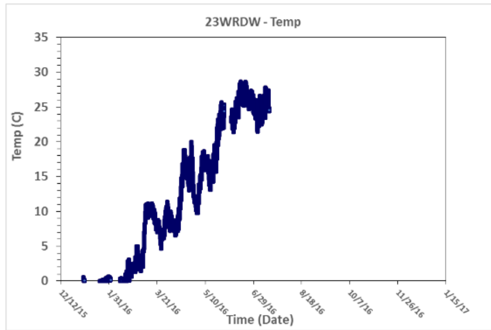
Discussion: This small watershed on the outskirts of Iowa City is the site of a paired watershed study. In this type of study, two or more similar watersheds are studied for a period of time to assess how conservation practices manifest themselves in stream water quality. Presumably weather is affecting all the basins nearly equally.

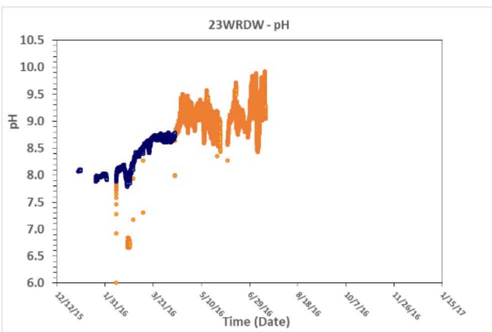
Practices are not implemented in a "control" watershed, while practices are implemented in one or more "treatment" watersheds. Such practices might include cover crops, buffers, reduced tillage and others. This watershed is the treatment watershed of the study; WQS0021 is the control watershed. The study is ongoing, but thus far it appears the nitrate concentration has declined more in the control watershed.

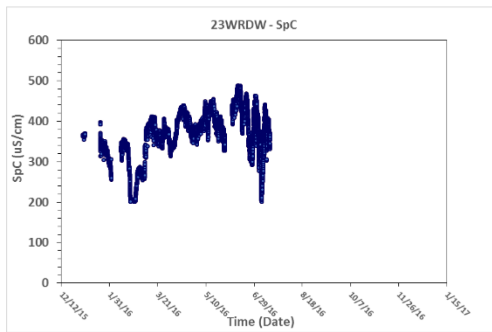
22. WQS0023 Wapsipinicon River at DeWitt

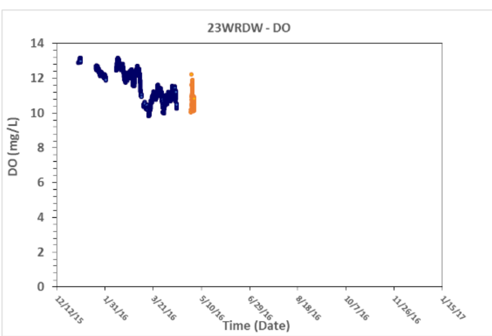
Site No.	WQS0023
Name	**Wapsipinicon River near De Witt, Iowa**
Location	Right bank of Wapsipinicon River, 80ft upstream of Scott Park Rd bridge (41.7668, -90.5349)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature, specific conductance, pH, dissolved oxygen
Period of Record	April 2015 – December 2016
Drainage Area	2336 sq mi
Funding Sources	INRC, HUD
Co-located Measurement	USGS 05422000 (stage, discharge) DNR Ambient Monitoring Site (Storet ID 10820001)
Purpose & Significance	The Wapsi River is a crucial site for N load estimations associated with the Iowa Nutrient Reduction Strategy.

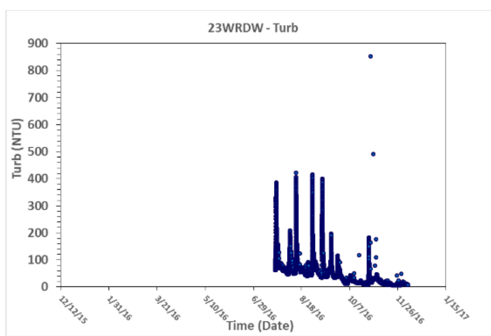


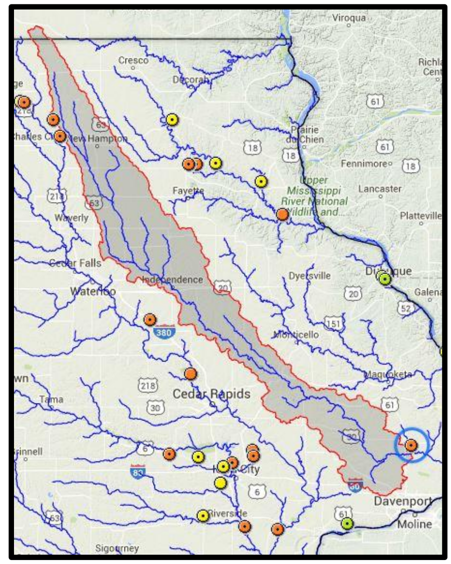












Discussion: The "Wapsi" is one of Iowa's premier rivers for angling, offering an excellent cool and warm water fishery for walleye, northern pike and smallmouth bass and catfish. It can also have very high nitrate concentrations and loads. Most of its course flows through the Iowan Surface Landform.

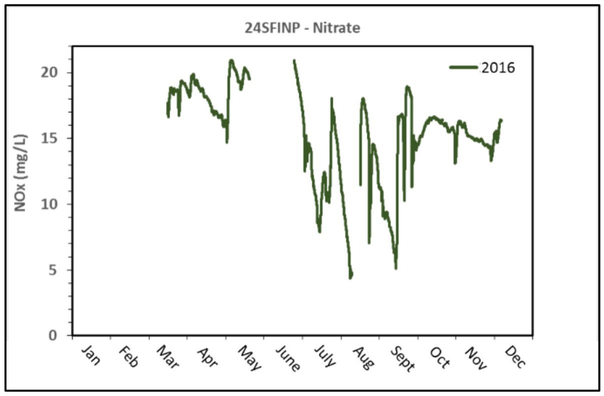
This will be a strategically important site in 2016 for load estimation associated with the Iowa Nutrient Reduction Strategy.

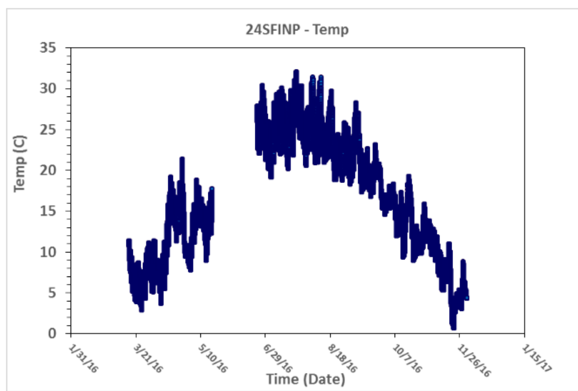
Wapsipinicon facts:

- 291 miles long, headwaters are in Minnesota
- Drains the Iowan Surface; watershed is boundary between Iowan surface and Driftless Area

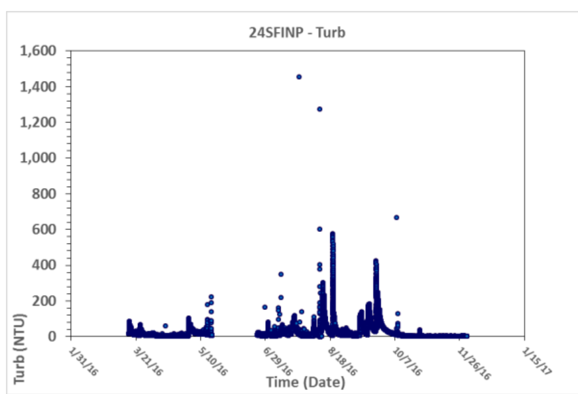
23. WQS0024 South Fork of the Iowa River at New Providence

Site No.	WQS0024
Name	South Fork Iowa River near New Providence, Iowa
Location	Right bank of SF Iowa River, 40ft upstream of R Ave bridge (42.3149, -93.1524)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature
Period of Record	April 2015 – November 2016
Drainage Area	224 sq mi
Funding Sources	INRC
Co-located Measurement	USGS 05451210 (stage, discharge)
Purpose & Significance	The South Fork Iowa River is a major tributary of the Iowa River in north-central Iowa, which drains an area of intense crop and livestock production. This site is co-located with an Agricultural Research Service (USDA-ARS) project area.



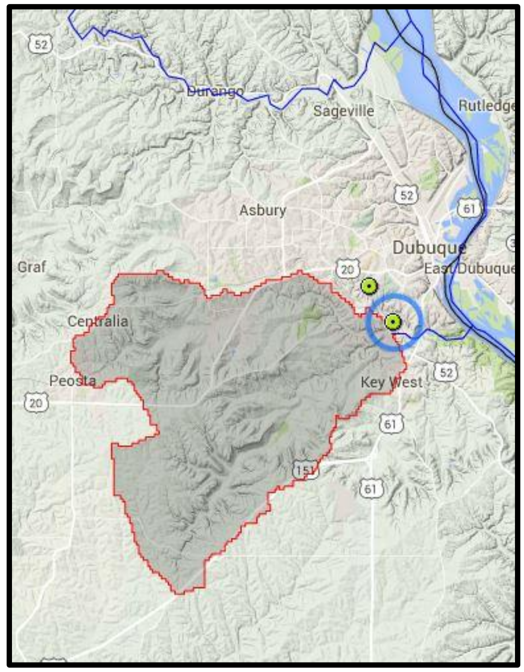


Discussion: This stream has one of the highest nitrate concentrations and yield (load per acre) in Iowa. This is an area of intense crop and livestock production, and it drains the intensely-tiled Des Moines Lobe Landform, a perfect formula for high nitrate concentrations. There are about 100 confined swine-feeding operations, most of which are located in Tipton Creek and the upper South Fork. For these reasons, this site is of interest to both water quality and agronomic researchers. The Agriculture Research Service arm of USDA has studied this watershed for many years. Because of its extremely high nitrate levels, this could be a good watershed to demonstrate the effectiveness of various practices.



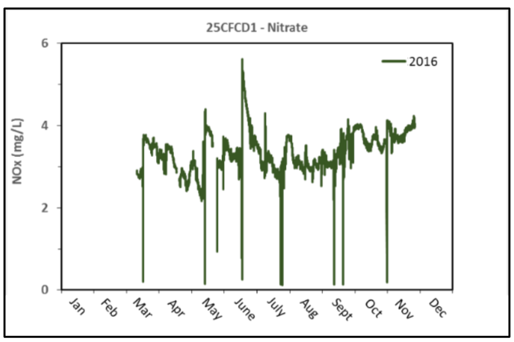
24. WQS0025 South Fork of Catfish Creek at Dubuque

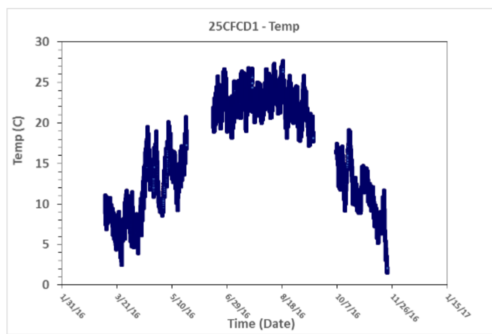
Site No.	**WQS0025**
Name	**South Fork Catfish Creek at Dubuque, Iowa**
Location	Right bank of Catfish Creek, upstream of Manson Rd bridge (42.4673, -90.6829)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature, specific conductance, pH, dissolved oxygen
Period of Record	April 2015 – November 2016
Drainage Area	41 sq mi
Funding Sources	INRC, City of Dubuque
Co-located Measurement	IFC CTFSHCR01 (stage)
Purpose & Significance	This site is one of two sites located on Catfish Creek related to a nutrient trading study funded by the INRC. The City of Dubuque is a partner of this site.

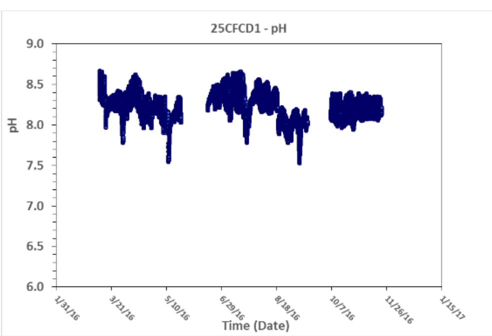


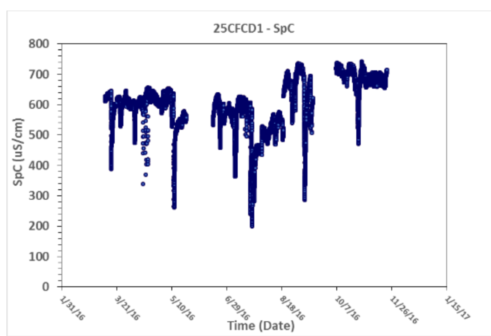
Discussion: Nutrient trading is an idea for improving water quality. The idea stems from the fact that costs to reduce nutrient loads from point sources may be far greater than the cost to reduce the same load amount from a non-point source. Wastewater treatment plants essentially pay upstream landowners to implement practices that will create load reduction credits for the point source discharger.

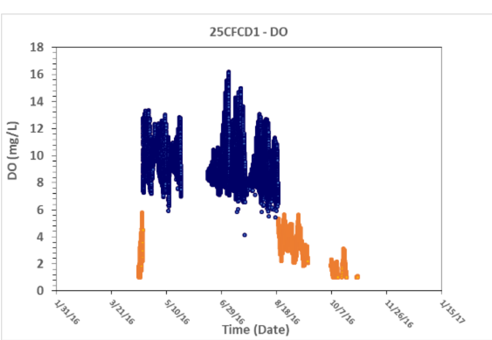
One IIHR research project focuses on the practicality of nutrient trading in this small watershed. Unlike many places in Iowa, it may actually be a good solution here because of the large point source discharge at the City of Dubuque wastewater treatment provides upstream farmers with a practical trading partner. The mostly agricultural south fork of this stream (this site) tends to have a higher nitrate level than the mostly urban middle fork.

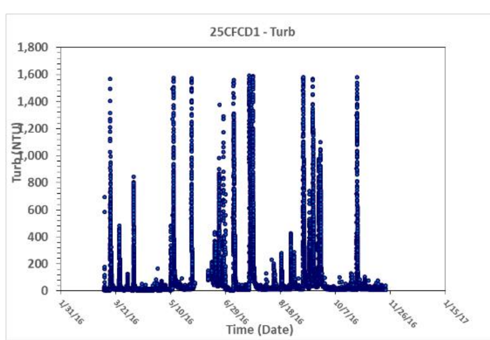






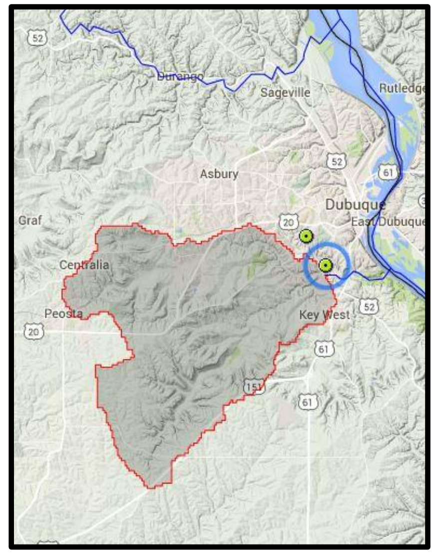






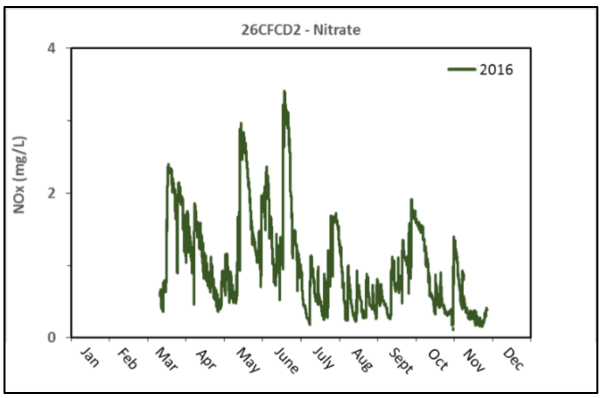
25. WQS0026 Middle Fork of Catfish Creek near Dubuque

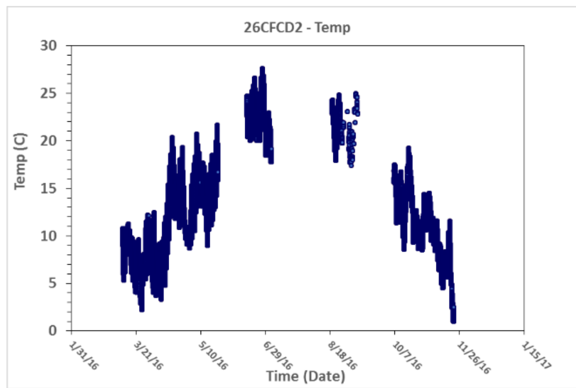
Site No.	WQS0026
Name	Middle Fork Catfish Creek at Dubuque, Iowa
Location	Right bank of Catfish Creek, upstream of Fremont Ave bridge (42.4812, -90.6953)
WQ Parameters	Nitrate + nitrite as N, turbidity, temperature, specific conductance, pH, dissolved oxygen
Period of Record	April 2015 – November 2016
Drainage Area	13 sq mi
Funding Sources	INRC, HUD
Co-located Measurement	None
Purpose & Significance	This site is one of two sites located on Catfish Creek related to a nutrient trading study funded by the INRC. The City of Dubuque is a partner of this site.

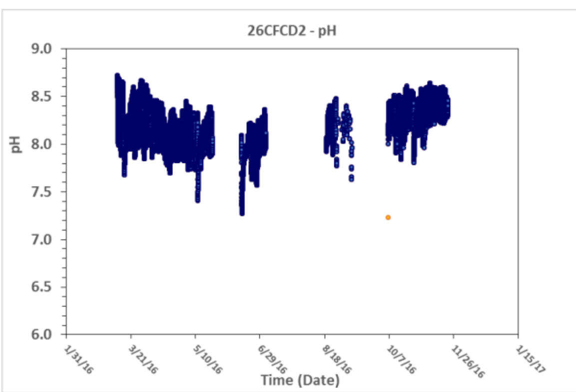


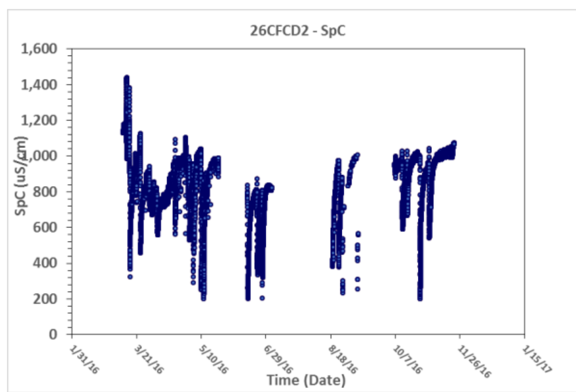
Discussion: The other watershed being studied for the practicality of nutrient trading (also WQS0025).

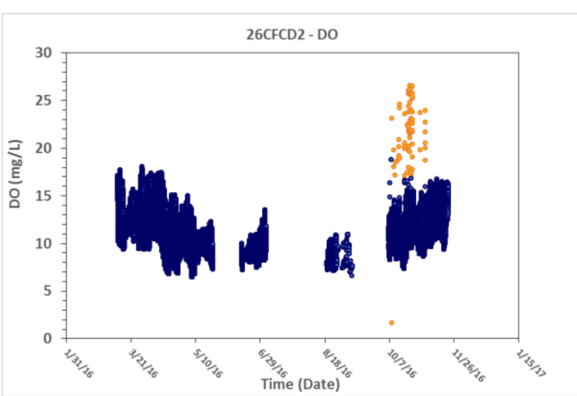
The mostly agricultural south fork of this stream (this site) tends to have a higher nitrate level than the mostly urban middle fork.

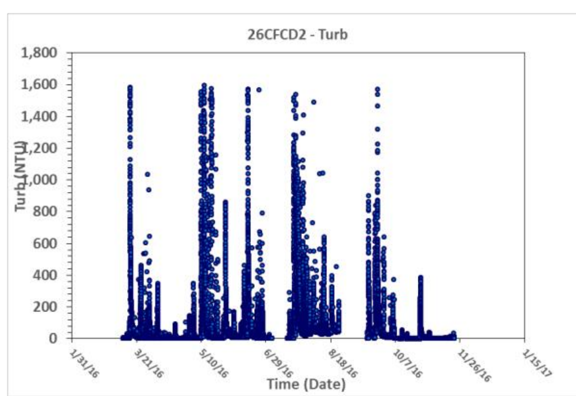






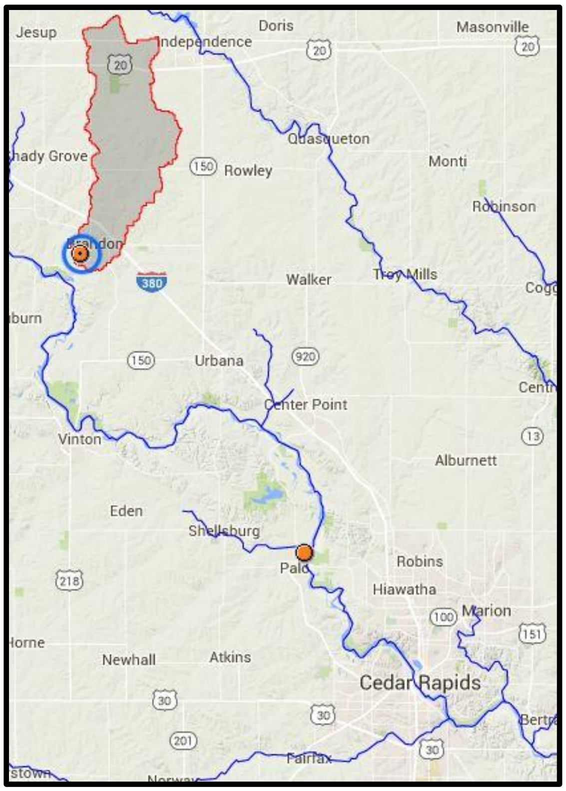




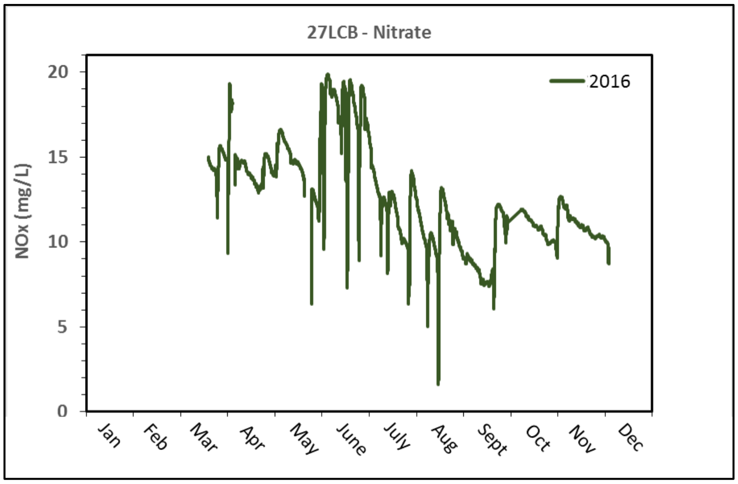


26. WQS0027 Lime Creek at Brandon

Site No.	WQS0027
Name	**Lime Creek near Brandon, Iowa**
Location	Left bank of Lime Creek, 15ft downstream of Benton-Buchanan Rd bridge (42.2974, -92.0177)
WQ Parameters	Nitrate + nitrite as N
Period of Record	April 2015 – November 2016
Drainage Area	41 sq mi
Funding Sources	Coe College, INRC
Co-located Measurement	IFC LIMECR01 (stage)
Purpose & Significance	Lime Creek is a tributary of the Cedar River in east-central Iowa. The nitrate sensor at this site is owned and operated by Coe College, and is part of a long-term monitoring project in the Lime Creek watershed.

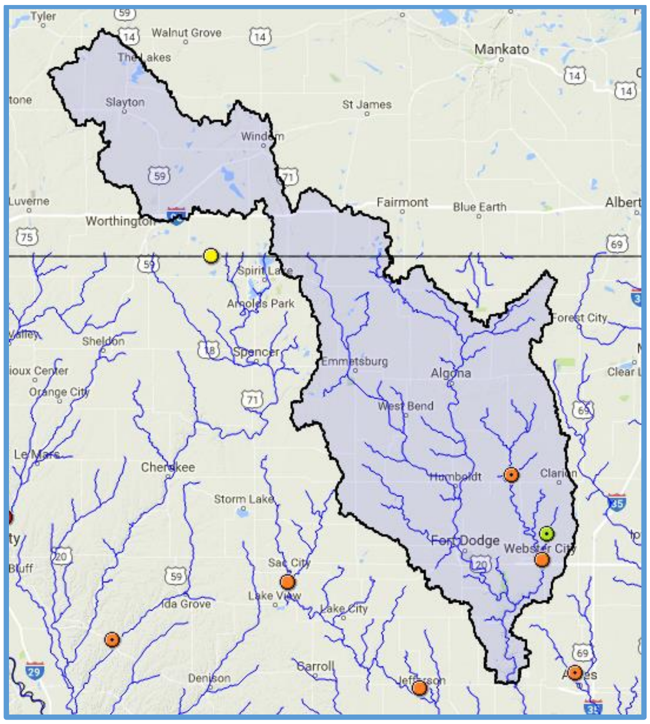


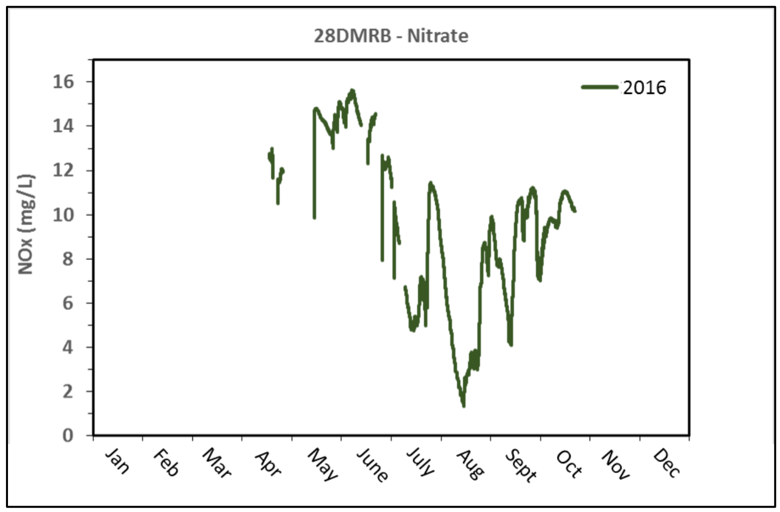
Discussion: Lime Creek is a tributary of the Cedar River. Monitoring here is coordinated by Coe College, with maintenance and data management assistance provided IIHR beginning in 2015. The Cedar River and groundwater under its influence are an important source of municipal drinking water for the downstream city of Cedar Rapids. Data from this site illustrates that nitrate levels can frequently exceed the drinking water standard of 10 mg/L in the Cedar watershed.



27. WQS0028 Des Moines River at Boone

Site No.	WQS0028
Name	Des Moines River near Boone, Iowa
Location	Left bank of Des Moines River, 0.1mi upstream of 188th Rd bridge (42.0823, -93.9385)
WQ Parameters	Nitrate + nitrite as N
Period of Record	September 2015 – October 2016
Drainage Area	
Funding Sources	INRC
Co-located Measurement	
Purpose & Significance	This site was one of two sites located in the Des Moines River watershed in cooperation with the City of Boone Water Works to evaluate the river-groundwater interaction at/near the Water Works intake wells. This site was discontinued in October 2016 and relocated upstream to Stratford (WQS0045) to be co-located with a discharge gage for better calculation of load estimates. In addition, placing the site upstream of the Water Works would provide advance notice of nitrate concentrations that would be moving downstream towards the intake wells.

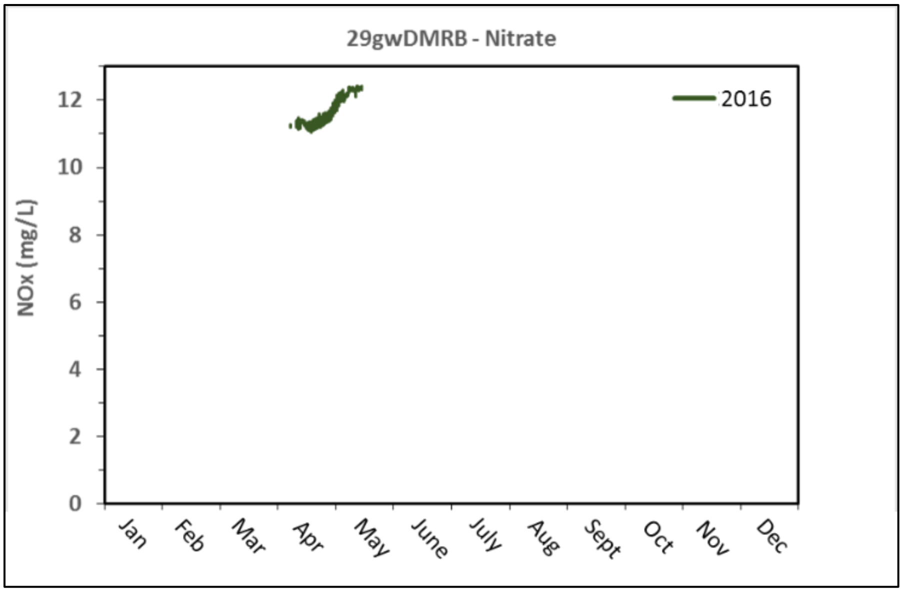




Des Moines River: This is the longest interior river in Iowa and the 32nd longest river in the continental U.S. It travels 525 miles from its source in Minnesota to its confluence with the Mississippi at Keokuk. Along with its major tributary the Raccoon River, its watershed covers about 14,000 square miles or about ¼ of Iowa. Along with Boone, Des Moines and Ottumwa both use the water for municipal supply. Nitrate loads from this important stream will be quantified next year with an IIHR sensor at Keosauqua.

28. WQS0029 Des Moines River Alluvial Well near Boone

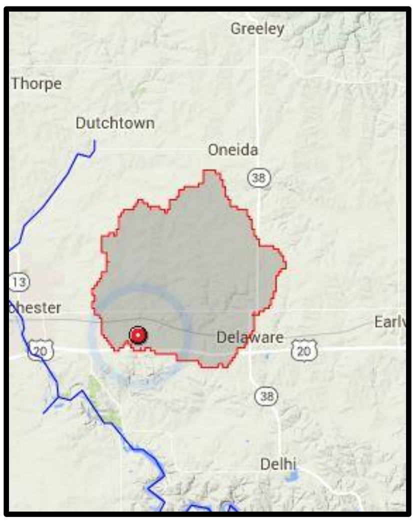
Site No.	WQS0029
Name	**Des Moines River alluvial well near Boone, Iowa**
Location	240ft south of 188th Rd, 260ft east of left bank of Des Moines River (42.0800, -93.9363)
WQ Parameters	Nitrate + nitrite as N
Period of Record	September 2015 – May 2016
Drainage Area	
Funding Sources	INRC
Co-located Measurement	
Purpose & Significance	This site was one of two sites located in the Des Moines River watershed in cooperation with the City of Boone Water Works to evaluate the river-groundwater interaction at/near the Water Works intake wells. This site is was discontinued in May 2016.



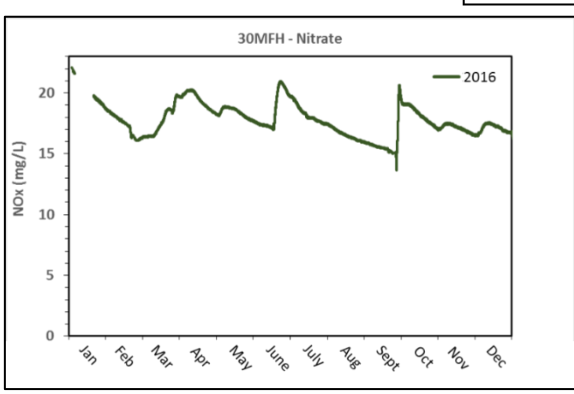
29. WQS0030 and 0031 Manchester Fish Hatchery Spring and Big Spring Fish Hatchery Spring

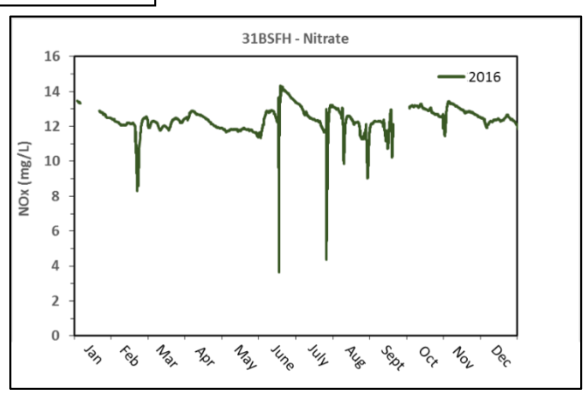
Site No.	WQS0030
Name	**Manchester Fish Hatchery near Delaware, Iowa**
Location	42.4621, -91.3969
WQ Parameters	Nitrate + nitrite as N
Period of Record	December 2015 – December 2016
Drainage Area	
Funding Sources	INRC, Iowa DNR
Co-located Measurement	
Purpose & Significance	This location is a karst groundwater monitoring site at the upper spring located at the Manchester Fish Hatchery, operated in cooperation with Iowa DNR.

Site No.	WQS0031
Name	**Big Spring Fish Hatchery near Elkader, Iowa**
Location	42.9201, -91.4862
WQ Parameters	Nitrate + nitrite as N
Period of Record	December 2015 – December 2016
Drainage Area	
Funding Sources	INRC, Iowa DNR
Co-located Measurement	
Purpose & Significance	This location is a long-term karst groundwater monitoring site at Big Spring Fish Hatchery, operated in cooperation with Iowa DNR.



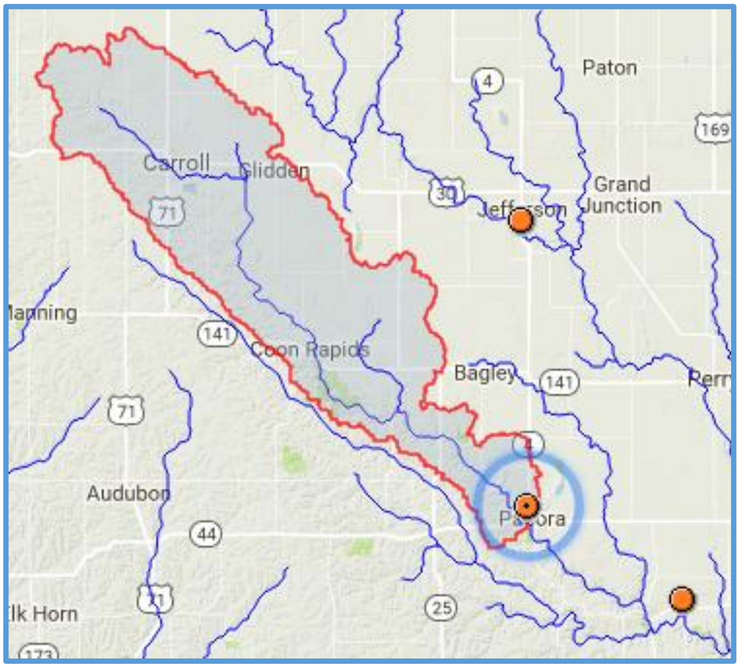
Discussion: These sensors were installed in late 2015 in collaboration with Iowa DNR. Both are measuring groundwater nitrate in DNR fish hatcheries. These sites provide a good way to constructively use the monitoring equipment in the winter months. The sites are both located in the Paleozoic Plateau region of Iowa. Karst geology makes shallow groundwater, like that emerging from these springs, very vulnerable to surface contamination. Both sites, especially the Manchester site, have quite high nitrate levels.

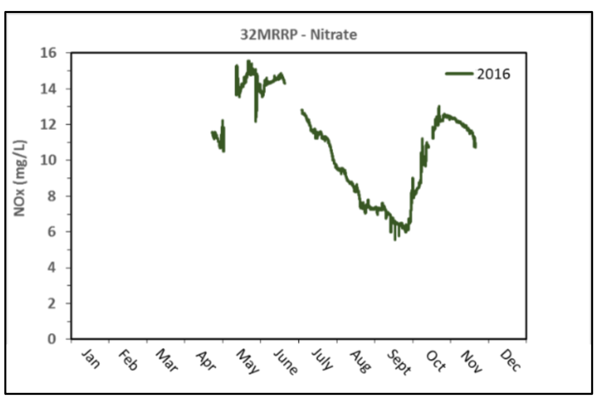




30. WQS0032 Middle Raccoon River at Panora

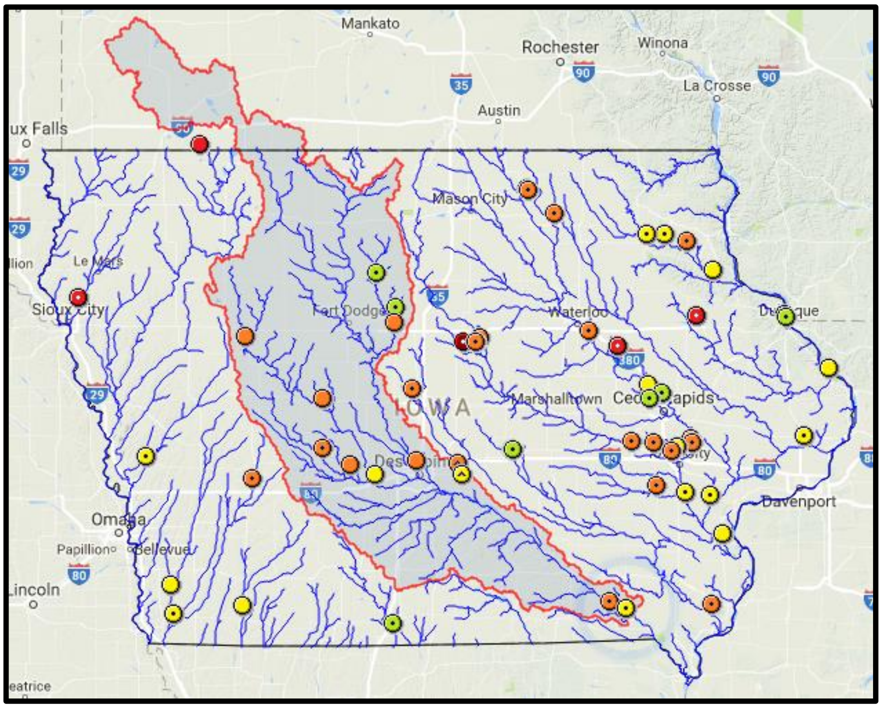
Site No.	WQS0032
Name	Middle Raccoon River at Panora, Iowa
Location	Left bank of Middle Raccoon River, upstream of W South St bridge (41.6874, -94.3710)
WQ Parameters	Nitrate + nitrite as N
Period of Record	April 2016 – December 2016
Drainage Area	440 sq mi
Funding Sources	INRC
Co-located Measurement	USGS 05483600 (stage, discharge)
Purpose & Significance	This site is located along the Middle Raccoon River, downstream of Lake Panorama.

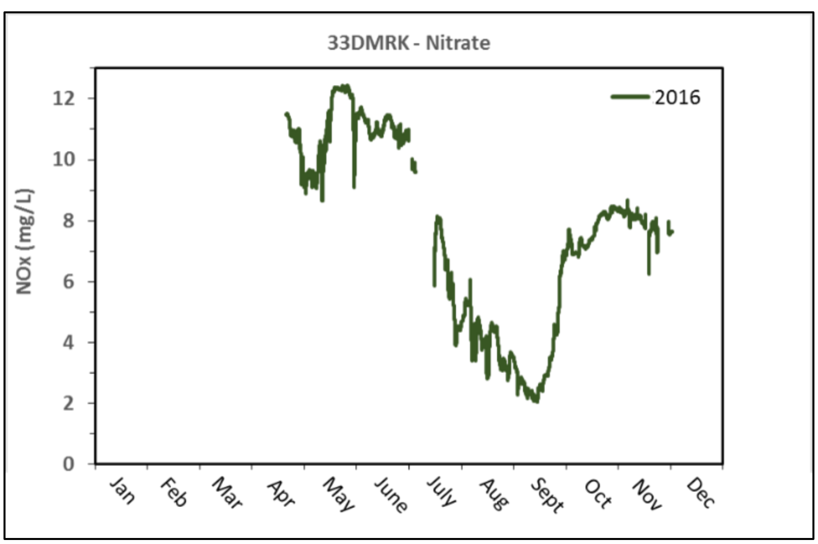




31. WQS0033 Des Moines River at Keosauqua

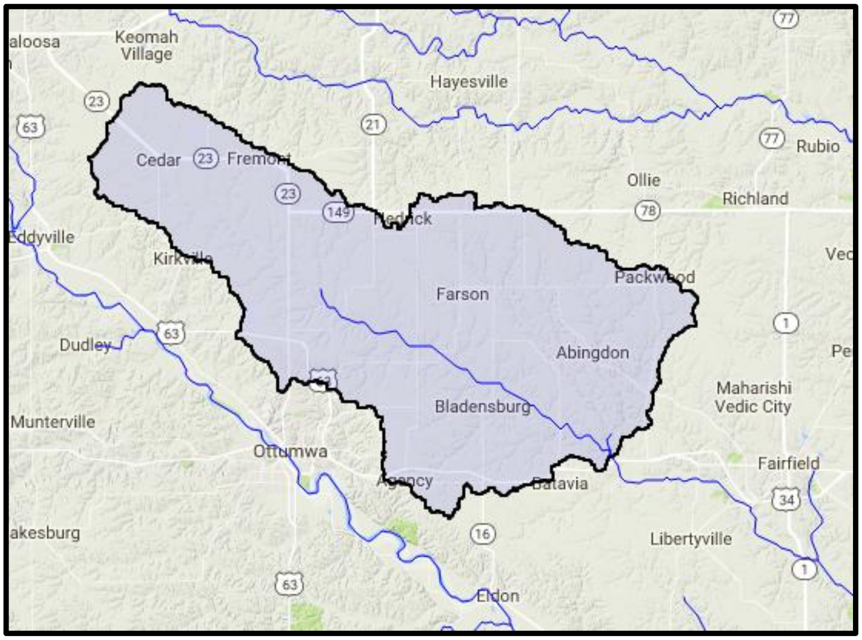
Site No.	WQS0033
Name	Des Moines River at Keosauqua, Iowa
Location	Right bank of Des Moines River, upstream of Hwy 1 bridge (40.7277, -91.9599)
WQ Parameters	Nitrate + nitrite as N
Period of Record	April 2016 – December 2016
Drainage Area	14038 sq mi
Funding Sources	INRC
Co-located Measurement	USGS 05490500 (stage, discharge) DNR Ambient Monitoring Site (Storet ID 10890001)
Purpose & Significance	This site is a significant state N-load estimate location, located along the Des Moines River in southeast Iowa.

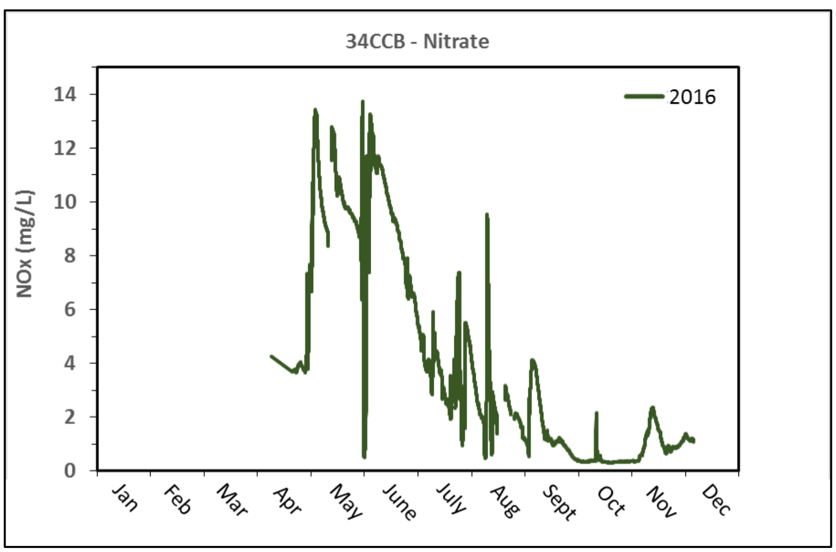




32. WQS0034 Cedar Creek near Batavia

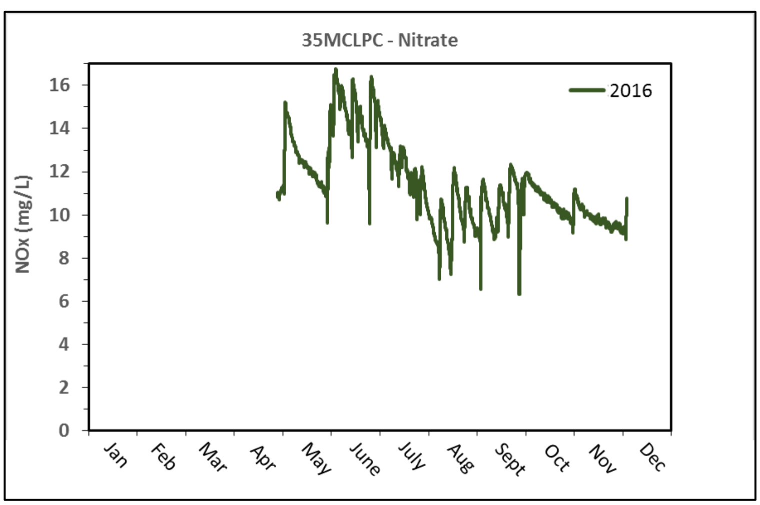
Site No.	WQS0034
Name	Cedar Creek near Batavia, Iowa
Location	Right bank of Cedar Creek, upstream of Hwy 34 bridge (41.0098, -92.1189)
WQ Parameters	Nitrate + nitrite as N
Period of Record	April 2016 – November 2016
Drainage Area	248 sq mi
Funding Sources	INRC
Co-located Measurement	IFC CEDARCRK01 (stage)
Purpose & Significance	This site is located in the Skunk River watershed, immediately downstream of several WQI demonstration projects.





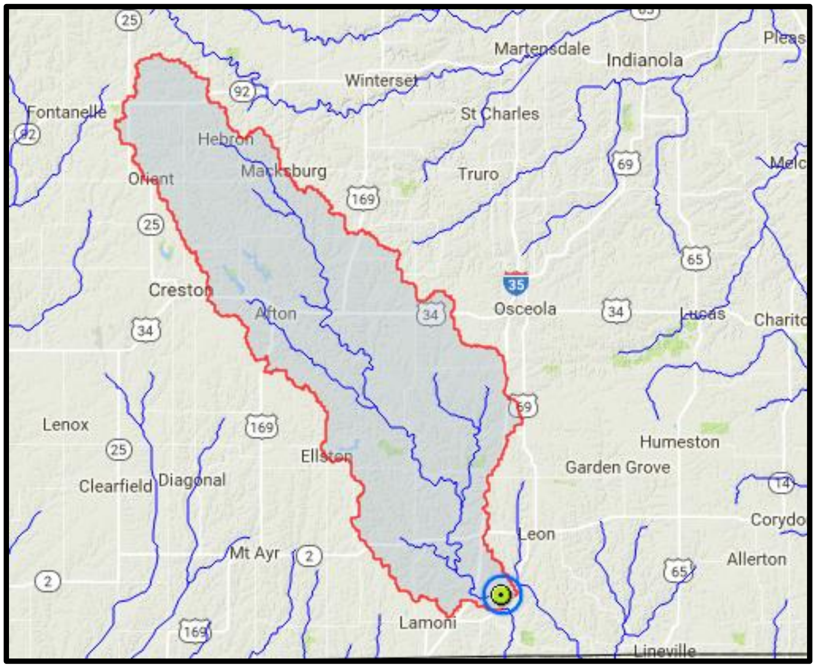
33. WQS0035 Miller Creek near LaPorte City

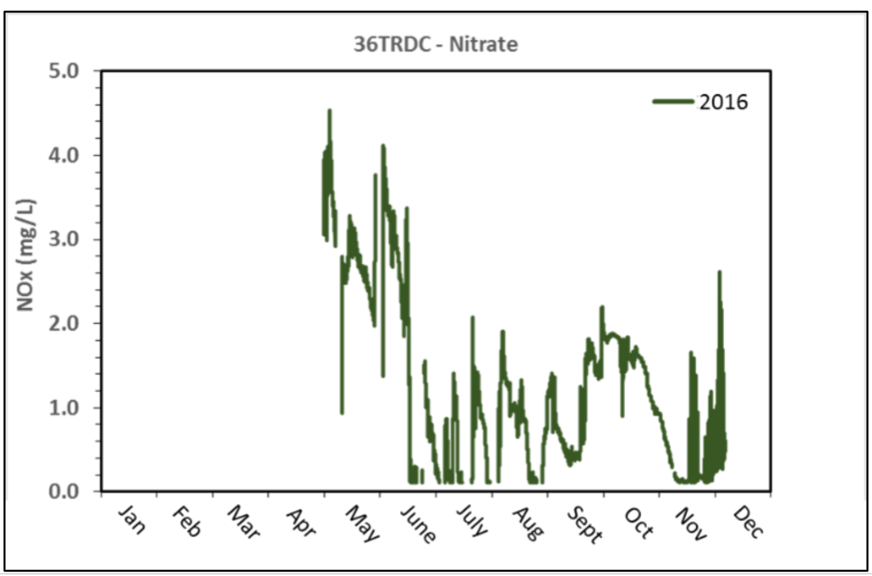
Site No.	WQS0035
Name	**Miller Creek near La Porte City, Iowa**
Location	Right bank of Miller Creek, upstream of Miller Creek Rd bridge (42.3846, -92.2544)
WQ Parameters	Nitrate + nitrite as N
Period of Record	April 2016 – November 2016
Drainage Area	23 sq mi
Funding Sources	INRC
Co-located Measurement	IFC MILLERCRK01 (stage)
Purpose & Significance	This site is located in the Cedar River watershed, downstream of WQI demonstration projects.



34. WQS0036 Thompson Fork at Davis City

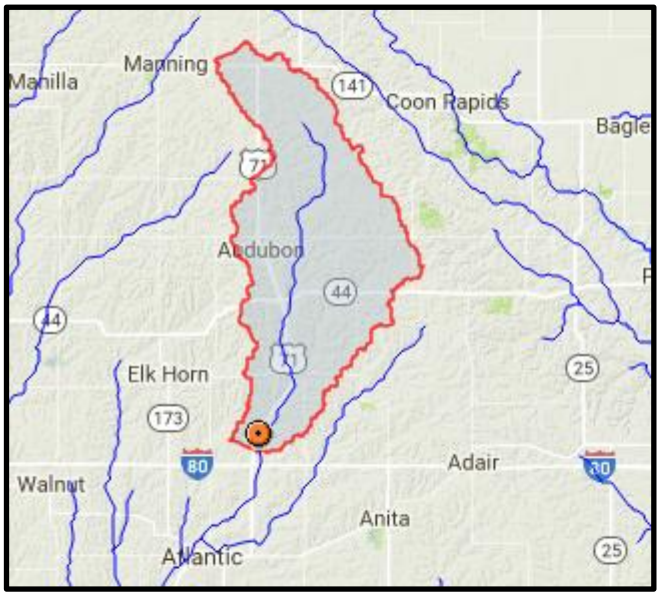
Site No.	WQS0036
Name	Thompson River at Davis City, Iowa
Location	Right bank of the Thompson River, upstream of Hwy 69 bridge (40.6405, -93.8080)
WQ Parameters	Nitrate + nitrite as N
Period of Record	April 2016 – December 2016
Drainage Area	701 sq mi
Funding Sources	INRC
Co-located Measurement	USGS 06898000 (stage, discharge) DNR Ambient Monitoring Site (Storet ID 10270001)
Purpose & Significance	This site is a state N-load estimate location, located along the Thompson River in south-central Iowa.

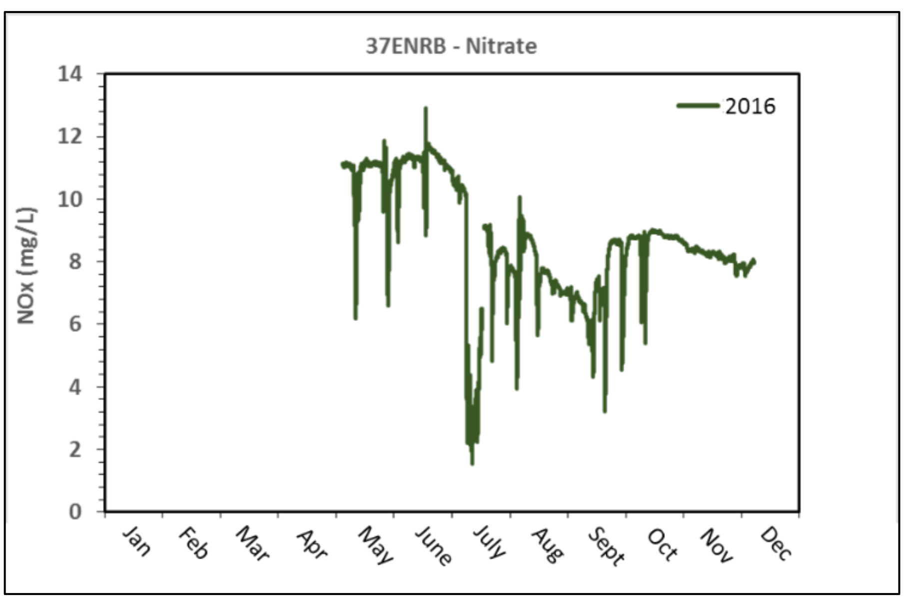




35. East Nishnabotna River near Brayton

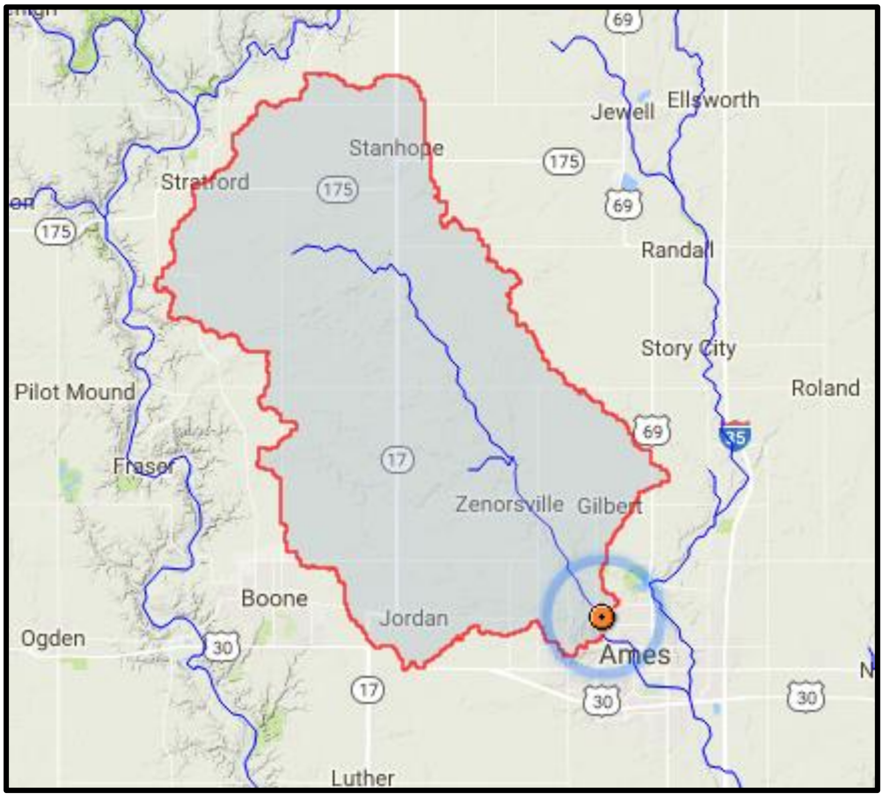
Site No.	WQS0037
Name	**East Nishnabotna River near Brayton, Iowa**
Location	Right bank of the East Nishnabotna River, upstream of 345th St bridge (41.5119, -94.9358)
WQ Parameters	Nitrate + nitrite as N
Period of Record	May 2016 – December 2016
Drainage Area	278 sq mi
Funding Sources	INRC
Co-located Measurement	IFC ENISH05 (stage)
Purpose & Significance	This site is located in the Nishnabotna River watershed in southwest Iowa, downstream of WQI demonstration projects.

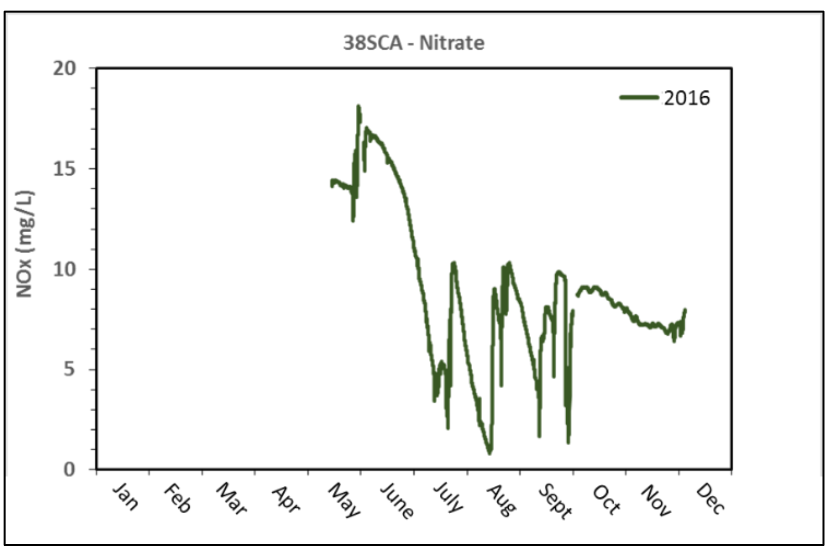




36. WQS0038 Squaw Creek at Ames

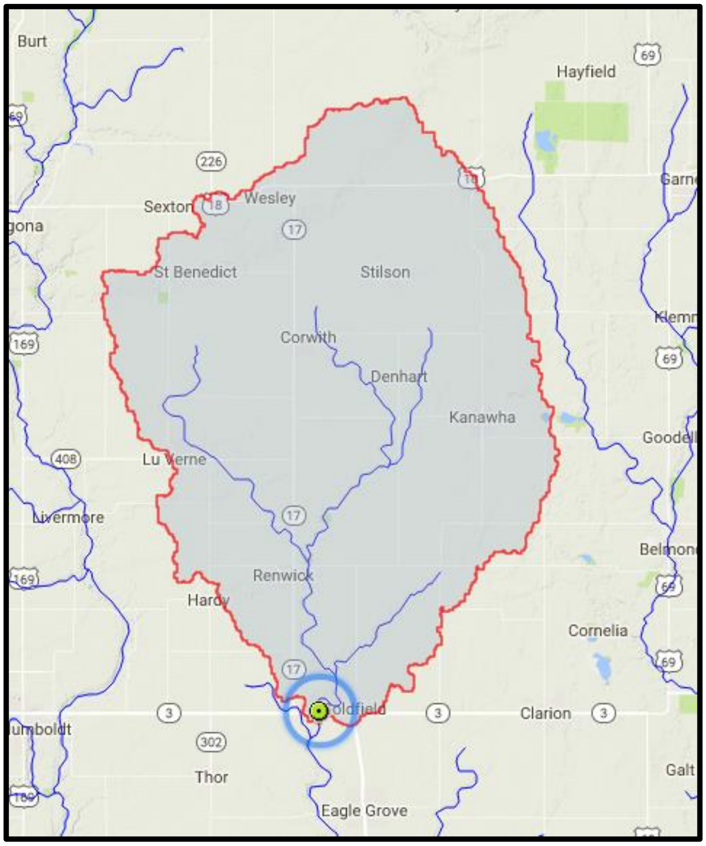
Site No.	WQS0038
Name	Squaw Creek at Ames, Iowa
Location	Left bank of Squaw Creek, off of Veenker Golf Course maintenance road (42.0414, -93.6539)
WQ Parameters	Nitrate + nitrite as N
Period of Record	May 2016 – November 2016
Drainage Area	196 sq mi
Funding Sources	INRC
Co-located Measurement	
Purpose & Significance	This site is located in the South Skunk River watershed, downstream of WQI demonstration projects.

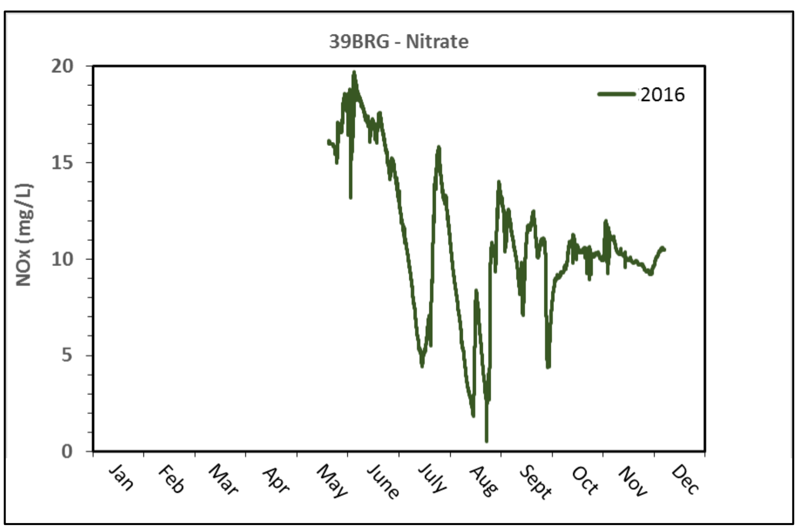




37. WQS0039 Boone River near Goldfield

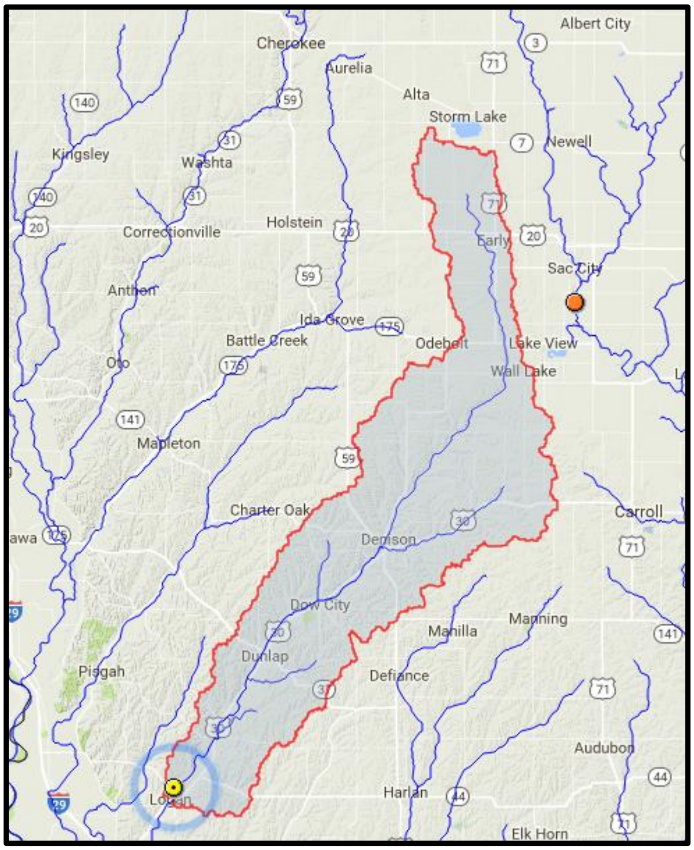
Site No.	WQS0039
Name	Boone River near Goldfield, Iowa
Location	Right bank of Boone River, upstream of 225th St bridge (42.7245,-93.9473)
WQ Parameters	Nitrate + nitrite as N
Period of Record	May 2016 – December 2016
Drainage Area	420 sq mi
Funding Sources	INRC
Co-located Measurement	USGS 05480820 (stage, discharge)
Purpose & Significance	This site is located in north-central Iowa, downstream of WQI demonstration projects.

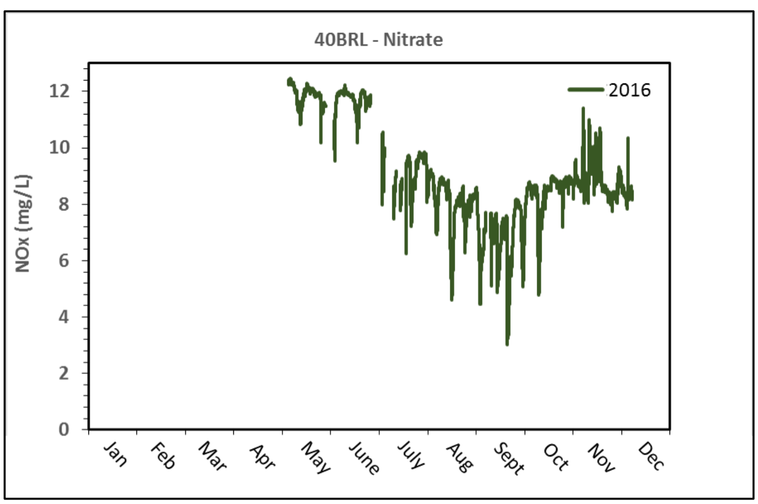




38. WQS0040 Boyer River at Logan

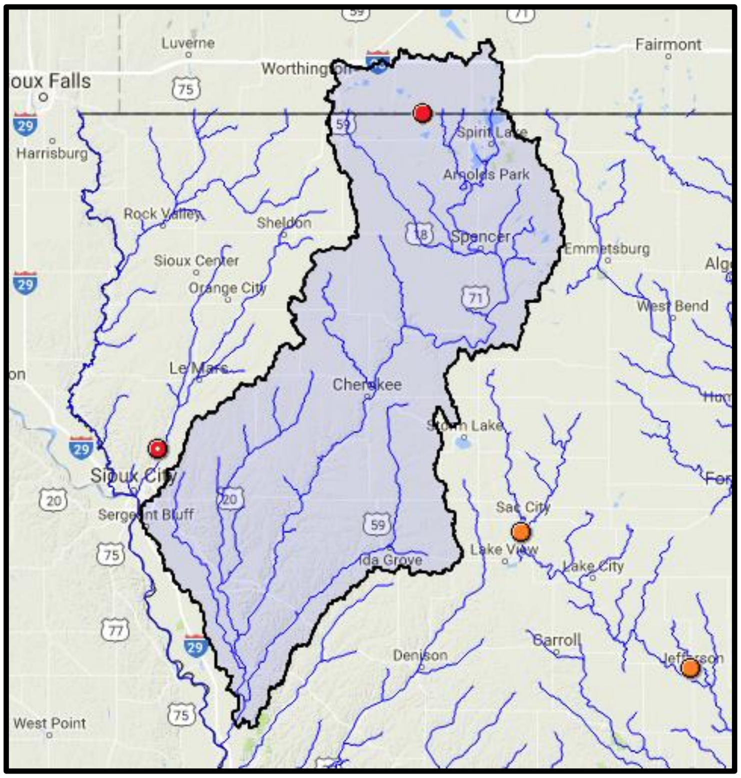
Site No.	WQS0040
Name	**Boyer River at Logan, Iowa**
Location	Right bank of Boyer River, upstream of 8th St bridge (41.6418, -95.7827)
WQ Parameters	Nitrate + nitrite as N
Period of Record	May 2016 – December 2016
Drainage Area	850 sq mi
Funding Sources	INRC
Co-located Measurement	USGS 06609500 (stage, discharge)
Purpose & Significance	This site is a significant state N-load estimate location, which drains into the Missouri River in west-central Iowa.

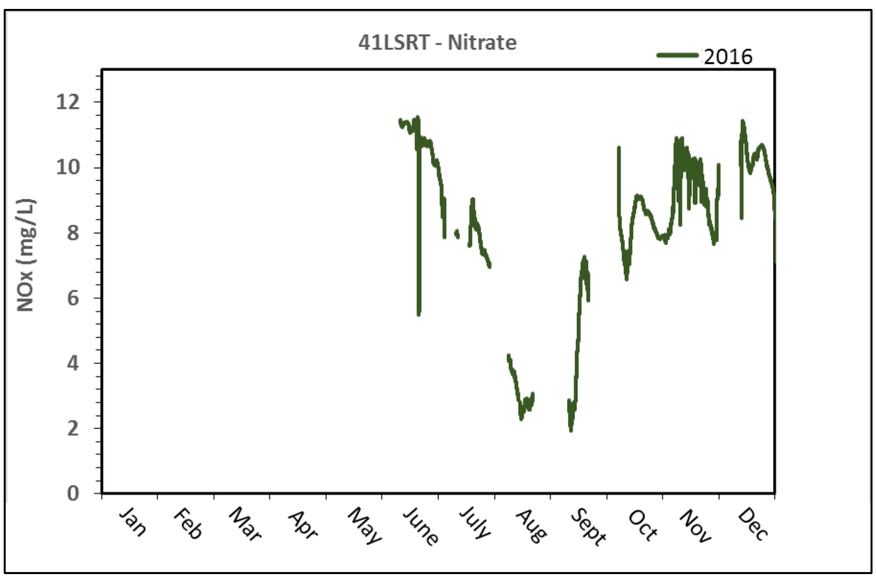




39. WQS0041 Little Sioux River near Turin

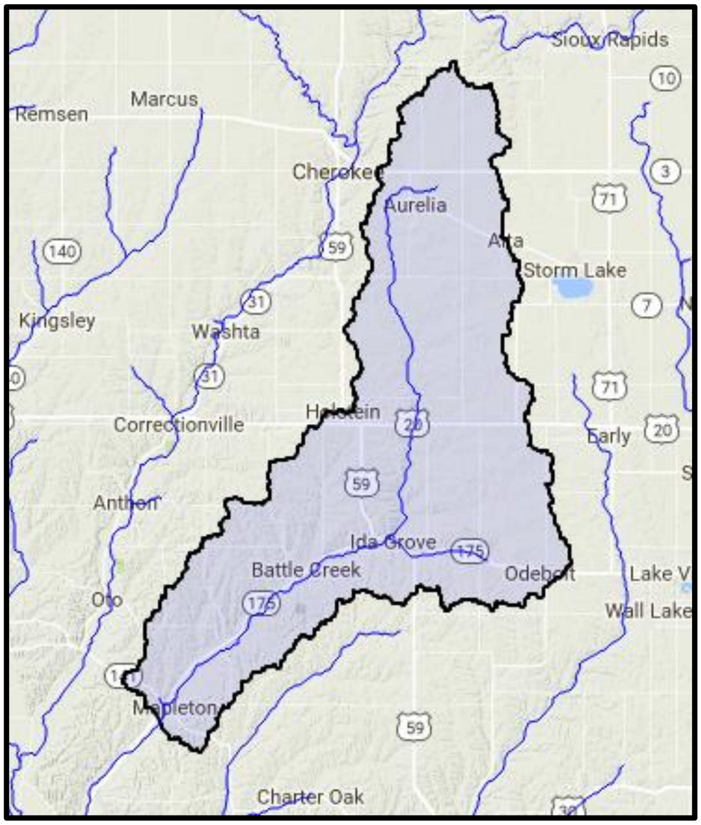
Site No.	WQS0041
Name	Little Sioux River near Turin, Iowa
Location	Right bank of Little Sioux River, upstream of E54 bridge (41.9651, -95.9733)
WQ Parameters	Nitrate + nitrite as N
Period of Record	June 2016 – December 2016
Drainage Area	3526 sq mi
Funding Sources	INRC
Co-located Measurement	USGS 06607500 (stage, discharge) DNR Ambient Monitoring Site (Storet ID 10670003)
Purpose & Significance	This site is a significant state N-load estimate location, which drains into the Missouri River in west-central Iowa.

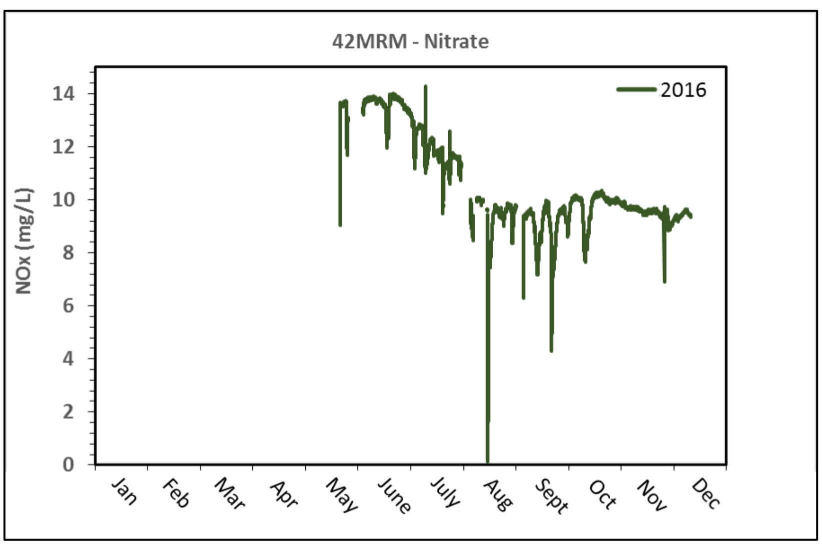




40. WQS0042 Maple River near Mapleton

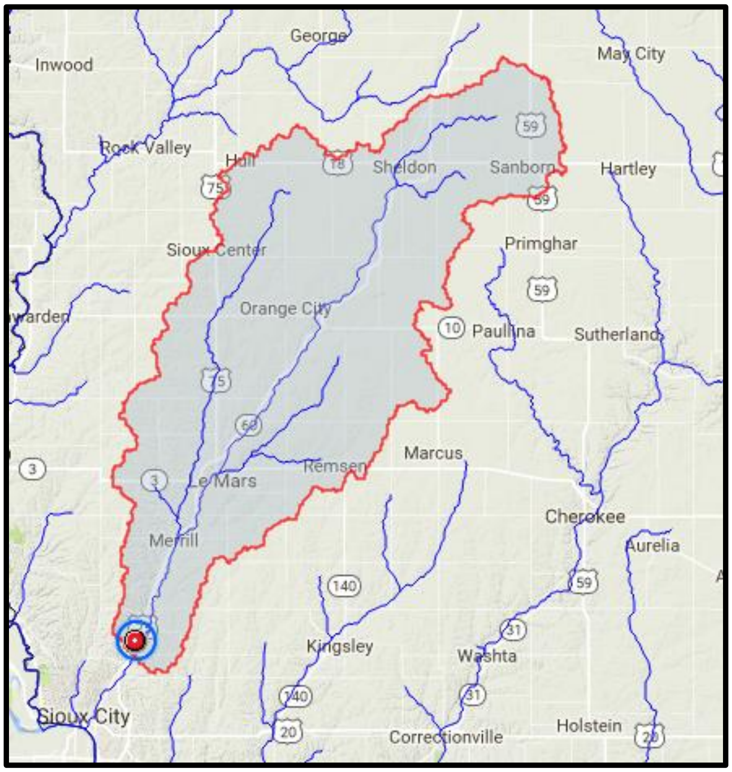
Site No.	WQS0042
Name	**Maple River near Mapleton, Iowa**
Location	Right bank of Maple River, upstream of the Hwy 175 bridge (42.1569, -95.8100)
WQ Parameters	Nitrate + nitrite as N
Period of Record	May 2016 – December 2016
Drainage Area	669 sq mi
Funding Sources	INRC
Co-located Measurement	USGS 06607200 (stage, discharge) Downstream of DNR Ambient Monitoring Site (Storet ID 10670002)
Purpose & Significance	This site is a significant state N-load estimate location, which drains into the Little Sioux River in west-central Iowa.

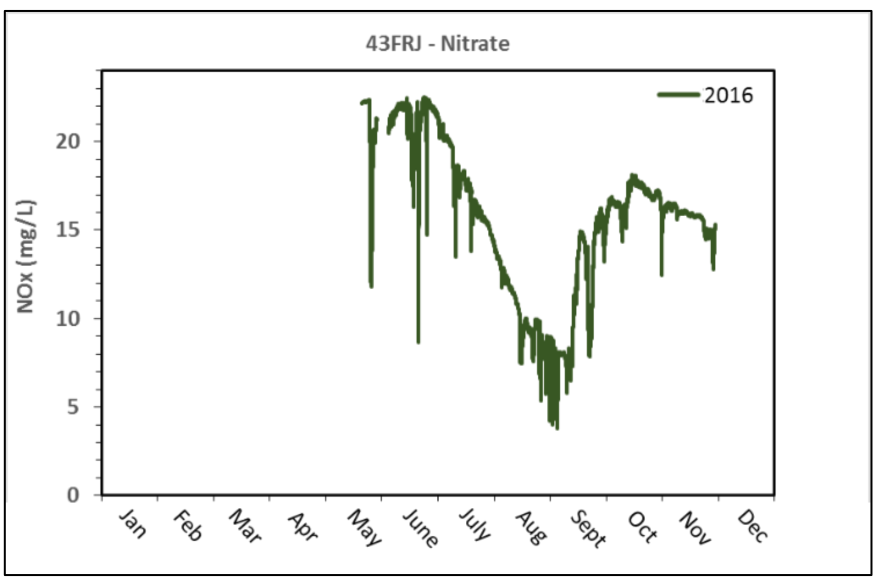




41. WQS0043 Floyd River near James

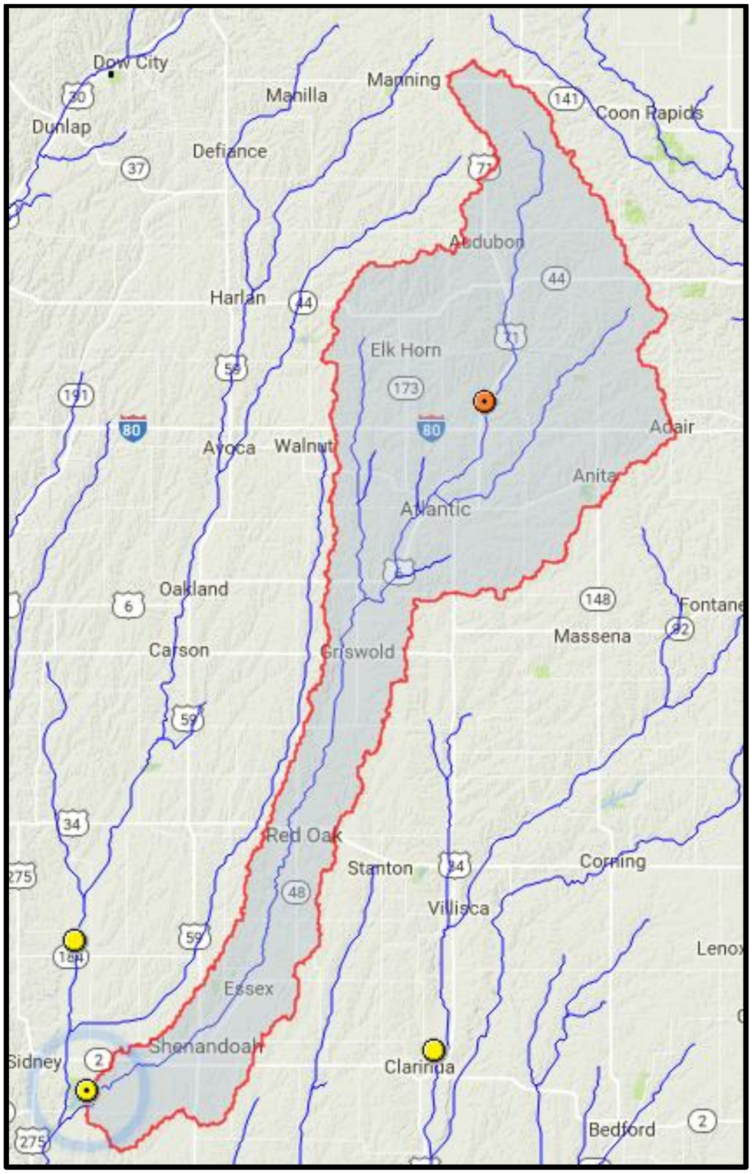
Site No.	WQS0043
Name	Floyd River near James, Iowa
Location	Right bank of Floyd River, upstream of the C70 bridge (42.5764, -96.3125)
WQ Parameters	Nitrate + nitrite as N
Period of Record	May 2016 – November 2016
Drainage Area	886 sq mi
Funding Sources	INRC
Co-located Measurement	USGS 06600500 (stage, discharge) DNR Ambient Monitoring Site (Storet ID 10750001)
Purpose & Significance	This site is located downstream of WQI demonstration projects and is a significant state N-load estimate location, which drains into the Missouri River in northwest Iowa.

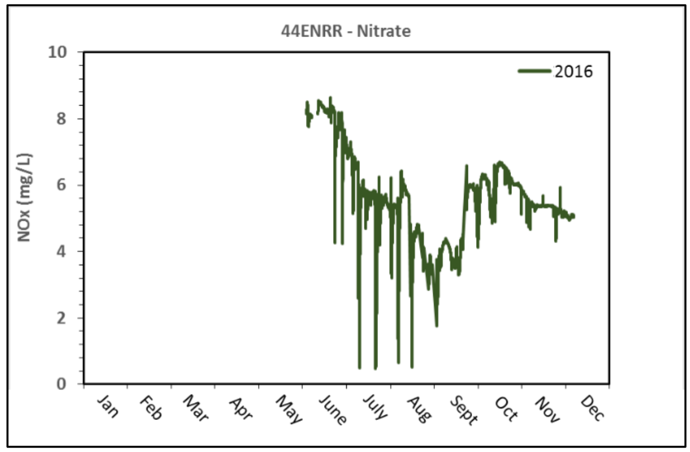




42. WQS0044 East Nishnabotna River near Riverton

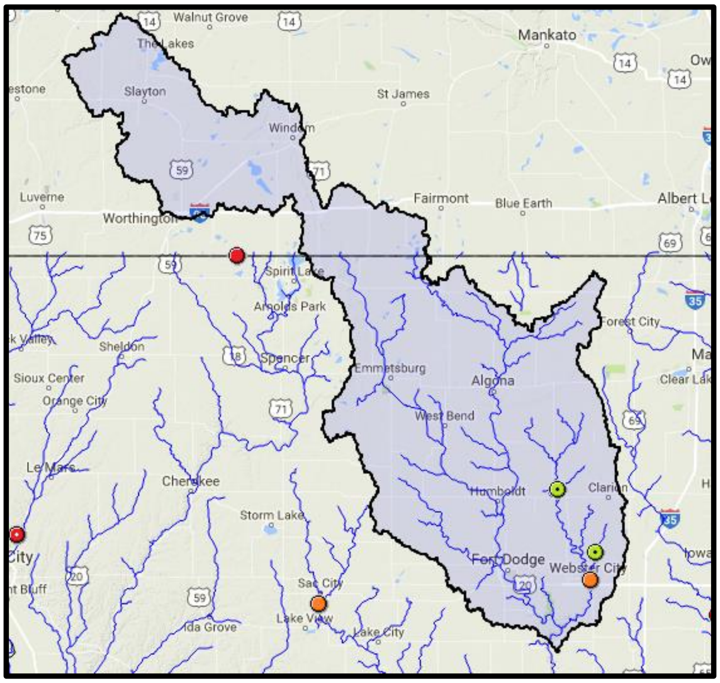
Site No.	WQS0044
Name	**East Nishnabotna River near Riverton, Iowa**
Location	Left bank of East Nishnabotna River, upstream of the L68 bridge (40.6943, -95.5623)
WQ Parameters	Nitrate + nitrite as N
Period of Record	June 2016 – December 2016
Drainage Area	1105 sq mi
Funding Sources	INRC
Co-located Measurement	
Purpose & Significance	This site is a significant state N-load estimate location, which drains into the Nishnabotna River in southwest Iowa.

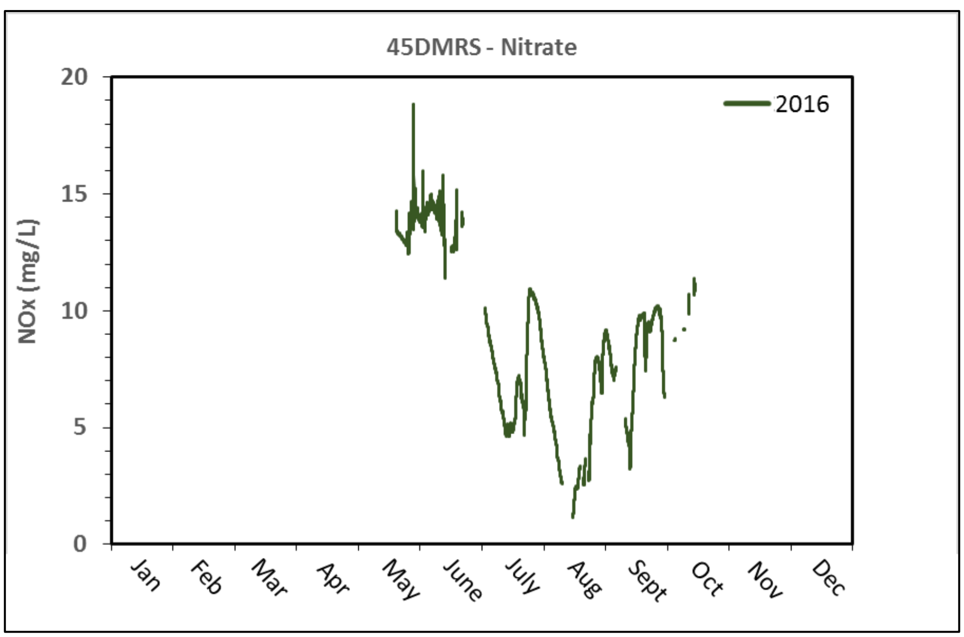




43. WQS0045 Des Moines River near Stratford

Site No.	**WQS0045**
Name	**Des Moines River near Stratford, Iowa**
Location	Right bank of Des Moines River, east side of River Rd (42.2396, -93.9955)
WQ Parameters	Nitrate + nitrite as N
Period of Record	May 2016 – October 2016
Drainage Area	5452 sq mi
Funding Sources	INRC
Co-located Measurement	1mi south of USGS 05481300 (stage, discharge)
Purpose & Significance	This site is a significant state N-load estimate location, and informs operations at the City of Boone Water Works.

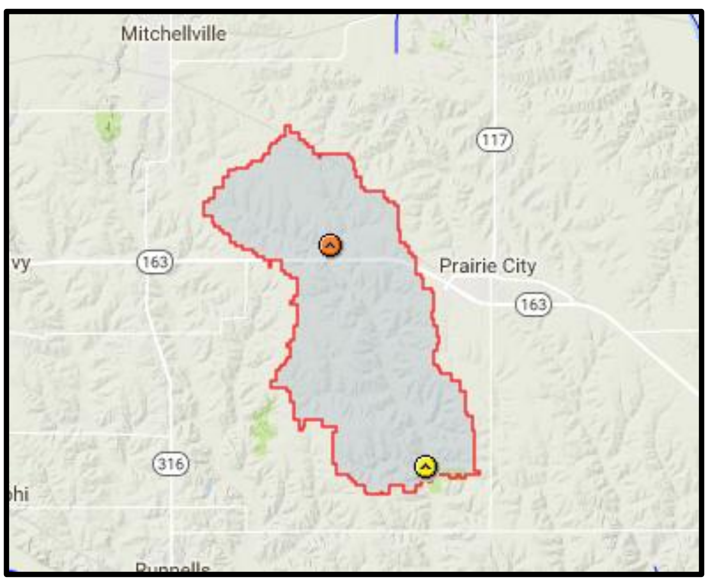


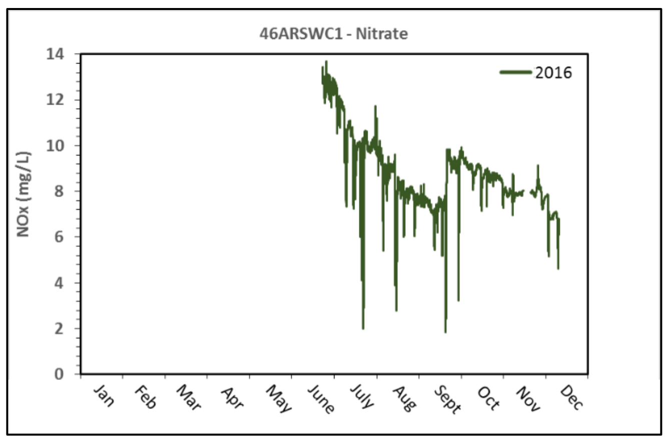


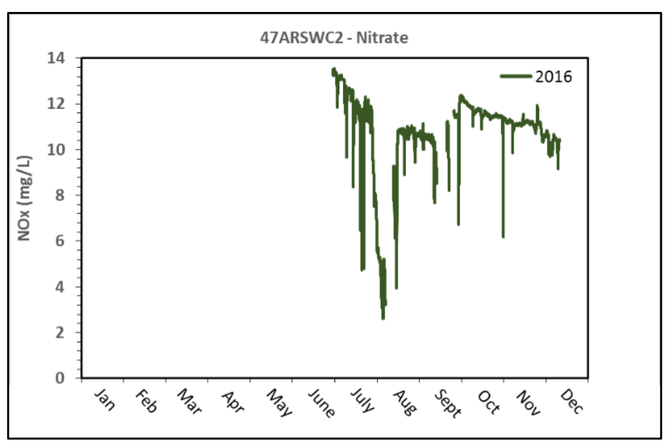
44. WQS0046 (downstream) and WQS0047 (upstream) Walnut Creek near Prairie

Site No.	WQS0046
Name	**Walnut Creek near Prairie City, Iowa**
Location	Downstream of S 112th St W bridge (41.5369, -93.2587)
WQ Parameters	Nitrate + nitrite as N
Period of Record	June 2016 – December 2016
Drainage Area	
Funding Sources	ARS, INRC
Co-located Measurement	USDA-ARS research equipment
Purpose & Significance	This site is operated and maintained by the USDA-ARS, and is one of two sites located on Walnut Creek near Prairie City and the Neil Smith National Wildlife Refuge.

Site No.	WQS0047
Name	**Walnut Creek near Prairie City, Iowa**
Location	Left bank of Walnut Creek, downstream of Hwy 163 bridge (41.6010, -93.2960)
WQ Parameters	Nitrate + nitrite as N
Period of Record	June 2016 – December 2016
Drainage Area	
Funding Sources	ARS, INRC
Co-located Measurement	USDA-ARS research equipment
Purpose & Significance	This site is operated and maintained by the USDA-ARS, and is one of two sites located on Walnut Creek near Prairie City and the Neil Smith National Wildlife Refuge.

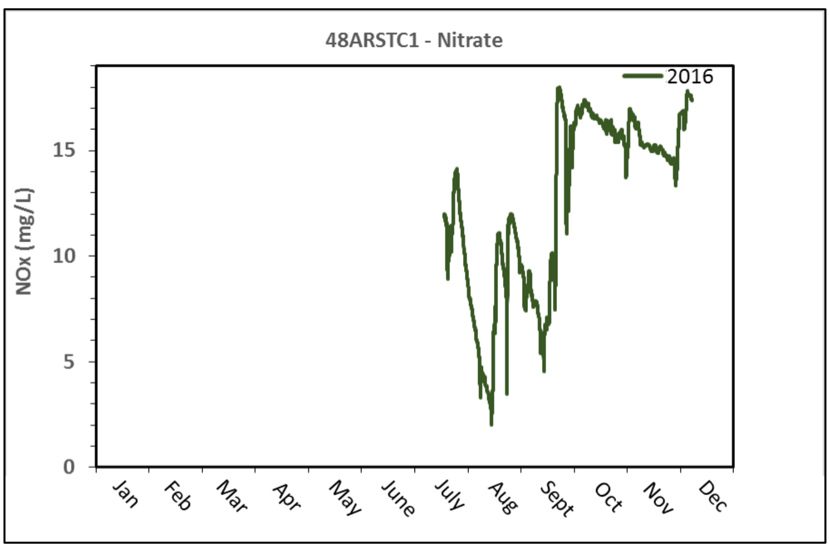






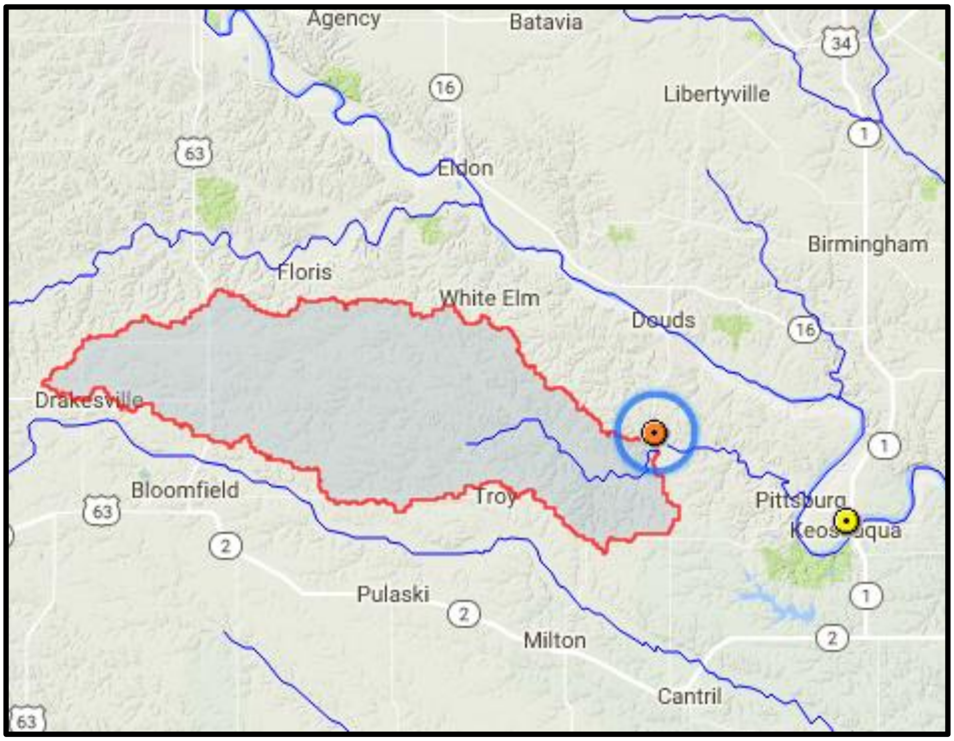
45. WQS0048 Tipton Creek near Hubbard

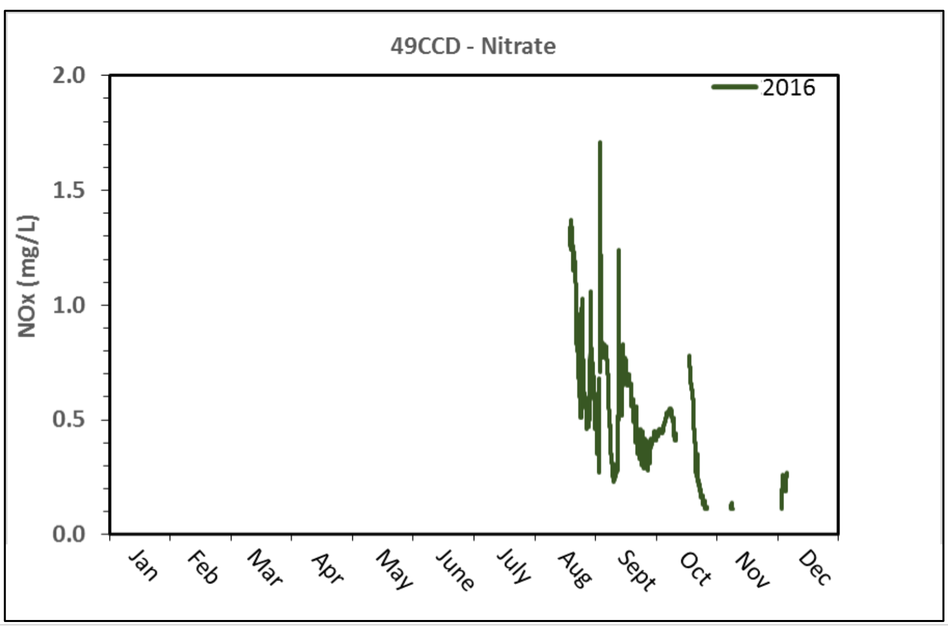
Site No.	WQS0048
Name	Tipton Creek near Hubbard, Iowa
Location	Upstream of M Ave bridge (42.3177, -93.2513)
WQ Parameters	Nitrate + nitrite as N
Period of Record	July 2016 – December 2016
Drainage Area	
Funding Sources	ARS, INRC
Co-located Measurement	USDA-ARS research equipment
Purpose & Significance	This site is operated and maintained by the USDA-ARS, and is one of three water quality sensor sites operated in the South Fork Iowa River watershed during the 2016 season.



46. Chequest Creek near Douds

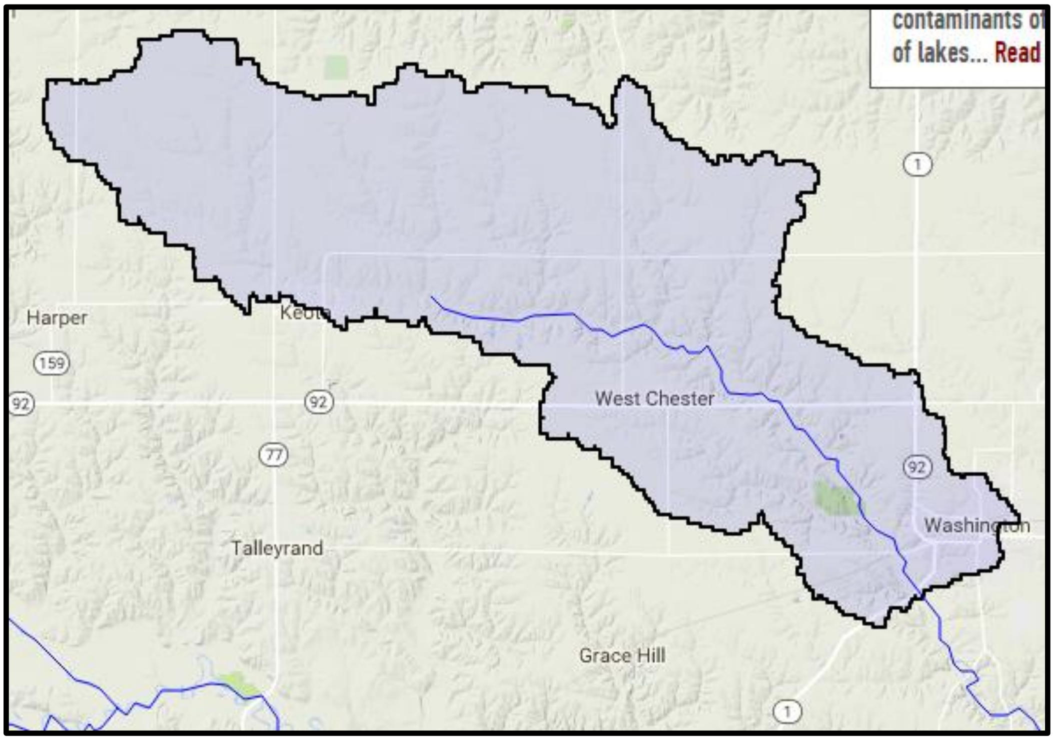
Site No.	WQS0049
Name	**Chequest Creek near Douds, Iowa**
Location	Right bank of Chequest Creek, upstream of Rte V64 bridge (40.7720, -92.0922)
WQ Parameters	Nitrate + nitrite as N
Period of Record	August 2016 – November 2016
Drainage Area	
Funding Sources	INRC, HUD
Co-located Measurement	
Purpose & Significance	This site was relocated from South Chequest Creek near Douds (WQS0019) due to sedimentation problems.

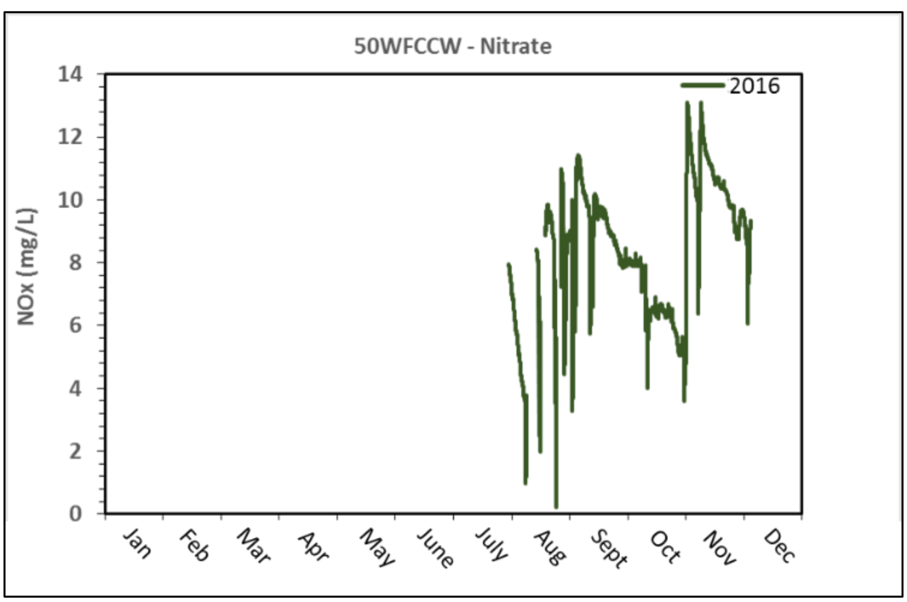




47. WQS0050 West Fork Crooked Creek near Washington

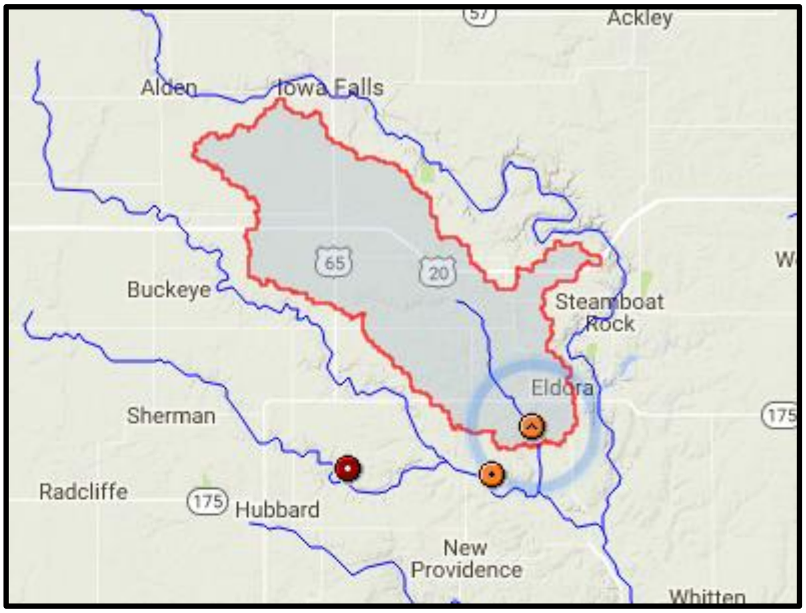
Site No.	WQS0050
Name	West Fork Crooked Creek near Washington, Iowa
Location	Right bank of West Fork Crooked Creek, upstream of Hwy 1 bridge (41.2817, -91.7161)
WQ Parameters	Nitrate + nitrite as N
Period of Record	July 2016 – November 2016
Drainage Area	
Funding Sources	INRC
Co-located Measurement	IFC WFCRKDCR01 (stage)
Purpose & Significance	This site was located downstream of WQI demonstration projects, and discontinued in November 2016.

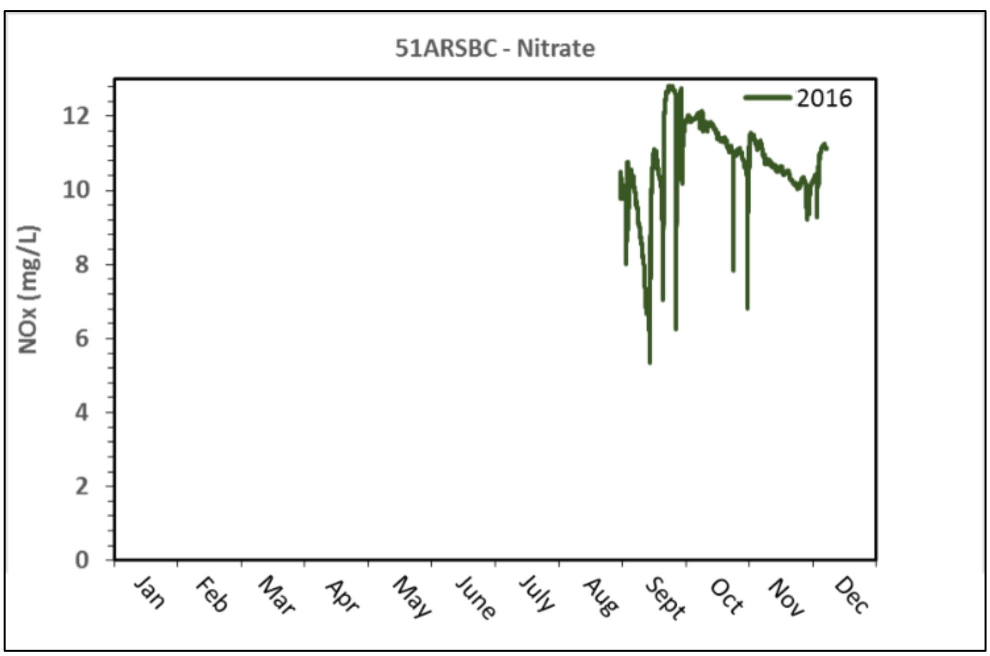




48. WQS0051 Beaver Creek near Eldora

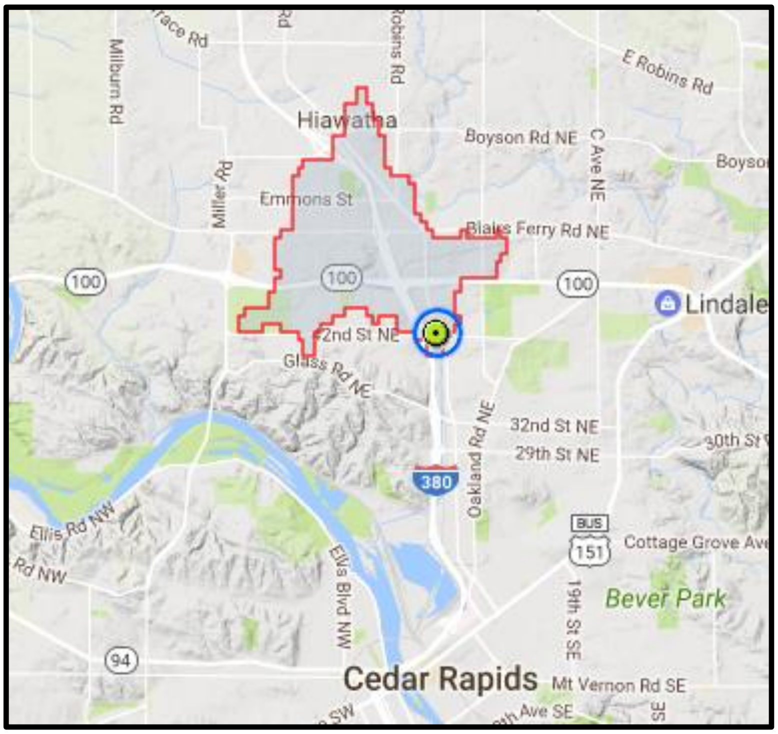
Site No.	WQS0051
Name	Beaver Creek near Eldora, Iowa
Location	Downstream of 250th St bridge (42.3389, -93.1250)
WQ Parameters	Nitrate + nitrite as N
Period of Record	August 2016 – December 2016
Drainage Area	
Funding Sources	ARS, INRC
Co-located Measurement	USDA-ARS research equipment
Purpose & Significance	This site is operated and maintained by the USDA-ARS, and is one of three water quality sensor sites operated in the South Fork Iowa River watershed during the 2016 season.

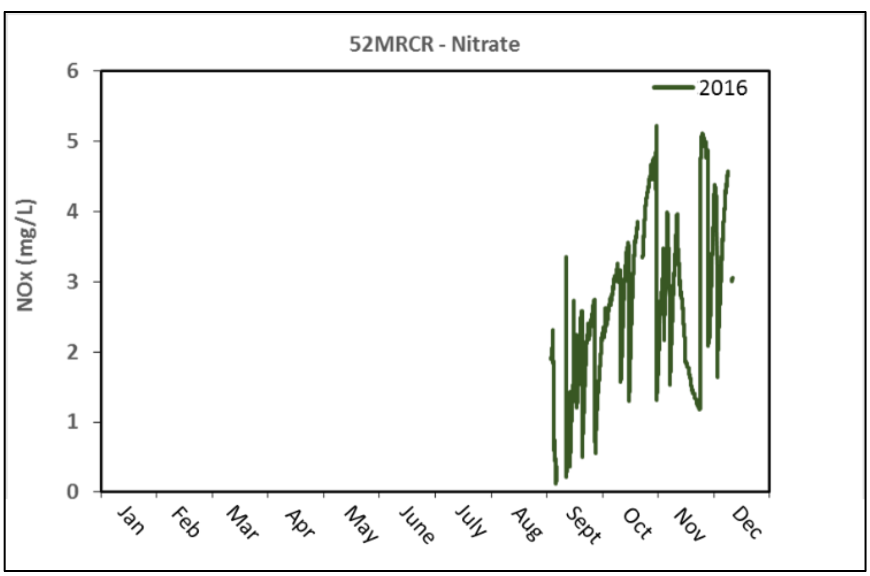




49. WQS0052 Stormwater Sewer, McLoud Run Cedar Rapids

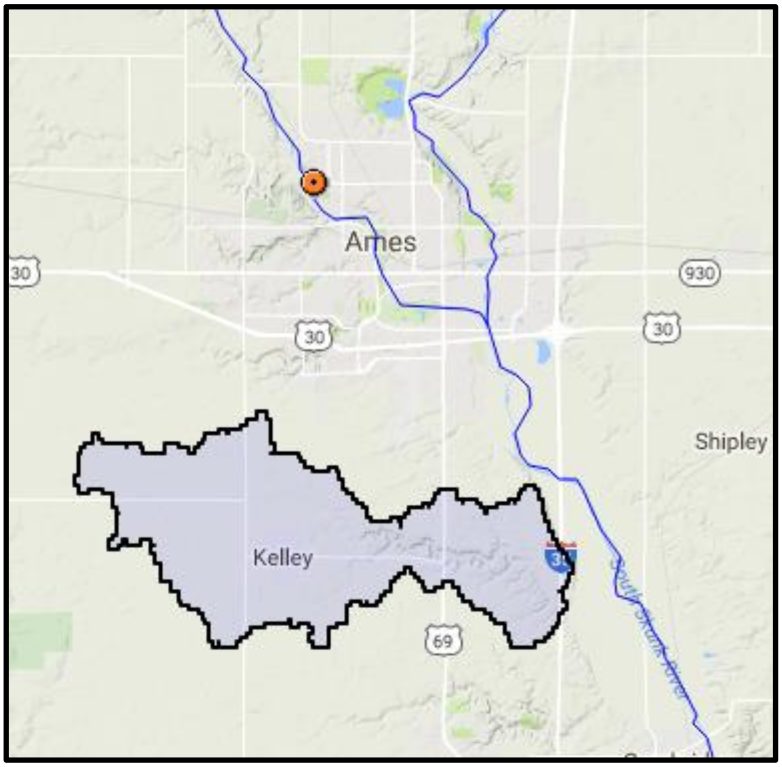
Site No.	WQS0052
Name	Stormwater Drainage Tile, McCloud Run at Cedar Rapids, Iowa
Location	Tile enters McCloud run west of Center Point Rd NE and Park Towne Ct NE (42.0197, -91.6660)
WQ Parameters	Nitrate + nitrite as N, temperature, specific conductance, pH, dissolved oxygen
Period of Record	August 2016 – December 2016
Drainage Area	
Funding Sources	INRC
Co-located Measurement	
Purpose & Significance	This site is operated in cooperation with the City of Cedar Rapids.

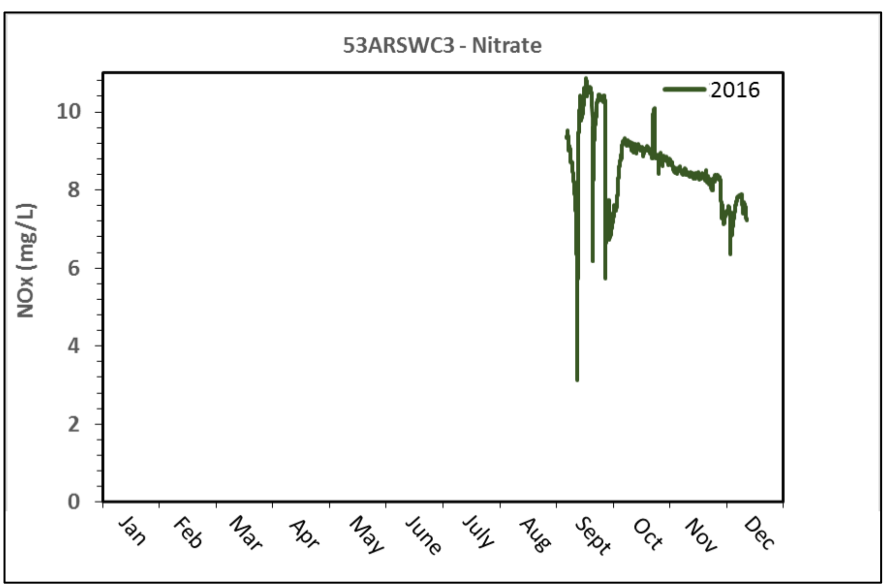




50. WQS0053 Walnut Creek near Kelley

Site No.	WQS0053
Name	Walnut Creek near Kelley, Iowa
Location	Upstream of 530th Ave bridge (41.9544, -93.6393)
WQ Parameters	Nitrate + nitrite as N
Period of Record	September 2016 – December 2016
Drainage Area	
Funding Sources	ARS, INRC
Co-located Measurement	USDA-ARS research equipment
Purpose & Significance	This site is operated and maintained by the USDA-ARS.





E. Year-to-Year Comparisons of Nitrate Concentration Data (Only Sites with Multiple Years of Data)

Site	Description	Drainage Area (mi^2)	Landform(s)	Climate Zone(s)	Concentration (mg/L)				
					2012	2013	2014	2015	2016
0001	Iowa River Iowa City	3147	DML, IS, SIDP	NC, C, EC	0.5	6.5	6.1	7.7	7.9
0002	Clear Creek Coralville	98	SIDP	EC	1.7	5.1	6.2	5.7	6.2
0003	Clear Creek Oxford	61	SIDP	EC	2.5	5.7	7.5	7.4	8.0
0005	English R. Kalona	576	SIDP	C, EC, SE	0.7	4.1	4.6	6.2	5.7
0006	Iowa River Lone Tree	4293	DML, IS, SIDP	NC, C, EC, SE	1.2	5.7	6.6	6.9	7.4
0007	Cedar River Conesville	7787	IS, SIDP	NC, NE, EC, SE	0.4	5.4	5.8	6.4	7.6
0008	Slough Creek Wetland Outlet	6	IS	NE		9.4	6.7	3.9	9.1
0009	Otter Cr. Elgin	46	PP	NE		6.0	6.8	5.8	8.1
0010	Skunk River Augusta	4312	DML, SIDP, AP	NC, C, SE		2.4	5.6	7.0	5.8
0012	Slough Creek Wetland Inlet	5	IS	EC			11.2	9.8	12.5
0013	Beaver Cr Bassett	17	IS	NE			10.8	9.3	11.0
0014	Beaver Cr Colwell	7	IS	NE			11.5	7.2	12.5
0015	Otter Cr Hornet Rd	26	PP	NE			9.9	8.7	10.7
0016	Otter Cr West Union	15	IS	NE			11.0	10.5	12.3
0017	Brockcamp Cr Ft. Atkinson	8	PP	NE			7.1	4.9	10.1
0018	Roberts Cr Elkader	116	PP	NE			7.7	6.7	10.9
0019	S. Chequest Cr. Douds	31	SIDP	SE			1.0	0.7	0.5
0020	Mississippi River Fairport	99,300	Multiple	Multiple			1.8	1.9	3.7
0021	Rapid Cr Iowa City	6	SIDP	EC			9.6	7.4	9.2
0022	Rapid Cr tributary Iowa City	3	SIDP	EC			9.3	8.9	10.6
0023	Wapsipinicon R. at De Witt	2336	IS, SIDP	NE, EC				5.5	7.2
0024	S. Fork of Iowa R. at New Providence	224	DML	C				16.7	15.0
0025	S. Fork Catfish Cr Dubuque	41	PP	NE				2.2	3.4
0026	Middle Fork Catfish Cr Dubuque	13	PP	NE				0.8	1.0
0027	Lime Creek Brandon	41	IS	EC				9.2	12.7

Table 3: Year-to-year comparisons of nitrate-N data for sites with multiple years' data.

F. 2016 Nitrate Summary

The following is a summary of stream nitrate data generated by IIHR, USGS, ARS, and Coe College sensors during 2016. The USGS data is harvested by IIHR's WQIS system, although IIHR plays no role in managing their sensors. Operation of the ARS sensors is coordinated by IIHR and ARS staff. The Coe College sensor (Lime Creek at Brandon) is managed by IIHR. All the IIHR/USGS sensor locations were shown previously in Fig. 7.

1. Site details.

Data was collected during 2016 at the sensor sites listed in Table 4 and shown in Fig. 7. Details of the area draining to each basin are shown in Table 4. The sensors are primarily capturing streamflow from five of the eight major Iowa landform regions: Des Moines Lobe (DML), Southern Iowa Drift Plain (SIDP), Northwest Iowa Plains (NWIP), Iowan Surface (IS), and Paleozoic Plateau (PP) (Fig. 1).

2. Crop and Precipitation data

Combined area in (corn (Zea mays L.) and soybean (Glycine max [L.] Merr.) shown in Table 4 was estimated from the 2009 Iowa Department of Natural Resources high resolution land cover database. Accumulated precipitation was estimated using monthly precipitation maps (approximately 4-km cell resolution) generated by Parameter-Elevation Regressions on Independent Slopes Model (PRISM) maintained by the PRISM Group (Oregon State University). During 2016, precipitation within the discharge-gaged watersheds ranged from 684 to 1010 mm (average of 843 mm), while discharge (normalized to watershed area) ranged from 239 to 596 mm (average of 402) (Table 4). The long-term annual average annual precipitation for Iowa is 803 mm.

3. Measured Nitrate Concentrations and Loads

Measurements of NO_x-N concentration were collected on an average of 225 days per site, with a range of 64 to 330 days for the 48 IIHR sites, and a range of 233 to 366 days for the 12 USGS sites. Daily average concentrations ranged from 0.46 mg/L (South Chequest Creek near Douds) to 15.8 mg/L (Floyd River near James). Average concentration of all the sites in aggregate was 8.7 mg/L. Discharge measurements were available for 35 of the 60 sites, and at these sites loads, N yields, and flow weighted average NO_x-N concentrations were calculated. Not including the two Mississippi River sites, daily average loading ranged from 961 (Clear Creek near Oxford) to 293,919 kg (Des Moines River at Keosauqua). Daily average NO_x-N yields varied from 0.01 (Thompson Fork at Davis City) to 0.18 lbs/ac (Boone River at Webster City). Flow-weighted average concentrations (total load divided by total discharge) ranged from 1.8 (Thompson Fork at Davis City) to 17.6 mg/L (Floyd River near James), with an overall average of 9.0 mg/L.

Sensor Sites						Nitrate-Nitrite N (NO_x-N)				
site	Category[1]	Watershed area (km^2)	Watershed Precipitation (mm)	Discharge (mm)	% row crop	N[2]	average concentration mg L^{-1}	average daily load (kg)	average daily yield (g ha^{-1})	Flow Weighted Average Concentration (mg L^{-1})
North Raccoon River @ Sac City	d	1813	872	421	84	366	11.5	26,433	146	12.1
North Raccoon River @ Jefferson	d	4193	818	391	82	292	10.7	57,984	138	12.6
Middle Raccoon River @ Panora	a	1140	767	396	72	222	10.3	13,634	120	11.4
South Raccoon River @ Redfield	d	2517	753	373	63	282	8.5	20,127	80	9.2
Raccoon River @ Van Meter	d	8912	789	350	75	361	9.4	87,239	98	10.3
South Fork of the Iowa River @ New Providence	c	580	834	352	82	228	15.0	7,920	137	16.2
Iowa River @ Iowa City	a	8151	808	395	68	330	7.9	66,576	82	7.9
Clear Creek @ Oxford	c	158	775	285	70	251	8.0	961	38	7.7
Clear Creek @ Coralville	c	254	775	299	54	247	6.2	1,290	51	6.0
English River @ Kalona	a	1492	725	277	59	310	5.7	7,058	47	6.5
Iowa River @ Lone Tree	a	11119	788	381	66	324	7.4	82,330	74	7.4
Iowa River @ Wapello	d	32331	894	470	70	245	7.0	280,800	87	6.9
Boone River @ Goldfield	b	1088	911	483	87	208	10.7	17,182	158	10.2
Boone River @ Webster City	d	2186	906	460	84	242	13.1	43,381	198	13.0
Des Moines River @ Stratford	a	14351	861	366	81	126	9.1	157,694	113	10.6
Des Moines River @ Des Moines	d	16175	790	324	78	360	10.0	151,454	94	10.5
Des Moines River @ Keosauqua	a	36358	872	370	62	204	7.5	293,919	81	8.4
Squaw Creek @ Ames	b	508	790	524	79	210	8.6	6,317	124	9.2
Skunk River @ Augusta	a	11168	684	277	62	325	5.8	52,147	47	6.5
Cedar River @ Palo	d	16377	1000	596	75	262	8.8	239,450	146	8.4
Cedar River @ Conesville	a	20168	964	549	73	228	7.6	242,631	119	7.3
Maquoketa River @ Green Island	d	4841	914	401	58	233	9.2	42,496	88	7.9
Otter Creek @ Elgin	c	119	960	453	54	215	8.1	972	82	7.6
Turkey River @ Garber	d	4002	1010	566	57	278	10.3	59,353	148	8.5
Wapsipinicon River @ DeWitt	a	6050	937	529	72	285	7.2	61,984	102	6.9
Thompson Fork @ Davis City	a	1816	711	239	52	214	1.3	2,009	12	1.8
Nodaway River @ Clarinda	a	1974	814	365	55	236	4.2	9,722	49	4.8
Boyer River @ Logan	a	2202	801	432	72	187	9.1	21,728	99	9.4
Little Sioux River @ Turin	a	9132	892	414	79	152	7.1	62,062	70	9.2
Maple River @ Mapleton	a	1733	839	426	81	198	10.8	17,742	102	11.4
Floyd River @ James	a	2295	854	306	83	198	15.8	28,427	124	17.6
West Nishnabotna River @ Randolph	d	3434	843	459	77	247	8.5	39,647	115	8.7
East Nishnabotna River @ Riverton	a	2862	864	541	69	168	5.6	19,651	69	5.7
Mississippi River @ Clinton	d	221704	847	304		305	3.5	630,841	29	3.3
Mississippi River @ Fairport	c	257187	849	301		221	3.7	817,252	36	3.4
Clear Creek @ Homestead	c	21			74	220	9.4			
Slough Creek Wetland Inlet	b,c	13			86	203	12.5			
Slough Creek Wetland Outlet	b,c	16			85	179	9.1			
Beaver Creek @ Bassett	c	44			75	248	11.0			
Beaver Creek @ Colwell	c	18			85	206	12.5			
Otter Creek US @ West Union	c	39			76	232	12.3			
Otter Creek DS @ West Union	c	67			68	239	10.7			
Brockamp Creek @ Fort Atkinson	c	21			44	226	10.1			
Roberts Creek @ Elkader	c	300			71	214	10.9			
S. Chequest Creek @ Douds	c	80			20	64	0.5			
Rapid Creek US @ Solon	b,c	8			64	232	10.6			
Rapid Creek DS @ Solon	b,c	16			74	235	9.2			
Catfish Creek-S @ Dubuque	b,c	106			22	248	3.4			
Catfish Creek-N @ Dubuque	b,c	34			48	257	1.0			
Lime Creek @ Brandon	c	106			80	241	12.7			
Cedar Creek @ Batavia	b	642			75	216	4.1			
Miller Creek @ LaPorte City	b	60			85	217	11.5			
Walnut Creek US @ Prairie City	c	18			79	146	10.9			
Walnut Creek DS @ Prairie City	c	52			62	96	8.4			
Tipton Creek @ Hubbard	c	186			87	141	13.8			
W. Fork Crooked Creek @ Washington	b	241			75	116	8.8			
Beaver Creek @ Eldora	c	3			86	99	10.7			
Walnut Creek @ Kelley	c	3			82	96	8.4			
Des Moines River @ Boone	c	14499			78	146	9.5			
East Nishnabotna River @ Brayton	b	278			77	231	8.6			

notes

[1]Load Calculation, a; Demonstration Project, b; Research Project, c; USGS sensor, d.

[2]Days with NO_x measurements

Table 4. Nitrate data and site information for stream sensors in the Iowa Water Quality Information System (2016).

4. Spatial Differences in Nitrate Flux

Of the 60 sensor sites, 41 capture flow from only one Iowa landform. These landforms include the NWIP, DML, IS, PP, and SIDP. Sites capturing streamflow from the extensively-tile-drained DML had the highest yield of NO_x-N, 0.13 lbs/ac, excluding the NWIP which had only one sensor site. This is an average yield on days of sensor deployment (average of 297 days per flow-gauged site). Extrapolated to a 366-day year (2016), annual flux totaled 47 lbs/ac for the DML. If the NWIP landform is not considered, where only one sensor was deployed, the DML also had the highest average NO_x-N concentration (11.0 mg/L). The IS landform, which is also extensively tile-drained, had the second highest concentration and daily yield of NOx-N (10.7 mg/L and 0.10 lb/ac). Extrapolated to an entire year, the resulting yield is 37 lbs/ac The PP and SIDP, where constructed drainage is less common, had concentrations well below the DML and IS. At 0.05 lbs per acre per day, yield from the SIDP likewise was less than half that of the tile-drained landscapes to the north (DML and IS).

5. Statewide nitrate-N load calculation

Data from the 13 sensor sites covering 82.5 percent of Iowa's area that were used to estimate statewide NOx-N loading are shown in Table 5. In aggregate, the six streams draining directly to the Upper Mississippi River (Des Moines, Iowa, Wapsipinicon, Skunk, Turkey, and Maquoketa) had a NO_x-N yield of 28 lbs/acre. Extrapolating this to the entire area of Iowa draining to the Mississippi but not the Missouri (69 percent, 100,564 km^2), Iowa's load to the Upper Mississippi River was 315,923,985 kg (695,032,767 lbs) in 2016. The seven streams draining to the Missouri River (East and West Nishnabotna, Nodaway, Thompson Fork, Boyer, Floyd, and Little Sioux) had an aggregated yield of 32 lbs/acre. Extrapolating this to Iowa's area draining to the Missouri River (31 percent, 45,181 km^2), Iowa's NO_x-N load to the Mississippi Basin via the Missouri River was 161,303,912 kg (354,868,606 lbs), making the state's total 477,227,897 kg (1.05 billion lbs) in 2016.

Table 5. Sensor sites used for 2016 Iowa statewide NO_x-N Load Estimation

site	WS area (km^2)	Estimated 2016 NO_x-N Load (kg)	Estimated 2016 NO_x-N Yield (kg ha^{-1})
Mississippi River Tributaries			
Des Moines River @ Keosauqua	36358	115,465,171	31.8
Iowa River @ Wapello	32331	106,880,020	33.1
Wapsipinicon River @ DeWitt	6050	20,730,474	34.3
Skunk River @ Augusta	11168	19,744,404	17.7
Turkey River @ Garber	4002	19,148,795	47.9
Maquoketa River @ Green Island	4841	15,691,133	32.4
Missouri River Tributaries			
West Nishnabotna River @ Randolf	3434	13,653,234	39.8
Floyd River @ James	2295	12,884,728	56.1
Boyer River @ Logan	2202	8,787,262	39.9
East Nishnabotna River @ Riverton	2862	8,571,909	30.0
Nodaway River @ Clarinda	1974	3,436,339	17.4
Thompson Fork @ Davis City	1816	764,418	4.2
Little Sioux River @ Turin	9132	36,564,478	40.0

Nitrate-N loads (2016) for the Mississippi-Atchafalaya Basin (MARB), the Missouri River Basin (MoRB) and the Upper Mississippi River Basin (UMRB, i.e. areas upstream of Thebes, IL not draining to the Missouri River) were estimated to assess Iowa's proportionate contribution. The 2016 load for the UMRB was calculated by subtracting the load for the Missouri River Basin (MoRB) at Hermann, MO from the load for the Mississippi River at Thebes, IL. For the Mississippi River at Thebes, IL, average daily discharge was accompanied by approximately monthly grab samples of concentration (n=14). For each month, the average daily discharge and concentration were computed, multiplied together to determine the average daily load, multiplied by the number of days in each month to determine the monthly load, and then summed to estimate the annual load. For the Missouri River at Hermann, MO, average daily discharge measurements were available for all 2016 calendar days, while NO_x-N concentration data were available on 301 days. On days with no NO_x-N data, concentration was estimated using linear interpolation. Individual daily loads were calculated and totaled to estimate annual load. Concentration and discharge data were obtained from USGS (U.S. Geological Survey, Open-File Report 2007-1080, accessed March, 2017, https://toxics.usgs.gov/pubs/of-2007-1080/gulf_site.html.).

The 2016 load for the entire MARB included the individual contributions from the Mississippi River and Atchafalaya River basins (U.S. Geological Survey, Hypoxia in the Gulf of Mexico https://toxics.usgs.gov/pubs/of-2007-1080/gulf_site.html.). Approximately monthly grab samples of concentration were available (n=10), so the same calculation method was used as for the Mississippi River at Thebes, IL. For both basins, loads were computed using discharge and concentration data from different sites. The Mississippi River Basin load was calculated using discharge from Tarbert Landing, MS and concentration from St. Francisville, LA. The Atchafalaya River Basin load was calculated using discharge from Simmesport, LA and concentration from Melville, LA. The sum of the loads from each basin estimated the entire MARB load. These loads are shown in Table 6.When considering total loads calculated for Missouri River, Upper Mississippi River, and the entire Mississippi River basin, Iowa's share of the 2016 NO_x-N load was 72%, 47% and 41% respectively. These figures are higher than what has been reported previously in published research, and it is possible that real-time, continuous monitoring is more suited than grab sampling and water quality prediction models to capture the dynamic relationships between streamflow volume and nitrate concentrations. Figure 13 illustrates Iowa's contributions to 2016 nitrate loads in the Mississippi Basin.

Table 6. 2016 Loads of NOx-N in Mississippi Basin, and the portion originating from Iowa		
Site	Calculated 2016 NO_x-N Load (Mg)	Iowa Fraction
Missouri River at Hermann, MO	222,953	72.3%
Mississippi River at Thebes, IL	896,088	53.3%
Upper Mississippi River Basin	673,135	46.9%
Mississippi-Atchafalaya River Basin	1,156,161	41.3%

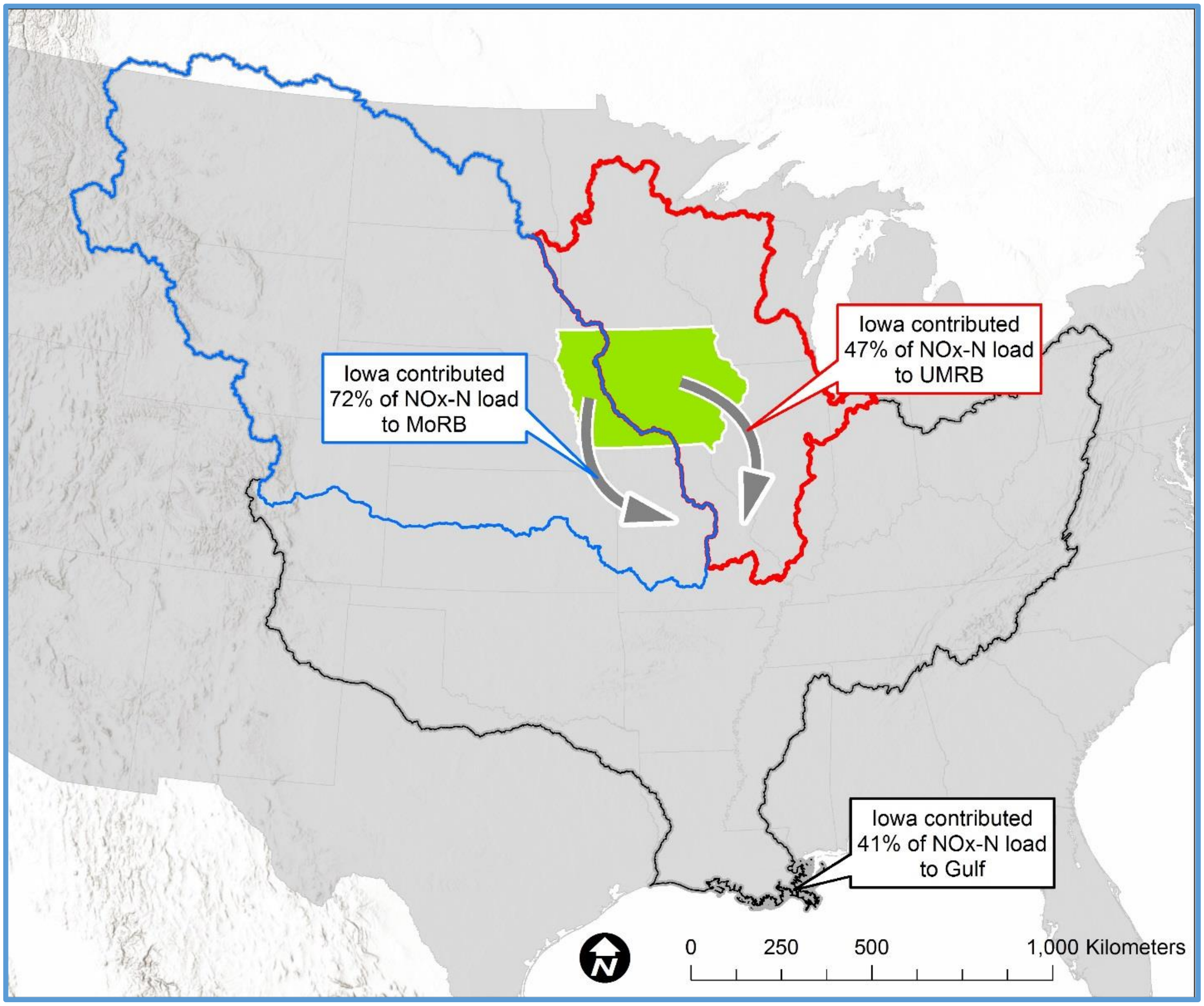


Figure 13: Iowa's contribution to total NOx-N loads in the Mississippi Basin in 2016.

VII. Monitoring Year 2017

In 2017, IIHR will deploy NO_x-N sensors on the Upper Iowa, Yellow, Rock, and Soldier Rivers to further expand coverage of the network for the purposes of statewide load estimation. Following deployment of these sensors, the network will capture water leaving greater than 90 percent of Iowa's land area. Sensors will also continue to be deployed to evaluate the effectiveness of practices designed to reduce NO_x-N loading to Iowa streams, such as wetlands, ponds, restored oxbows, and saturated buffers, and cover crops. This data will inform conservation efforts linked to the Iowa Nutrient Reduction Strategy. In addition, real-time ortho phosphorous sensors will also be deployed in 2017 to estimate flux of that pollutant from selected watersheds. Table 7 on the next page lists IIHR 2017 sites. Also listed in the table are USGS sites. IIHR sites fall into one of three basic categories: 1) strategic site for N load estimations related to the Iowa Nutrient Reduction Strategy (INRS); 2) monitoring for INRS Water Quality Initiative (WQI) projects; 3) IIHR Research Projects. In the table below, USGS and ARS sites are designated as category 4. Many of the USGS will be similar in purpose to the IIHR load estimation sites.

Site	Description	Type	Site	Description	Type
0001	Iowa River Iowa City	1	0043	Floyd River James	1
0002	Clear Creek Coralville	3	0044	Des Moines River Stratford*	1,3
0003	Clear Creek Oxford	3	0045	East Nishnabotna River Riverton	1
0005	English River Kalona	1,2,3	0046	Walnut Creek near Prairie City, IA (ARS)	4
0006	Iowa River Lone Tree	1	0047	Walnut Creek near Prairie City, IA (ARS)	4
0007	Cedar River Conesville	1	0048	Tipton Creek near Hubbard, IA (ARS)	4
0008	Slough Creek Wetland Outlet	3	0049	Chequest Creek near Douds, IA	2
0009	Otter Creek Elgin	3	0051	Beaver Creek near Eldora, IA (ARS)	4
0010	Skunk River Augusta	1	0052	Stormwater tile at Mc Loud Run at Cedar Rapids, IA	3
0011	Clear Creek Homestead	3	0053	Walnut Creek near Kelley, IA (ARS)	4
0012	Sough Creek Wetland Inlet	3	0054	ARS tile site (on Walnut Creek upstream of 53ARSWC3)	4
0013	Beaver Creek Bassett	3	0055	ARS tile site (on Tipton Creek near 48ARSTC)	4
0014	Beaver Creek Colwell	3	0056	ARS tile site (on Tipton Creek near 48ARSTC)	4
0016	Otter Creek West Union	3		Cedar Rapids Wastewater Treatment Plant	3
0020	Mississippi River Pool 16 Fairport	1,3		Rock River near Hawarden, IA	1
0021	Rapid Creek Iowa City	3		Yellow River at Ion, IA	1
0022	Rapid Creek tributary Iowa City	3		Soldier River near Pisgah, IA	1
0023	Wapsipinicon River De Witt	1		Gere Creek	2
0024	S. Fork Iowa River New Providence	1,3		Practice assessment-Pond (Grinnell) (2 sensors)	3
0025	S. Fork Catfish Creek Dubuque	3		Upper Iowa River at Dorchester, IA	1
0026	Middle Fork Catfish Creek Dubuque	3	USGS	North Raccoon River Sac City	4
0027	Lime Creek Brandon	3	USGS	North Raccoon River Jefferson	4
0030	Manchester Fish Hatchery Spring	3	USGS	South Raccoon River Redfield	4
0031	Big Spring Fish Hatchery Spring	3	USGS	Raccoon River Van Meter	4
0032	Middle Raccoon River Panora	1	USGS	Des Moines River Des Moines 2nd Ave.	4
0033	Des Moines River Keosauqua	1	USGS	Boone River Webster City	4
0034	Cedar Creek Batavia	2	USGS	Nodaway River Clarinda	4
0035	Miller Creek LaPorte City	2	USGS	Maquoketa River Green Island	4
0036	Thompson River Davis City	1	USGS	Turkey River Garber	4
0037	East Nishnabotna River Brayton	2	USGS	Iowa River Wapello	4
0038	Squaw Creek Ames	2	USGS	Cedar River Palo	4
0039	Boone River Goldfield	2	USGS	Mississippi River Comanche	4
0040	Boyer River Logan	1	USGS	West Nishnabotna at Randolph	4
0041	Little Sioux River Turin	1	USGS	W. Branch Little Sioux R. near Lake Park	4

Table 7: 2017 WQIS monitoring locations