Cedar River Tributary Study
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Introduction

Water quality remained a headline issue in Iowa during 2016. While much of the news continued to center on the Des Moines Water Works lawsuit against northwestern Iowa drainage districts, there were other developments as wekk. Governor Branstad proposed a funding mechanism for expansion of water quality efforts in the state, but could not get agreement in the legislature during the 2016 session. It appears that water quality and developing an ongoing funding mechanism for mitigation efforts will be a top issue in the 2017 legislative session. In the meantime, the Iowa Department of Agriculture and Land Stewardship continues to fund demonstration projects throughout the state, but implementation outside of these projects is lagging. While Iowa farmers planted about 64,000 more cover crop acres funded through state and federal incentives in the fall of 2015 compared to fall 2014, the total still represents only 1.2% of Iowa's corn and soybean acres.[1] Federal resources are also being put to use in implementing nutrient reduction around the state – the Middle Cedar Partnership Project[2] is in full swing as a collaboration between the city of Cedar Rapids and fifteen other organizations to address water quality problems in the Middle Cedar River watershed. Funded in part by USDA's Natural Resources Conservation Service (NRCS) through a Regional Conservation Partnership Program (RCPP) grant, the project is developing watershed plans, implementing BMPs, and carrying out outreach in targeted watersheds in the Middle Cedar. In addition, Iowa received a Disaster Resilience Grant[3] from the Department of Housing and Urban Development in 2016 which includes implementation of the "Iowa Watershed Approach", which includes "construction of farm ponds, wetlands, and storm water detention basins; restoration of floodplains and oxbows; and implementation of perennial cover and buffer strips" in targeted watersheds.

The assessment of how effective these efforts have been also remains challenging. A report[4] from the Iowa DNR (in conjunction with IDALS, ISU, and IIHR Hydroscience and Engineering) begins by listing the "challenges inherent in collecting and using water quality data":

1. the impact that legacy nutrients and lag time have on documenting water quality changes;
2. the importance of having comprehensive data on nutrient reduction practices implementation;
3. the effect of variable precipitation and steam flow and the impact that climate change could have on determining water quality trends; and,
4. the value of long-term monitoring to measure progress and the importance of properly situated and maintained monitoring locations.

Despite the acknowledgement of the needs, lack of funding makes it difficult to address these points. A recent analysis points out that "the number of stream discharge measurement sites and sediment concentration measurements have been reduced despite an expanded need for them. Monitoring for particulate and especially dissolved phosphorus is a major gap in the Iowa's monitoring efforts…In the fiscal year beginning July 2016 alone, 16 continuous stream discharge sites were discontinued from the cost-share program between IDNR and the U.S. Geological Survey."[5] The recent "Ambient Water

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[1] Data from NRCS (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ia/newsroom/releases/?cid= NRCSEPRD1258613) and NASS (https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php? state=IOWA)

[2] More information at http://www.cedar-rapids.org/residents/utilities/middle_cedar_partnership_project.php.

[3] Press release at http://www.iowaeconomicdevelopment.com/Community/NDR

[4] "Stream Water-Quality Monitoring Conducted in Support of the Iowa Nutrient Reduction Strategy", prepared by the Iowa Department of Natural Resources in collaboration with the Iowa Department of Agriculture and Land Stewardship, Iowa State University and the IIHR Hydroscience and Engineering Center, August 2016. (Accessed at http://www.nutrientstrategy.iastate .edu/sites/default/files/documents/Water%20Monitoring%20and%20the%20NRS%20_%20Final%208-24-16.pdf.)

[5] Sara Conrad, David Osterberg, Michael Burkhart "Water Quality in Iowa and the Mississippi River Basin", November 2016, Iowa Policy Project. (Accessed at http://www.iowapolicyproject.org/2016docs/161117-water.pdf.)

Monitoring Strategy for Iowa: 2016-2021[6]" indicates that "…the ambient program is not designed to monitor nutrient loads in small watersheds (e.g., HUC12 scale) where reductions are first likely to be observed following the implementation of nutrient management practices and technologies. Any significant redirection of currently-available ambient monitoring resources into monitoring of implementation effectiveness in small watersheds would severely hinder the ambient program's ability to achieve its objectives, and therefore is not recommended." In essence, the type of demonstration projects funded by IDALS are at a scale too small for effects to be picked up by the current IDNR monitoring network. Some of this gap is being filled by IIHR-Hydroscience and Engineering's expansion of its network of real-time water quality sensors. This data is easily accessible through the Iowa Water Quality Information System (IWQIS).[7]

Water quality will remain an issue in the state for the forseeable future, and assessing the success of efforts to improve the quality of our streams and rivers will require sustained monitoring to judge their effects. The monitoring carried out for the past fifteen years by students at Coe has provided the type of long-term baseline data in small (HUC 10 and 12) watersheds which can help assess the impact of BMPs, land use changes, and climate effects. Data collected over this time period, as well as more intensive monitoring carried out in 2013 and 2014, was key to the development of the Indian Creek Watershed Management Authority's management plan.[8] When the Iowa Soybean Association developed a watershed plan for Lime Creek[9], the watershed coordinator who prepared the report commented that Lime Creek had more monitoring data than any watershed in the state. The field level data collected in Lime Creek through monitoring tile line effluent enables farmers to assess their own practices – and their neighbors' practices – on an ongoing basis.

The following report presents highlights from measurements carried out in calendar year 2016 by the Coe Water Quality Laboratory (as well as the data itself). It addresses a number of the issues mentioned above – in addition to collecting data on nitrate over an extended period of time, data on dissolved reactive phosphorus in tile drainage and in surface water is addressed, and we are beginning to collect more flow data in order to better assess nutrient loading.

Methods

Sampling Sites

The same seven Cedar River tributary sampling sites near the mouths of Otter Creek, Lime Creek, Mud Creek, Morgan Creek, Blue Creek, Bear Creek, and North Bear Creek have been monitored for the past fifteen years, and were sampled on a weekly basis from May through August 2016. Additional sites in the Lime Creek watershed, including tile sampling sites, were sampled on a weekly basis to support the work of the Lime Creek Watershed Improvement Association. Sampling occurred at seven sites (five surface water and two tile sites) in the Indian Creek watershed from May to August as well as on McLoud Run. Flow measurements were made on four streams in the Mid Cedar project (Wolf, Rock, Pratt, and Miller) as well as in Lime Creek. Sample locations for the surface water sites are given in Appendix 1.

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[6]The complete plan is available at http://publications.iowa.gov/23083/1/2016%20Ambient%20Water%20Monitoring%20Strategy_Final.pdf.
[7] See IWQIS at http://iwqis.iowawis.org/.
[8] For the complete plan, see http://indiancreekwatershed.weebly.com/the-plan.html.
[9] For the complete plan, see http://www.iasoybeans.com/pdfs/EPS16_LimeCreekWatershedPlan.pdf.

Field Measurements

Dissolved oxygen, water temperature, pH, conductivity, and turbidity were measured on-site for most surface-water samples collected. Dissolved oxygen, water temperature, pH, and conductivity were measured with either a YSI 556 MPS or a YSI Professional Plus multi-parameter system. Turbidity was determined using a Hach 2100Q or 2100 P Turbidimeter. Field instruments were calibrated on a regular basis. Dissolved oxygen values are reported in mg O_2/L, turbidity is reported in NTU, and conductivity is reported in μS/cm.

Surface water samples were collected by direct grab sampling in containers with Teflon lined lids from public right-of-ways or by bucket from bridges. Samples from tile boxes were collected either by grab sampling (with an extension pole) or by using a Global Water SP100 portable pump. Samples to be analyzed for nitrate, chloride, sulfate, and TSS were collected in 500 mL polyethylene bottles. Samples to be analyzed for dissolved reactive phosphorus (DRP) were filtered in the field through a 0.45 μm nylon syringe tip filter into a 60 mL acid-washed brown glass bottle. Samples for *E. coli* determination were collected by grab sampling in sterile Whirl-Paks. Field blanks and duplicates were collected on each sampling trip. All samples were immediately stored in a cooler at 4°C until they could be transported back to the laboratory and refrigerated. Samples were typically analyzed within 24 hours of sampling.

Stage measurements were made near the mouth of the Miller Creek, Rock Creek, and Pratt Creek watersheds using Solinst Leveloggers, which were corrected for fluctuations in barometric pressure using a Solinst Barologger. (Stage measurements for Wolf Creek and for all of the Cedar River tributary sites are available through the Iowa Flood Information System (IFIS).) Level measurements were also made in the tile boxes installed in Lime Creek using Hobo Water Level Dataloggers from Onset, which were also corrected for barometric pressure fluctuations. The tile boxes also had weirs – fabricated by the tile box manufacturer – installed.

Flow measurements were made on several of the sites using either a Sontek FlowTracker2 Acoustic Doppler Velocimeter (for wadable stream flow measurements) or a Teledyne RDI Stream Pro - Acoustic Doppler Profile Velocimeter (for higher flows).

Laboratory Measurements

In the laboratory, nitrate, sulfate, and chloride were measured using a Dionex ICS-1000 ion chromatograph equipped with an AS-14A 5μm ion exchange column, an AS-14A guard column, an AMMS-III 2mm suppressor, and Na_2CO_3/NaHCO3 eluant.[10] A Dionex autosampler (AS40) was utilized with autosampler vials fitted with 20 μm filter caps. Nitrate is reported as mg/L of NO_3^--N, sulfate is reported as mg of SO_4^{-2}/L, and chloride as mg of Cl^-/L. Dissolved reactive orthophosphate (DRP) was analyzed using a Lachat QuikChem 8500 Series 2 flow injection analyzer running Lachat method 10-115-01-1-P.[11] All glassware used in sampling and analysis of DRP was acid washed in 1 M hydrochloric acid. Phosphate values are reported as mg PO_4^{3-}/L. Total suspended solids were measured using standard

[10] American Public Health Association (APHA). 2005. Standard Methods of Water and Wastewater. 20th ed. American Public Health Association, American Water Works Association, Water Environment Federation publication. APHA, Washington D.C. Method 4110B (ion chromatography)

[11] Equivalent to Method 4500-P G. in American Public Health Association (APHA). 2005. Standard Methods of Water and Wastewater. 20th ed. American Public Health Association, American Water Works Association, Water Environment Federation publication. APHA, Washington D.C.

gravimetric techniques, and reported as mg solid/liter.[12] *E. coli* counts were determined using the IDEXX Colilert/Quanti-Tray 2000 most probable number technique.[13] Results are reported as colony forming units (CFU/100 mL). Samples are typically diluted by 10X with sterile water to extend the countable range. Instrument blanks and reagent blanks were run daily, and did not indicate significant levels of contamination. Field blanks and site duplicates were collected and analyzed regularly. Three to five standards were run daily for each analysis. If data is reported as NA, the sample was not analyzed; if reported as BDL, no analyte was detected.

Quality Control and Quality Assurance

Data collected was recorded immediately on waterproof field data forms or on instrumental data forms. (These forms were then placed in binders and archived.) Individuals who collected the data or carried out the analysis were responsible for data reduction and for entering the data into a Microsoft Access database housed on a desktop computer in the laboratory. The Access database was backed up regularly on Coe's server.

Results

Cedar River Tributaries

These streams are the core of our monitoring program, as we have been continuously sampling and measuring their water quality properties since 2000. In general, they are small (12,000 to 60,000 acres) and agricultural (~60-80% row crop). As can be seen in Table 1, samples from near where these streams enter the Cedar exhibit water quality values typical of Iowa streams. (These samples were all collected on the same day each week.)

Most parameters are relatively tightly clustered, though Morgan typically has a lower pH, higher chloride concentration, and higher sulfate concentration than the other streams. Morgan and Mud exhibit higher conductivity levels than the other streams. Dissolved reactive phosphorus (DRP) is consistently higher in Mud; though often associated with higher transport of sediment into the stream, turbidity and total suspended solids are mid-range for Mud.

Nitrate-N concentrations for this group of streams is shown in Figure 1. In past years, a spring pulse peaking in June and then declining is more evident in all of the streams. With the exception of Lime and North Bear, the streams remained relatively constant throughout the measurement period until early July, when concentrations begin to drop off. Lime Creek and North Bear Creek consistently exhibit the highest concentrations of nitrate, with Mud generally being the next highest in nitrate level. Those three watersheds are also the three highest in % row-crop, consistent with previous research findings.[14] Similarly, Blue and Otter, with the lowest % row-crop acreage, generally have the lowest concentrations of nitrate both early and late in the season.

[12] American Public Health Association (APHA). 2005. Standard Methods of Water and Wastewater. 20th ed. American Public Health Association, American Water Works Association, Water Environment Federation publication. APHA, Washington D.C. Method 2540D.

[13] IDEXX procedure available at http://www.idexx.com/.

[14] a. Row crop % determined in 2002 by Iowa DNR.

b. KE Schilling, and RD Libra, Relationship of Nitrate Concentrations in Streams to Row Crop Land Use in Iowa: Journal of Environmental Quality [J. Environ. Qual.], vol. 29, no. 6, pp. 1846-1851, Dec 2000.

Table 1. Means, medians, and standard deviations for May-August 2016 measurements

Site		DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO_3-N	SO_4	*E coli*
Bear	mean	8.94	19.0	7.94	483	15.7	20.9	0.17	18.8	9.3	19.1	917
	median	8.72	20.1	7.92	494	11.8	15.0	0.17	19.2	9.5	19.2	795
	SD	*1.17*	*3.3*	*0.21*	*46*	*10.9*	*14.9*	*0.07*	*1.8*	*2.0*	*2.1*	*519*
Blue	mean	9.32	19.5	7.91	452	18.6	18.8	0.14	22.6	7.7	19.2	1204
	median	9.07	20.7	7.91	428	9.0	9.0	0.13	22.4	8.0	19.4	650
	SD	*1.46*	*2.9*	*0.21*	*439*	*34.3*	*33.0*	*0.07*	*2.1*	*2.3*	*2.8*	*2329*
Lime	mean	10.15	19.4	8.00	474	12.6	14.5	0.16	20.4	14.8	15.0	760
	median	10.03	20.3	8.13	476	6.0	6.9	0.15	20.1	14.7	15.6	633
	SD	*2.26*	*3.5*	*0.25*	*63*	*21.3*	*18.2*	*0.10*	*3.3*	*4.2*	*3.1*	*549*
Morgan	mean	8.82	16.7	7.75	539	16.5	19.4	0.14	29.7	9.3	27.9	1879
	median	8.83	18.5	7.73	547	12.3	15.4	0.14	29.5	9.2	26.6	717
	SD	*1.26*	*3.2*	*0.19*	*53*	*12.1*	*17.1*	*0.05*	*2.2*	*2.1*	*4.1*	*3553*
Mud	mean	9.73	18.0	7.96	541	12.8	15.2	0.24	19.2	11.7	25.7	925
	median	9.65	18.6	7.97	547	9.9	10.0	0.24	20.1	11.9	26.0	959
	SD	*1.44*	*2.9*	*0.19*	*49*	*8.4*	*10.1*	*0.06*	*1.9*	*1.2*	*2.6*	*664*
N. Bear	mean	9.34	19.4	8.00	453	20.0	17.9	0.15	20.0	14.6	18.1	1156
	median	9.14	20.0	8.09	457	6.0	8.3	0.12	20.1	14.1	18.6	805
	SD	*1.72*	*3.1*	*0.26*	*70*	*41.5*	*27.6*	*0.12*	*3.5*	*3.4*	*3.4*	*1484*
Otter	mean	8.60	19.0	7.93	471	12.6	15.7	0.26	24.6	8.0	17.4	1193
	median	8.51	20.6	7.89	477	6.2	7.2	0.17	24.9	8.1	17.7	855
	SD	*1.29*	*3.3*	*0.15*	*38*	*17.8*	*19.5*	*0.35*	*1.5*	*1.9*	*1.9*	*1251*

Figure 2 illustrates the long term trends in average nitrate-N concentrations for these streams. (In each year, data from May to August was averaged to obtain these numbers.) The large decline in concentration in 2012 coincides with the drought that year, which meant that nitrate stayed in the soils rather than being transported to streams by rainfall. If the data from 2012 is excluded from consideration, then the overall slope (mean concentration vs. time) for all streams is +0.09; with 2012 included, it is +0.03. With 2012 data excluded, North Bear has a slope of +0.19 and Lime has a slope of +0.10. Mud's slope with 2012 excluded is +0.03; with 2012 data included, Mud's slope is -0.03 (the only negative slope of any watershed, with or without the 2012 data). As mentioned above, there is an issue of lag time in measuring a clear signal in stream nutrient concentrations in response to changing practices in the landscape. As yet, however, it is difficult to see signs of decreasing nutrient levels in our surface waters as a result of efforts underway in the state to lower them.

Figure 1. Nitrate-N concentrations during May-August 2016

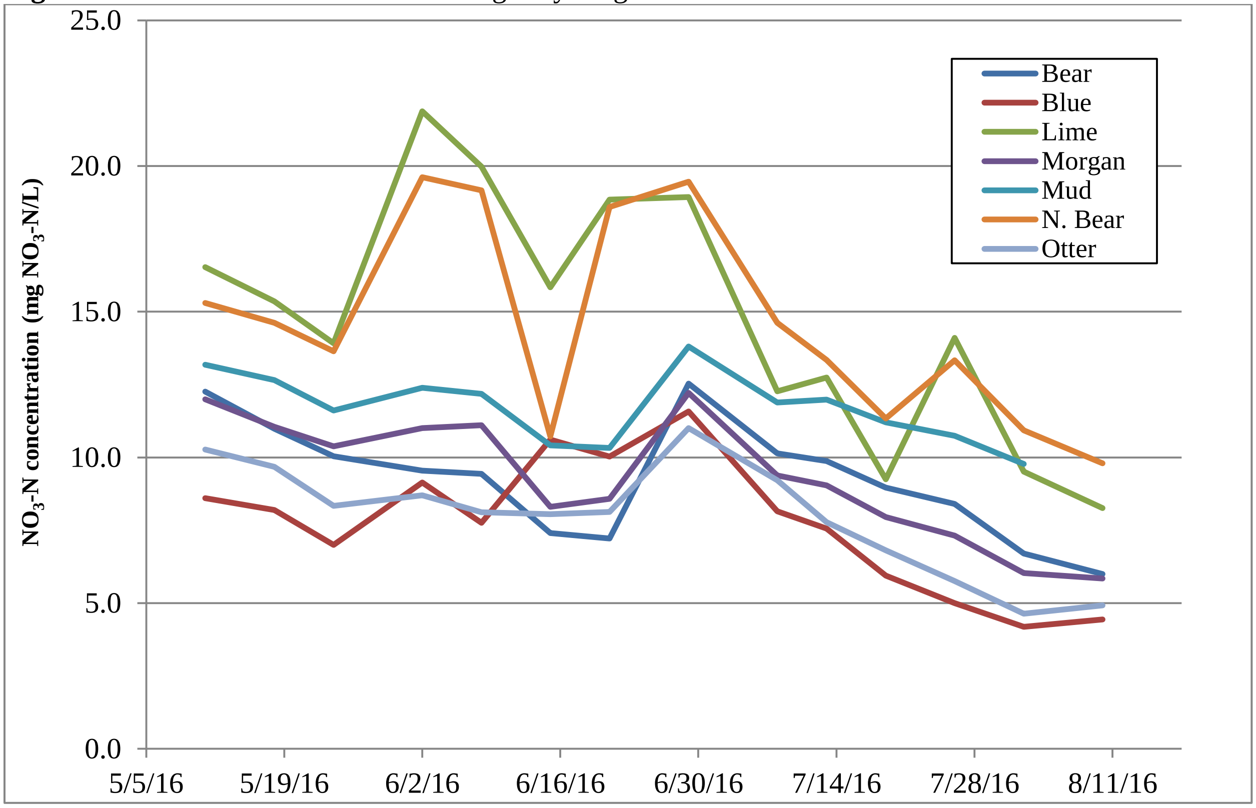
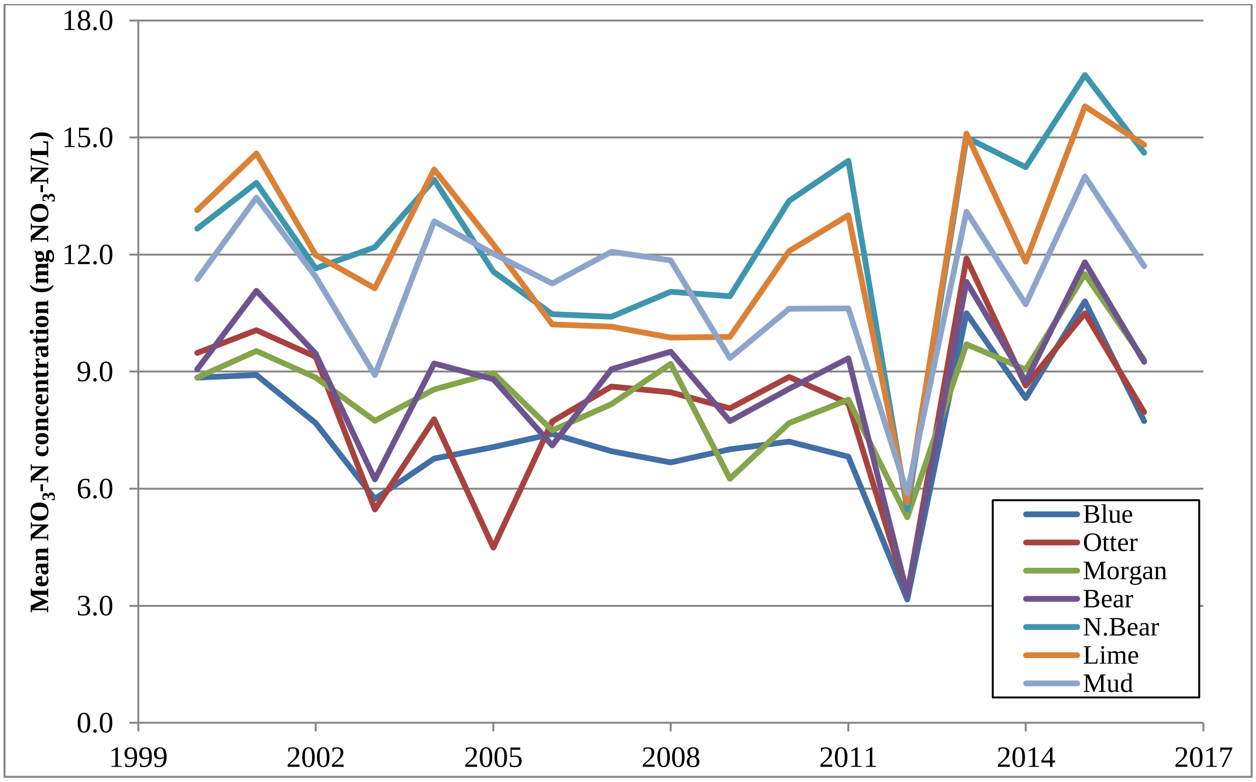


Figure 2. Mean nitrate-N concentrations (May-August) from 2000-2016.



Indian Creek/McLoud Run

Indian Creek is an interesting watershed, as it has significant agricultural land use as well as an increasing level of residential development. As a result, Indian Creek experiences significant nutrient inputs from row crop agriculture and (limited) animal agriculture, but is also subject to problems related to increasing amounts of non-permeable development associated with urban and suburban land uses. Between 1992 and 2013, the percentage of the watershed in row crop dropped from 62% to 53%; correspondingly in the same time period, the percentage of the watershed classified as "urban/developed" went from 16% to 29%.[15]

Monitoring in 2016 occurred at five sites in the watershed. The Artesian site is just south of the Cedar Rapids-Linn County Solid Waste Agency Landfill, while Linn Mar is located at Linn Mar High School, downstream of the Artesian site. The area upstream of these two sites is primarily rural, so measurements at these sites primarily reflect agricultural land use. Dry Creek at Donnelly Park samples Dry Creek right before it joins Indian Creek. While the Dry Creek watershed is also primarily rural, there are also significant ground water inputs which result in lower nutrient concentrations than Indian Creek. The site at Thomas Park includes the input from Dry Creek. Finally, Indian Creek South (ICS) is sampled at Mt. Vernon Road, before Indian Creek empties into the Cedar River.

Table 2. Means, medians, and standard deviations for May-August 2016 measurements of Indian Creek

Site		DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO_3-N	SO_4	*E coli*
Artesian	mean	8.55	19.2	7.87	480.8	36.9	38.0	0.16	29.4	9.6	19.5	5022
	median	8.17	20.3	7.91	486.1	11.1	9.7	0.12	30.9	10.6	20.1	882
	SD	*1.65*	*3.8*	*0.19*	*116.4*	*94.6*	*102.7*	*0.18*	*6.8*	*3.2*	*5.1*	*12186*
Linn Mar	mean	8.63	19.4	7.88	501.7	27.6	31.3	0.23	30.2	9.3	20.5	10917
	median	8.16	20.5	7.92	506.2	10.7	13.4	0.17	30.8	10.1	21.1	873
	SD	*1.77*	*3.5*	*0.18*	*77.3*	*60.9*	*70.9*	*0.25*	*5.0*	*3.0*	*4.2*	*31851*
DryDonn	mean	8.35	17.5	7.79	525.1	38.1	28.8	0.22	32.2	4.6	28.4	1414
	median	8.04	16.3	7.84	565.7	5.3	6.3	0.17	34.5	4.0	30.5	617
	SD	*1.33*	*3.3*	*0.15*	*122.7*	*103.6*	*70.3*	*0.14*	*8.5*	*2.6*	*9.2*	*2080*
Thomas	mean	9.08	19.2	7.78	490.1	32.3	29.0	0.23	32.5	6.9	24.3	9756
	median	8.86	19.9	7.88	510.3	9.0	11.1	0.17	34.2	7.4	24.1	621
	SD	*1.50*	*3.4*	*0.31*	*89.6*	*72.9*	*55.4*	*0.20*	*6.8*	*2.4*	*5.6*	*32050*
ICS	mean	8.98	20.9	7.83	466.0	84.3	39.7	0.20	35.1	4.8	23.3	2766
	median	8.54	21.9	7.97	539.5	10.8	7.5	0.21	37.0	4.8	24.0	328
	SD	*1.74*	*3.7*	*0.38*	*178.6*	*183.1*	*102.3*	*0.12*	*10.0*	*2.4*	*6.1*	*7159*

As can be seen from the data in Table 2, Dry Creek adds cooler water to Indian Creek, with lower nitrate and higher sulfate concentrations. Median values of turbidty and total suspended solids are also somewhat lower than the main stem of Indian Creek. Using median DRP concentrations, there is an increase in phosphorus concentrations moving down the watershed, which does not correspond to either turbidity or total suspended solid trends. Median *E. coli* levels indicate a decrease moving from

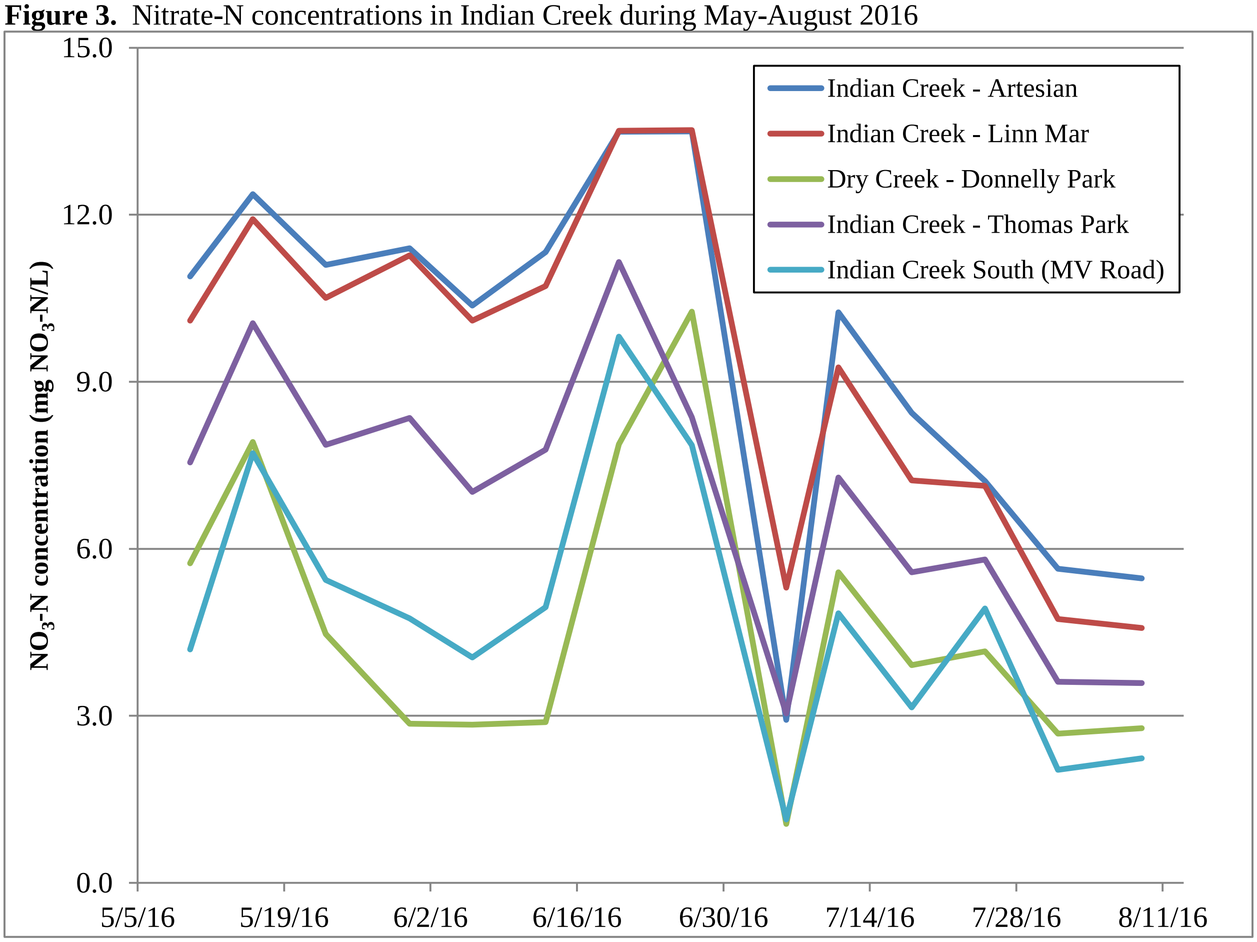
[15] Indian Creek Watershed Management Plan, Indian Creek WMA, June 2015. Available at http://indiancreekwatershed.weebly.com/the-plan.html.

upstream to downstream. 86% of samples taken exceeded the Iowa *E. coli* standard for children's recreation of 235 cfu/100 mL. A snapshot sampling of more sites under low flow conditions on August 9 showed the highest *E. coli* counts in areas of Indian Creek with surrounding pasture (and, in some cases, where cattle were directly observed in the stream).

Figure 3 illustrates nitrate-N concentrations over the summer at the monitored sites. As has been observed in the past, nitrate-N concentrations typically decrease moving down the main stem of Indian Creek. The influence of Dry Creek is apparent; however, the concentrations continue to decrease between Thomas Park and Mt. Vernon Road – reflecting either processing, uptake, or additional dilution from groundwater sources. The large increase in nitrate-N concentration observed in mid-June is the product of a large rain event (>4 inches during the day at the Cedar Rapids airport) following a relatively dry period.

Samples from two drainage tiles in adjacent fields was analyzed in the Indian Creek watershed. The farmer is planning to implement conservation practices and this data serves to establish a baseline. Nitrate and DRP values in these tile lines are already relatively low relative to other tile lines sampled.

Figure 3. Nitrate-N concentrations in Indian Creek during May-August 2016



McLoud Run (sampled at J Avenue) is an entirely urban watershed which is fed by groundwater as well as by urban run-off. The groundwater contribution is evident in the low temperatures, high conductivities, and high chloride levels. Nitrate concentrations are relatively low, though dissolved reactive phosphorus levels are comparable to agricultural sites. None of the *E. coli* samples taken from McLoud Run were less than the state level for children's recreational use.

Table 3. Means, medians, and standard deviations for May-August 2016 measurements of McLoud Run

Site		DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO_3-N	SO_4	*E coli*
McLoud	mean	9.06	15.2	7.57	678.7	9.1	7.9	0.11	74.2	3.1	38.5	1871
	median	8.97	15.1	7.56	721.5	3.8	4.2	0.12	77.1	3.5	41.7	760
	SD	1.11	2.5	0.20	122.8	17.5	14.5	0.05	15.2	0.9	6.9	4160

<u>Lime</u>

As noted above, Lime Creek was one of the original Cedar River tributaries monitored for the past sixteen years. The Lime Creek Watershed Improvement Association, a group of farmers in the watershed, has undertaken a concerted program to implement best management practices and has received a number of grants to undertake these efforts. We have increased monitoring in the watershed to provide feedback for this group. Sampling at 240th and 250th Streets brackets the Crumbacher Wildlife Area, a 368 acre natural area which is bisected by Lime Creek. 290th Street is farther down the stream, slightly downstream from an unnamed tributary enters Lime. The tributary is sampled on Hamline Avenue. Farther downstream is the Finley Avenue sampling site, upstream of the Brandon wastewater treatment facility. The Lime site (on Benton-Buchanan Road) is near where Lime empties in the Cedar (and is also the site of an Iowa Water Quality Information System *in-situ* nitrate monitor.)

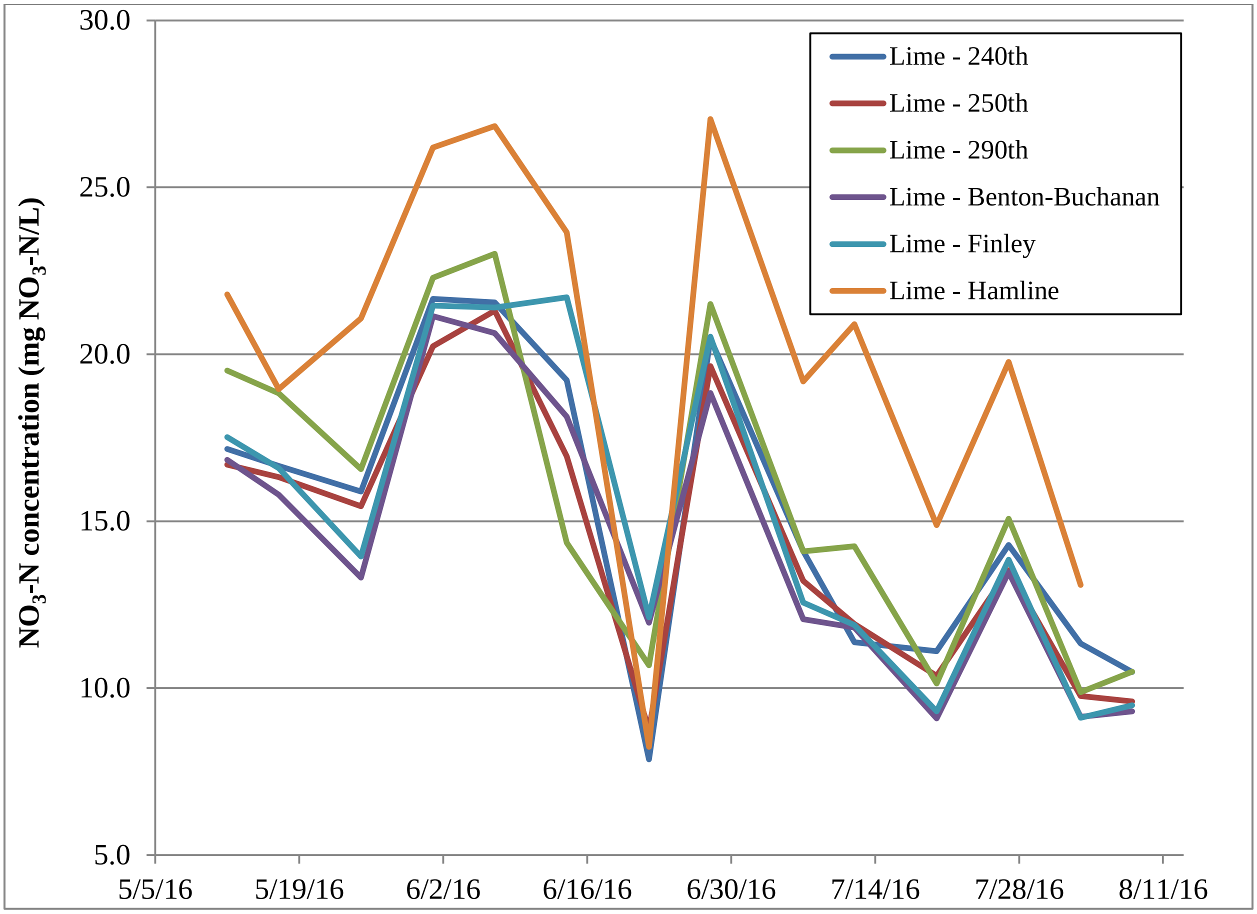
Table 4. Means, medians, and standard deviations for May-August 2016 measurements of Lime Creek

Site		DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO_3-N	SO_4	*E coli*
240th	mean	8.52	16.9	7.53	532	11.8	20.2	0.18	23.8	15.2	14.7	1802
	median	7.78	18.2	7.51	456	7.4	8.9	0.11	23.3	15.1	14.8	547
	SD	*2.10*	*3.1*	*0.22*	*195*	*15.9*	*27.6*	*0.21*	*4.4*	*4.4*	*3.5*	*3739*
250th	mean	8.75	16.3	7.63	535	14.5	21.4	0.17	21.0	14.6	13.9	1785
	median	7.95	18.1	7.65	456	10.8	11.0	0.13	20.5	14.5	14.3	700
	SD	*3.37*	*5.7*	*0.24*	*188*	*15.0*	*33.5*	*0.13*	*3.3*	*4.2*	*3.1*	*3167*
Hamline	mean	8.86	17.2	7.61	626	21.4	20.0	0.17	19.5	19.6	15.9	810
	median	8.25	18.1	7.65	503	5.3	4.9	0.11	19.5	20.3	15.6	617
	SD	*2.10*	*3.4*	*0.22*	*251*	*53.2*	*40.0*	*0.23*	*4.6*	*5.6*	*6.0*	*814*
290th	mean	8.72	18.7	7.72	530	31.7	30.5	0.20	19.0	15.8	14.5	2590
	median	7.86	19.6	7.76	472	7.3	8.4	0.12	19.1	14.7	14.6	1460
	SD	*2.15*	*3.8*	*0.24*	*196*	*65.2*	*58.4*	*0.21*	*4.5*	*4.6*	*4.4*	*2981*
Finley	mean	8.91	18.0	7.62	558	17.4	14.7	0.17	20.7	15.1	14.8	3491
	median	8.38	18.9	7.62	476	8.5	9.8	0.12	20.2	13.9	15.2	2214
	SD	*1.83*	*3.3*	*0.27*	*221*	*24.0*	*16.8*	*0.14*	*2.9*	*4.7*	*2.9*	*4890*
Lime*	mean	9.61	18.9	7.88	538	15.7	17.9	0.18	20.3	14.6	14.7	2160
	median	8.74	19.9	7.83	480	6.1	7.0	0.14	20.0	14.0	15.2	980
	SD	*2.12*	*3.3*	*0.24*	*171*	*23.6*	*24.7*	*0.13*	*3.1*	*4.1*	*3.0*	*5206*

*site was sampled twice per week; all data included

Most of the measurements fall well within the range of values observed in other rural Iowa watersheds. The nitrate values generally decrease coming down the watershed (as shown in Figure 4), with the exception of the tributary sampled at Hamline Avenue. This small tributary consistently has higher nitrate concentrations, which results in the mainstem Lime sample at 290th Street being elevated relative to 250th. Dissolved reactive phosphorus concentrations are generally constant moving down through the watershed.

Figure 4. Nitrate-N concentrations in Lime Creek during May-August 2016



Lime tiles

The Lime Creek Watershed Improvement Association received a grant in 2013 to install tile boxes on drainage tile lines draining individual fields. These boxes allow the drainage tile to be sampled under a variety of conditions, as well as enabling flow measurements. This access to field scale drainage allows comparison of a variety of actual farm practices with respect to loss of nutrients.

Figures 4 and 5 illustrate the concentrations found in the drainage from these fields. (For each plot, the box represents the 25th to 75th percentiles with the median as the middle line. The maximums and minimums are displayed at the ends of the whiskers. Both (a) and (b) are divided by crop cover for the 2016 growing season, represented by the line between Tiles 11 and 6.) In addition, farmers were surveyed to determine their practices to be able to correlate the nutrient concentrations with practices. These are summarized in Table 5. Clearly, the fields planted in cover crops did have among the lowest nitrate concentrations observed. Interestingly, they also showed high levels of dissolved reactive phosphorus.

There are some reports in the literature suggesting that no-till farming results in macropores which allow DRP to more effectively reach tile drainage.[16]

Flow measurements

During 2016, the Coe Water Quality Lab obtained two pieces of instrumentation which enable us to make accurate flow measurements under a variety of conditions. Both instruments use acoustic Doppler velocimetry to measure stream velocity. From the Teledyne RDI website[17]:

> "An ADCP transmits sound bursts into the water column. Suspended particles carried by water currents produce echoes (from these sound bursts) which are "heard" by the ADCP. Echoes arriving later, from deeper in the water column, are assigned greater depths in the echo record. This allows the ADCP to form vertical profiles of current velocity. The ADCP senses in four directions simultaneously. Particles within the current flow moving towards the instrument exhibit different frequencies from those moving away. This is the famous Doppler shift, which enables precise measurement of current speed and direction."

The Sontek FlowTracker2 is used with a wading rod and is designed for use in a wadable stream. The Teledyne RDI Stream Pro is a towable instrument (from a bridge) which may be used in a stream with water levels too deep for wading. The Sontek unit was obtained early in the summer and was used relatively frequently. The Stream Pro was received in mid-July and, after familiarization, was only used a handful of times at the end of the summer. Nevertheless, together they will enable us to make more extensive flow measurements in future summers.

At Miller Creek (and at Pratt and Rock Creeks), a pressure tranducer was secured to a fence post in the stream to measure stage (water level). These small devices log the pressure in the stream, which can then (after correction for atmospheric pressure) be converted to depth of water in the stream. These devices were set to log the pressure at 15 minute intervals. Flow measurements were made at various times throughout the summer – at Miller Creek, flow was measured five times between June 27 and July 25. Flow measurement is a relatively time intensive process involving measurement of velocity at 25-35 location across a transect in the stream. The measured flow is then plotted versus the stage (depth) of the stream to develop a rating curve. Figure 5 illustrates this relationship for Miller Creek. As can be seen, the relationship is quite linear. However, at lower flows and particularly at higher flows, the rating curve will not be linear and must be established empirically.

The relationship between stage and flow can then be combined with the stage data to create a flow curve for the stream in question. As Figure 6 illustrates, it is critical to obtain flow data at high and low stages to accurately characterize flow for an entire season. The area between the red lines on the plot indicate the region for which the rating curve is valid. The numbers given on the right side of the plot reflect the number of stage data points above, between, and below the maximum and minimum stages measured for flow.

[16] Williams, M. R., K. W. King, W. Ford, A. R. Buda, and C. D. Kennedy (2016), Effect of tillage on macropore flow and phosphorus transport to tile drains, Water Resour. Res., 52, 2868–2882.

[17] See http://www.teledynemarine.com/streampro/?BrandID=16

Figure 5. Box and whisker plots of nitrate-N tile concentrations in Lime tile boxes

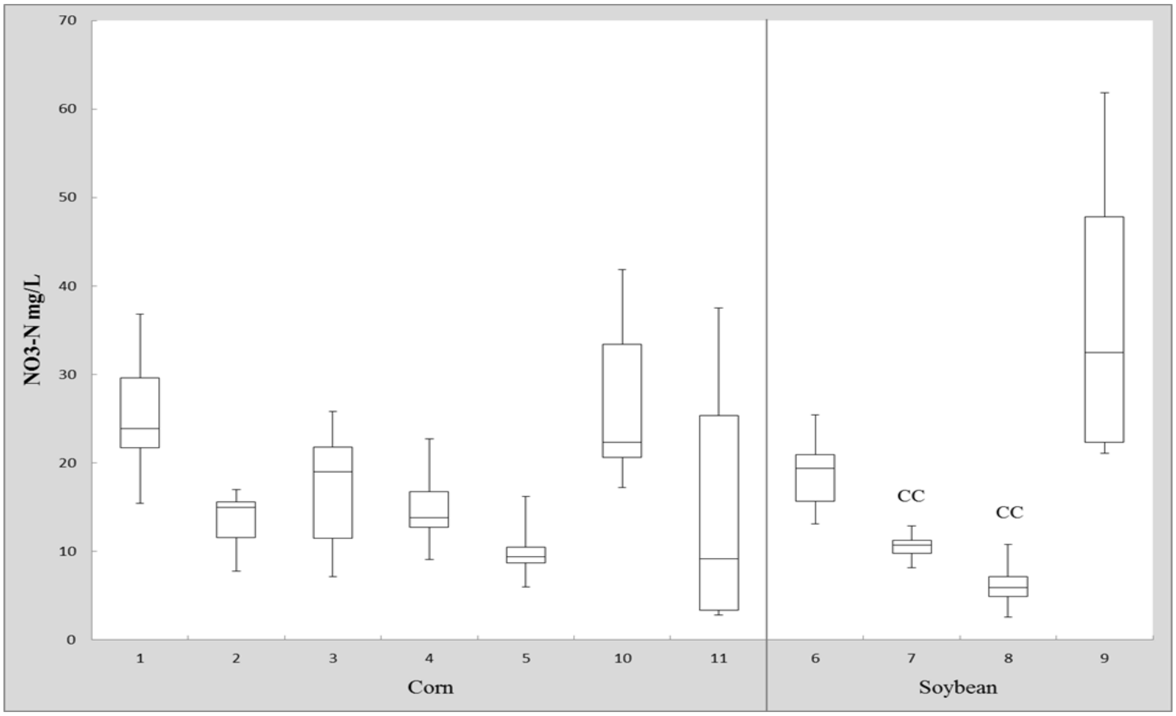


Figure 6. Box and whisker plots of dissolved reactive phosphorus tile concentrations in Lime tile boxes

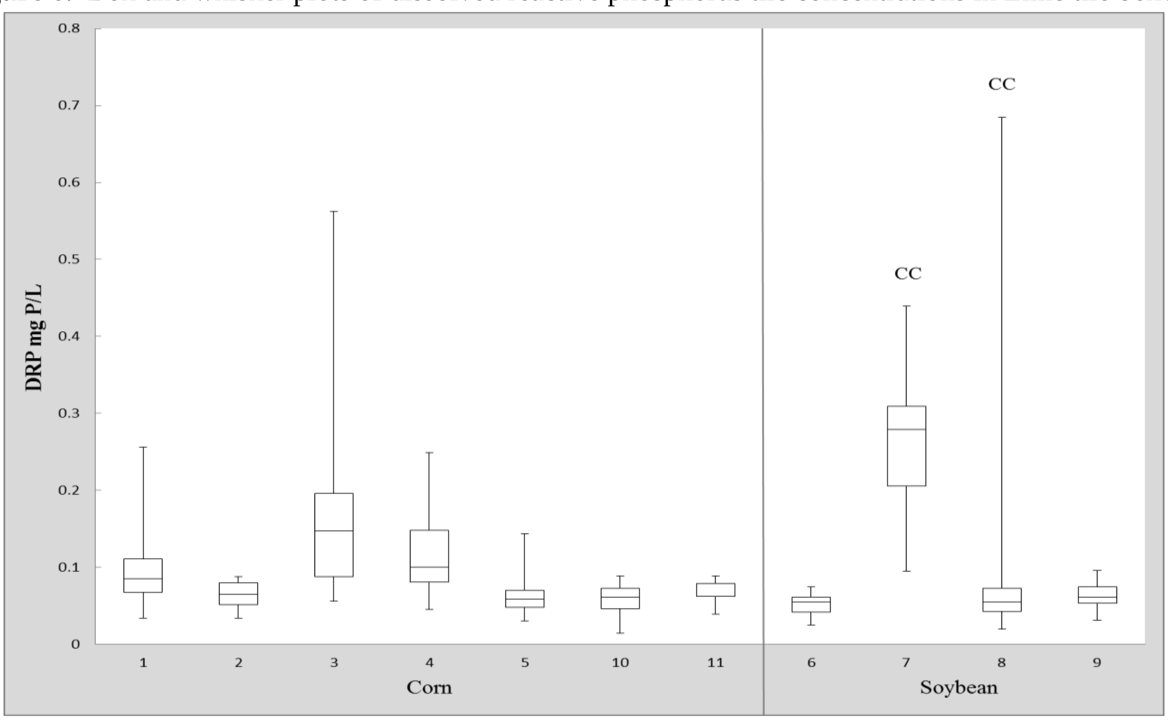


Table 5. Crop and management practices in fields drained by tiles sampled.

Tile	Rotation	Notes (as of 2015)	CC 2015	Crop 2015 (2015 survey data)	CC 2016	Crop 2016
1	2C-1S			corn		corn
2	2C-1S			corn		corn
3	3C-1S					corn
4	C-S			soybeans		corn
5	C-S			soybeans		corn
6	C-S			corn		soybean
7	C-S		wheat blend	corn	rye	soybean
8	2C-1S	2nd year corn	wheat blend	corn	rye	soybean
9	2C-1S	2nd year corn		half corn, half no crop	tillage radish & wheat blend	*soybean
10	4C-1S	3rd year corn		beans		corn
11	C-S					corn

*for tile 9, CC info is correct but crop is conjectured based on 2015 survey info

Figure 5. Rating curve for Miller Creek

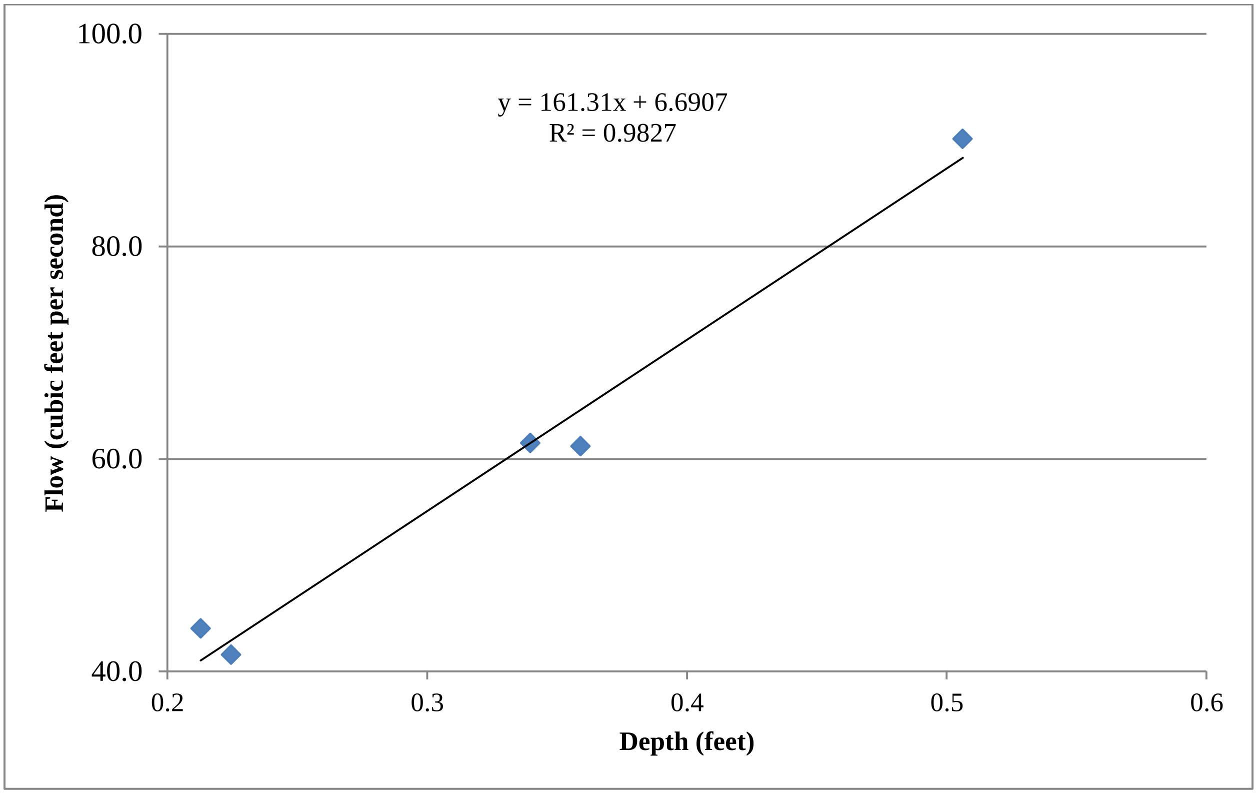
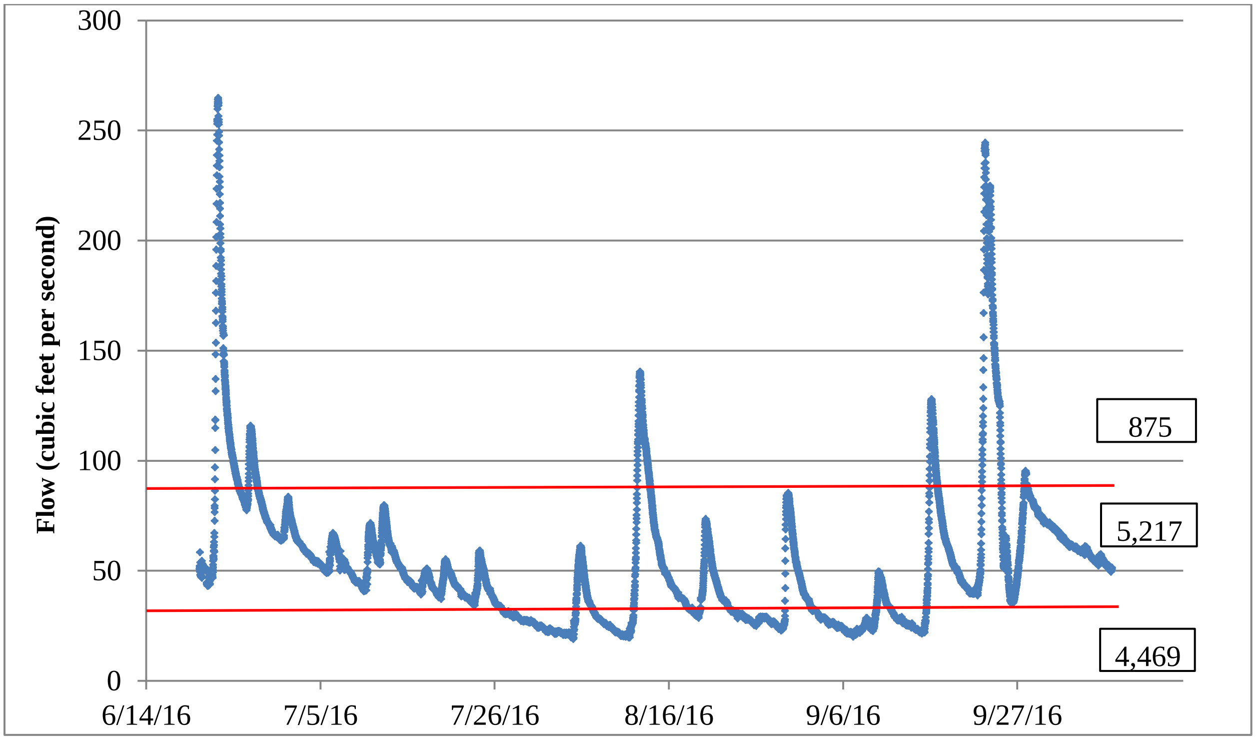


Figure 6. Flow data for Miller Creek



Future work

Our plan for the 2017 season is to continue measurements at our long term monitoring sites to better understand the impact of land use changes and implementation of different management practices. A continuous record allows us to develop a better understanding of the dynamics of nutrient movement in the landscape. We also hope to be able to contribute to larger efforts going on in the Middle Cedar watershed, including the Middle Cedar Partnership Project and the HUD funded Iowa Watershed Approach (IWA) with the Middle Cedar Watershed Management Authority.

In particular, the Lime Creek watershed seems well-suited for the type of work outlined in the IWA. As mentioned earlier, the Iowa Soybean Association has prepared a plan to reduce nutrients in the watershed, there is an excellent database for comparison, and there is an active conservation-minded farmer group in the watershed. Our monitoring at the Hamline Avenue site illustrates the potential impact of nutrient reduction in strategic positions in the watershed. We will also be working with Keith Schilling and Matthew Streeter of the Iowa Geological Survey on an Iowa Nutrient Center funded project[18] to evaluate the potential effectiveness of roadside ditches in the Lime Creek watershed for nutrient processing. We will continue to work with the data from the tile boxes to convert that data to load, which will enable farmers to put an economic value on nutrients lost.

Having acquired appropriate instrumentation and familiarized ourselves with their use, we will be primed to capture both low and high flow events in the Middle Cedar watersheds under study. This will enable to develop a more complete rating curve for these streams and thus contribute to the calculation of loads for these streams.

[18] Abstract at https://www.cals.iastate.edu/sites/default/files/misc/183758/inrc-projects-approved-funding-2016-fy2017.pdf

Acknowledgements

We appreciate continued support from the City of Cedar Rapids Utilities Department for student support, instrumentation, and supplies. In particular, our discussions with Steve Hershner, Mike Kuntz, and Tariq Baloch have been very helpful in moving this collaboration forward. Chad Ingels and Dick Sloan continue to be excellent collaborators for our work in the Lime Creek watershed. Support for student stipends from the Dave Mehaffy fund at Coe is gratefully acknowledged. Coe College provided housing for the students.

Appendix 1. Sampling sites

Cedar River Tributaries	**Latitude**	**Longitude**
Bear	42° 04’ 50.61”	91° 48’ 32.25”
Blue	42° 11’ 12.64”	91° 49’ 29.24”
Lime	42° 17’ 51.30”	92° 01’ 04.98”
Morgan	41° 59’ 21.88”	91° 45’ 33.50”
Mud	42° 09’ 16.81”	92° 00’ 20.38”
N Bear (North Bear)	42° 15’ 48.92”	91° 59’ 08.58”
Otter	42° 04’ 17.17”	91° 43’ 31.79”
Lime Watershed	**Latitude**	**Longitude**
240 (240th St.)	42° 26’ 33.71”	91° 58’ 52.34”
250 (250th St.)	42° 25’ 41.86”	91° 58’ 51.02”
Ham (Hamilton Ave.)	42° 22’ 41.17”	91° 56’ 51.92”
290 (290th St.)	42° 22’ 11.56”	91° 57’ 12.57”
Fin (Finley)	42° 18’ 44.80”	91° 59’ 38.40”
Lime (Benton-Buchanan)	42° 17’ 51.27”	92° 01’ 05.12”
Indian Creek Watershed	**Latitude**	**Longitude**
ICLM (Linn Mar)	42° 03’ 05.69”	91° 35’ 44.89”
ICThom (Thomas Park)	42° 01’ 43.61”	91° 36’ 36.98”
ICS (Mt. Vernon Rd.)	41° 58’ 36.11”	91° 34’ 40.83”
DryDonn (Donnelly Park)	42° 02’ 09.34”	91° 36’ 45.17”
Artesian	42° 04’ 45.31”	91° 33’ 42.95”

Flow measurement sites	**Latitude**	**Longitude**
Miller Creek	42° 23’ 04.79”	92° 15’ 15.84”
Wolf Creek	42° 19’ 05.16”	92° 11’ 25.84”
Rock Creek	42° 17’ 50.62”	92° 08’ 53.28”
Pratt Creek	42° 13’ 05.71”	92° 03’ 57.91”

Site	Date	Time	DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO3-N	SO4	*E coli*
Bear	5/11/16	9:38:00 AM	11.3	13.0	7.86	495	10.6	11.5	0.10	21.7	12.3	17.3	563
Bear	5/18/16	9:25:00 AM	11.2	12.1	8.05	478	6.8	10.8	0.09	20.4	11.0	18.9	268
Bear	5/24/16	9:13:00 AM	9.5	17.8	8.13	432	9.2	12.5	0.09	20.4	10.0	19.4	495
Bear	6/2/16	9:19:00 AM	9.0	18.2	7.93	494	13.0	13.4	0.17	20.3	9.6	19.8	650
Bear	6/8/16	9:46:00 AM	9.6	17.6	7.86	427	9.4	13.0	0.16	20.3	9.4	20.9	350
Bear	6/15/16	9:38:00 AM	8.2	23.3	7.91	537	16.5	28.0	0.22	19.1	7.4	20.1	2014
Bear	6/21/16	9:21:00 AM	8.7	21.4	8.24	567	10.2	16.5	0.20	19.9	7.2	21.9	934
Bear	6/29/16	9:25:00 AM	9.1	16.8	8.12	NA	30.3	33.0	0.20	19.3	12.5	17.6	631
Bear	7/8/16	9:42:00 AM	8.3	20.2	7.74	498	33.2	40.8	0.28	16.7	10.1	16.8	1187
Bear	7/13/16	9:13:00 AM	8.7	19.9	7.55	NA	40.3	60.0	0.30	16.4	9.9	14.4	1816
Bear	7/19/16	9:04:00 AM	7.7	21.3	7.76	503	13.1	17.3	0.17	17.3	9.0	18.9	932
Bear	7/26/16	9:02:00 AM	8.0	20.6	7.76	461	15.7	20.5	0.21	16.5	8.4	18.6	1291
Bear	8/2/16	9:53:00 AM	8.5	21.4	7.99	407	6.4	6.5	0.10	16.9	6.7	21.1	657
Bear	8/10/16	9:24:00 AM	7.3	21.9	8.31	498	5.3	8.5	0.15	17.8	6.0	22.2	1046
Blue	5/11/16	10:26:00 AM	11.4	13.3	7.85	434	7.1	4.8	0.07	25.9	8.6	19.0	637
Blue	5/18/16	11:31:00 AM	12.1	13.6	7.92	423	6.5	4.8	0.08	24.2	8.2	19.8	155
Blue	5/24/16	11:23:00 AM	10.7	18.5	8.09	448	7.0	7.5	0.08	24.8	7.0	20.7	218
Blue	6/2/16	11:34:00 AM	10.3	19.1	7.89	445	9.0	9.0	0.14	24.6	9.1	18.5	464
Blue	6/8/16	12:11:00 PM	10.3	19.2	7.60	383	5.8	7.7	0.12	23.8	7.8	20.5	86
Blue	6/15/16	10:27:00 AM	8.2	20.2	7.63	374	137.0	132.5	0.35	17.3	10.6	11.2	9208
Blue	6/21/16	11:50:00 AM	9.4	21.4	8.05	491	12.3	15.3	0.15	22.1	10.0	18.1	906
Blue	6/29/16	10:17:00 AM	9.6	17.5	8.10	NA	12.2	16.3	0.14	22.8	11.6	18.1	677
Blue	7/8/16	10:29:00 AM	7.9	21.8	7.59	451	13.4	18.0	0.20	20.9	8.2	17.9	1354
Blue	7/13/16	10:02:00 AM	8.8	21.3	7.72	NA	17.0	14.8	0.18	21.9	7.6	17.7	928
Blue	7/19/16	9:54:00 AM	7.7	21.6	7.96	451	5.5	7.0	0.12	21.8	5.9	20.8	663
Blue	7/26/16	9:50:00 AM	8.4	22.2	8.14	413	5.7	9.0	0.09	22.4	5.0	21.2	605
Blue	8/2/16	12:05:00 PM	7.9	21.5	7.85	369	12.5	6.5	0.09	21.7	4.2	22.9	288
Blue	8/10/16	10:05:00 AM	7.7	21.2	8.28	452	9.1	10.3	0.17	22.3	4.4	22.3	670
Lime	5/11/16	11:40:00 AM	12.8	13.0	7.98	482	3.8	5.0	0.05	25.2	16.5	15.1	288
Lime	5/18/16	12:36:00 PM	14.3	14.6	8.28	464	2.9	5.2	0.06	24.6	15.4	16.1	131
Lime	5/24/16	12:34:00 PM	11.6	20.4	8.26	477	6.1	10.5	0.08	24.7	13.9	16.9	341
Lime	6/2/16	12:48:00 PM	10.1	16.9	7.85	475	21.5	21.5	0.18	21.0	21.9	11.2	809
Lime	6/8/16	1:16:00 PM	10.4	18.3	8.12	411	5.8	30.0	0.11	22.1	20.0	13.1	364
Lime	6/15/16	11:53:00 AM	8.3	20.2	7.59	388	84.8	72.0	0.47	12.5	15.8	7.5	1989
Lime	6/21/16	1:02:00 AM	14.0	14.5	8.17	629	8.6	10.8	0.15	20.2	18.9	13.8	908
Lime	6/29/16	11:45:00 AM	9.9	18.7	8.14	NA	6.0	6.0	0.13	20.2	18.9	15.2	197
Lime	7/8/16	11:37:00 AM	8.2	23.4	7.67	510	5.9	5.3	0.18	19.7	12.3	16.9	408

Site	Date	Time	DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO3-N	SO4	*E coli*
Lime	7/13/16	11:45:00 AM	10.3	21.9	7.82	NA	6.0	7.8	0.14	19.0	12.7	16.1	910
Lime	7/19/16	11:11:00 AM	7.4	21.2	7.60	505	4.9	5.7	0.23	19.8	9.3	18.1	457
Lime	7/26/16	11:00:00 AM	8.0	22.3	8.14	449	11.5	14.0	0.19	17.3	14.1	13.3	1354
Lime	8/2/16	1:12:00 AM	8.3	22.7	8.16	402	6.1	5.2	0.13	19.6	9.5	18.0	1059
Lime	8/10/16	11:19:00 AM	8.5	23.8	8.25	500	3.2	3.5	0.19	20.0	8.3	19.5	1421
Morgan	5/11/16	9:15:00 AM	11.0	12.0	7.61	554	7.3	7.3	0.08	35.2	12.0	24.5	620
Morgan	5/18/16	9:05:00 AM	11.2	9.9	7.74	535	5.9	7.8	0.08	31.3	11.1	26.2	122
Morgan	5/24/16	8:52:00 AM	8.8	15.6	7.85	451	10.2	10.3	0.08	30.7	10.4	26.9	197
Morgan	6/2/16	9:00:00 AM	9.0	14.8	7.54	540	11.9	15.3	0.14	30.2	11.0	24.1	512
Morgan	6/8/16	9:23:00 AM	9.6	14.0	7.72	465	12.2	15.5	0.13	29.8	11.1	26.1	13960
Morgan	6/15/16	9:06:00 AM	8.4	18.9	7.48	578	54.4	73.8	0.19	32.7	8.3	23.4	2489
Morgan	6/21/16	9:02:00 AM	8.0	18.8	7.92	611	19.7	24.0	0.13	30.0	8.6	28.2	1333
Morgan	6/29/16	8:56:00 AM	9.5	14.6	7.83	NA	21.8	28.0	0.16	29.2	12.2	24.7	204
Morgan	7/8/16	9:19:00 AM	8.9	18.5	7.70	578	14.1	16.5	0.19	28.1	9.4	28.0	1374
Morgan	7/13/16	8:56:00 AM	8.9	18.4	7.44	NA	20.8	20.8	0.20	27.4	9.0	24.5	1916
Morgan	7/19/16	8:45:00 AM	7.9	19.6	7.70	581	11.1	11.8	0.17	28.4	8.0	31.0	1789
Morgan	7/26/16	8:38:00 AM	8.3	19.3	7.99	532	12.3	13.0	0.20	28.4	7.3	33.0	771
Morgan	8/2/16	9:35:00 AM	7.5	19.7	7.85	465	8.3	4.0	0.08	26.7	6.0	34.1	359
Morgan	8/10/16	9:05:00 AM	6.5	19.7	8.12	576	21.3	23.8	0.14	28.4	5.9	36.4	663
Mud	5/11/16	10:57:00 AM	11.3	12.1	7.84	544	9.9	10.0	0.16	20.1	13.2	23.5	171
Mud	5/18/16	11:58:00 AM	12.7	13.1	8.12	533	6.6	8.3	0.23	21.3	12.7	26.0	396
Mud	5/24/16	11:53:00 AM	11.7	17.0	8.25	547	6.3	7.3	0.24	20.2	11.6	26.7	613
Mud	6/2/16	12:05:00 PM	10.2	17.7	7.97	548	7.0	8.0	0.18	20.1	12.4	25.3	213
Mud	6/8/16	12:40:00 PM	10.0	18.4	8.06	469	5.9	9.3	0.18	20.3	12.2	27.3	959
Mud	6/15/16	11:03:00 AM	8.8	21.0	7.94	609	12.7	21.5	0.41	20.3	10.4	26.0	1376
Mud	6/21/16	12:21:00 PM	9.7	22.2	8.21	623	7.4	12.0	0.16	22.3	10.3	29.0	1050
Mud	6/29/16	10:57:00 AM	9.7	15.7	8.02	NA	27.6	35.2	0.25	18.1	13.8	23.0	226
Mud	7/8/16	10:58:00 AM	8.0	20.7	7.54	555	23.7	26.5	0.27	16.9	11.9	23.8	1046
Mud	7/13/16	10:33:00 AM	9.2	18.8	7.76	NA	29.6	32.0	0.26	15.8	12.0	20.3	2548
Mud	7/19/16	10:31:00 AM	8.2	18.6	7.80	552	11.0	13.3	0.29	17.3	11.2	26.2	1565
Mud	7/26/16	10:22:00 AM	8.6	19.5	8.04	516	8.3	9.2	0.23	17.8	10.7	27.2	1119
Mud	8/2/16	12:36:00 PM	8.6	19.3	7.92	460	10.5	5.3	0.25	18.7	9.8	29.9	744
Mud	8/10/16	10:37:00 AM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N. Bear	5/11/16	11:22:00 AM	11.8	13.1	7.96	459	5.1	5.5	0.05	24.1	15.3	18.6	282
N. Bear	5/18/16	12:24:00 PM	12.7	15.4	8.28	442	4.8	6.7	0.06	23.1	14.6	19.5	171
N. Bear	5/24/16	12:18:00 PM	10.4	19.8	8.27	462	5.2	2.8	0.07	22.9	13.6	20.4	426

Site	Date	Time	DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO3-N	SO4	*E coli*
N. Bear	6/2/16	12:29:00 PM	9.5	17.9	7.87	456	30.9	36.3	0.18	21.7	19.6	13.9	780
N. Bear	6/8/16	1:03:00 PM	9.3	19.3	8.16	401	11.3	14.7	0.12	22.5	19.2	16.6	480
N. Bear	6/15/16	11:35:00 AM	7.8	20.2	7.55	314	162.0	108.0	0.54	9.4	10.7	9.0	6131
N. Bear	6/21/16	12:46:00 PM	11.8	15.2	8.12	608	15.2	23.8	0.14	20.3	18.6	17.6	1019
N. Bear	6/29/16	11:27:00 AM	9.1	17.9	8.12	NA	11.6	14.3	0.13	20.5	19.5	18.2	717
N. Bear	7/8/16	11:22:00 AM	7.7	23.0	7.82	501	6.0	7.8	0.16	19.2	14.6	19.1	1723
N. Bear	7/13/16	10:58:00 AM	9.2	21.6	7.83	NA	6.0	8.8	0.12	19.4	13.4	18.6	930
N. Bear	7/19/16	10:57:00 AM	7.9	21.0	7.53	486	4.2	5.4	0.13	19.2	11.3	21.1	830
N. Bear	7/26/16	10:47:00 AM	7.6	22.3	8.05	447	10.6	10.3	0.19	18.5	13.3	17.2	1050
N. Bear	8/2/16	12:56:00 PM	7.9	21.7	8.14	389	4.1	2.5	0.10	19.3	10.9	21.7	605
N. Bear	8/10/16	11:06:00 AM	8.2	22.5	8.36	466	2.4	3.0	0.10	19.9	9.8	22.2	1046
Otter	5/11/16	10:00:00 AM	10.8	13.3	7.86	472	5.9	4.5	0.08	27.3	10.3	16.6	504
Otter	5/18/16	9:45:00 AM	11.2	11.7	8.02	464	3.5	4.3	0.07	25.9	9.7	17.4	271
Otter	5/24/16	9:30:00 AM	9.2	17.8	8.06	490	4.1	6.5	0.09	25.5	8.3	18.3	496
Otter	6/2/16	9:38:00 AM	8.5	18.1	7.87	483	6.5	6.5	0.17	25.9	8.7	17.6	420
Otter	6/8/16	10:04:00 AM	9.2	17.0	7.87	419	4.1	5.2	0.14	25.7	8.1	18.8	399
Otter	6/15/16	9:57:00 AM	7.9	21.1	7.82	434	72.3	77.5	0.28	21.5	8.1	13.8	5172
Otter	6/21/16	9:41:00 AM	8.1	20.5	8.12	546	9.5	11.0	0.19	25.2	8.1	17.7	934
Otter	6/29/16	9:45:00 AM	9.3	17.2	8.12	NA	13.4	17.3	0.17	25.2	11.0	16.0	776
Otter	7/8/16	10:00:00 AM	8.5	20.7	7.69	484	20.9	29.3	1.45	23.1	9.2	14.4	2143
Otter	7/13/16	9:34:00 AM	8.5	21.1	7.69	NA	12.9	15.3	0.20	22.7	7.8	15.8	1366
Otter	7/19/16	9:24:00 AM	7.9	21.9	7.91	505	5.7	7.8	0.18	23.9	6.8	18.8	1236
Otter	7/26/16	9:24:00 AM	7.4	21.8	7.84	446	7.6	24.0	0.33	24.1	5.8	17.8	723
Otter	8/2/16	10:12:00 AM	7.4	21.7	7.93	413	4.9	3.8	0.13	24.5	4.6	20.6	933
Otter	8/10/16	9:40:00 AM	6.5	21.9	8.15	498	5.2	6.5	0.21	24.3	4.9	20.0	1333

Site	Date	Time	DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO3-N	SO4	*E coli*
Dry-Donnelly	5/10/16	10:40 AM	9.65	13.3	7.53	463.6	9.7	8.5	0.12	32.9	5.7	19.3	1162
Dry-Donnelly	5/16/16	11:00 AM	10.20	12.7	7.73	534.6	3.7	3.5	0.11	37.1	7.9	23.8	226
Dry-Donnelly	5/23/16	10:42 AM	8.78	14.8	7.83	563.6	4.9	8.0	0.15	39.6	4.5	29.5	1450
Dry-Donnelly	5/31/16	10:52 AM	6.47	15.7	7.77	553	6.8	5.0	0.17	39.4	2.9	30.5	613
Dry-Donnelly	6/6/16	10:57 AM	7.13	15.7	7.84	567.8	4.0	4.1	0.16	38.6	2.8	32.2	556
Dry-Donnelly	6/13/16	11:08 AM	8.73	17.7	7.82	581	4.7	7.5	0.22	35.5	2.9	28.9	808
Dry-Donnelly	6/20/16	3:45 PM	7.95	23.4	7.89	576	11.1	13.5	0.21	33.5	7.9	30.8	275
Dry-Donnelly	6/27/16	10:54 AM	7.71	21.2	7.84	432.6	62.1	67.5	0.60	25.9	10.3	16.8	7308
Dry-Donnelly	7/6/16	10:26 AM	6.35	21.5	7.39	148.6	394.0	266.0	0.45	6.3	1.1	6.8	4962
Dry-Donnelly	7/11/16	11:13 AM	NA	NA	7.86	660.5	16.1	10.3	0.22	26.8	5.6	30.4	620
Dry-Donnelly	7/18/16	11:00 AM	7.94	19.2	7.75	502	5.7	4.0	0.17	31.3	3.9	39.5	506
Dry-Donnelly	7/25/16	11:11 AM	8.93	19.8	7.97	569	4.8	4.0	0.22	32.5	4.2	37.7	262
Dry-Donnelly	8/1/16	11:10 AM	10.69	16.3	7.87	596	4.2	1.3	0.13	35.7	2.7	30.8	657
Dry-Donnelly	8/9/16	10:43 AM	8.04	16.1	7.90	603	2.1	0.5	0.17	35.4	2.8	40.2	393
IC - Artesian	5/10/16	10:10 AM	11.03	12.8	7.81	477.2	5.9	1.8	0.04	35.1	10.9	20.0	1376
IC - Artesian	5/16/16	10:28 AM	11.35	12.4	7.98	470.7	7.4	4.5	0.06	32.9	12.4	19.0	96
IC - Artesian	5/23/16	10:10 AM	10.42	15.8	8.10	463.9	6.5	6.0	0.08	32.8	11.1	20.1	538
IC - Artesian	5/31/16	10:16 AM	8.16	18.7	7.85	465.3	10.3	9.8	0.11	32.0	11.4	21.4	546
IC - Artesian	6/6/16	10:21 AM	8.14	18.2	8.00	473.3	9.7	9.5	0.12	33.4	10.4	20.5	504
IC - Artesian	6/13/16	10:29 AM	9.24	19.5	7.89	514	15.4	21.0	0.13	31.1	11.3	18.0	677
IC - Artesian	6/20/16	3:09 PM	8.28	25.9	8.05	515	17.7	16.5	0.14	30.5	13.5	16.8	689
IC - Artesian	6/27/16	10:16 AM	7.76	20.3	7.93	518.2	26.4	24.5	0.20	30.5	13.5	15.8	2900
IC - Artesian	7/6/16	9:48 AM	5.68	20.7	7.31	155	365.0	394.0	0.76	7.4	2.9	5.9	46040
IC - Artesian	7/11/16	10:28 AM	NA	NA	7.85	731.5	13.3	12.3	0.15	25.8	10.3	17.7	12033
IC - Artesian	7/18/16	10:31 AM	7.96	20.8	7.76	444	6.9	4.0	0.11	27.6	8.4	21.1	2086
IC - Artesian	7/25/16	10:34 AM	8.59	22.0	7.79	498	8.2	7.8	0.12	32.1	7.2	25.2	987
IC - Artesian	8/1/16	10:40 AM	8.17	21.9	7.94	495	11.8	9.5	0.08	29.7	5.6	26.6	776
IC - Artesian	8/9/16	10:12 AM	6.35	21.1	7.96	509.8	12.8	10.8	0.14	30.8	5.5	25.5	1054
IC - Linn Mar	5/10/16	10:25 AM	10.95	12.8	7.77	485.3	7.3	6.5	0.12	35.1	10.1	21.3	8664
IC - Linn Mar	5/16/16	10:44 AM	12.60	12.8	7.99	486.5	5.5	3.5	0.07	33.8	11.9	20.3	134
IC - Linn Mar	5/23/16	10:25 AM	9.55	16.6	8.02	484.9	7.3	8.0	0.10	33.3	10.5	21.4	259
IC - Linn Mar	5/31/16	10:33 AM	7.78	18.9	7.85	481.3	10.4	14.8	0.15	34.8	11.3	21.5	591
IC - Linn Mar	6/6/16	10:46 AM	8.09	18.9	7.98	495.4	10.9	15.4	0.16	33.4	10.1	21.0	464
IC - Linn Mar	6/13/16	10:46 AM	8.81	19.8	7.89	537	15.8	20.8	0.18	31.3	10.7	19.3	933
IC - Linn Mar	6/20/16	3:25 PM	7.97	25.4	8.06	533	13.5	16.3	0.17	30.2	13.5	17.7	627
IC - Linn Mar	6/27/16	10:34 AM	7.81	20.6	7.95	534.9	27.2	32.0	0.26	30.6	13.5	15.8	5446
IC - Linn Mar	7/6/16	10:05 AM	6.14	20.5	7.35	283.4	238.0	276.0	1.09	15.2	5.3	10.5	120980
IC - Linn Mar	7/11/16	10:46 AM	NA	NA	7.85	648.6	21.0	19.5	0.23	26.9	9.3	19.0	10462

Site	Date	Time	DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO3-N	SO4	*E coli*
IC - Linn Mar	7/18/16	10:43 AM	8.16	21.0	7.76	466	5.5	4.0	0.14	28.2	7.2	22.2	1632
IC - Linn Mar	7/25/16	10:51 AM	8.90	21.4	7.77	517	13.0	12.0	0.18	29.7	7.1	23.7	1050
IC - Linn Mar	8/1/16	10:55 AM	9.35	21.7	8.00	528	4.6	4.2	0.12	29.4	4.7	27.1	813
IC - Linn Mar	8/9/16	10:28 AM	6.13	21.2	8.05	542	6.9	5.3	0.19	30.9	4.6	26.6	789
IC - Thomas	5/10/16	10:54 AM	10.86	13.2	7.64	469.3	10.0	12.8	0.10	34.3	7.6	21.1	1314
IC - Thomas	5/16/16	11:13 AM	11.96	13.2	7.87	513.2	5.4	6.7	0.08	36.7	10.1	22.2	145
IC - Thomas	5/23/16	10:55 AM	10.05	16.6	7.95	514.1	7.0	8.2	0.11	37.2	7.9	24.8	309
IC - Thomas	5/31/16	11:04 AM	8.17	19.3	7.73	507.4	8.0	9.5	0.17	37.8	8.4	24.4	437
IC - Thomas	6/6/16	11:10 AM	NA	NA	8.03	522.6	10.4	12.8	0.17	37.2	7.0	25.0	384
IC - Thomas	6/13/16	11:20 AM	8.58	20.3	7.97	556	19.6	27.7	0.22	34.1	7.8	22.9	959
IC - Thomas	6/20/16	4:03 PM	8.76	25.4	8.04	418.8	16.1	19.3	0.22	32.6	11.2	22.8	294
IC - Thomas	6/27/16	11:09 AM	8.96	19.7	7.90	489.5	51.3	54.0	0.48	32.2	8.4	23.3	5818
IC - Thomas	7/6/16	10:35 AM	6.68	20.5	7.27	216.2	282.0	216.0	0.85	10.5	3.0	8.9	120980
IC - Thomas	7/11/16	11:30 AM	NA	NA	6.96	475	17.7	17.5	0.22	28.8	7.3	23.9	3255
IC - Thomas	7/18/16	11:11 AM	8.22	20.8	7.77	489	7.2	6.8	0.16	31.7	5.6	29.8	942
IC - Thomas	7/25/16	11:21 AM	9.32	21.6	7.88	541	7.1	5.9	0.21	32.8	5.8	29.1	617
IC - Thomas	8/1/16	11:24 AM	10.19	19.9	7.81	572	4.5	4.0	0.11	34.4	3.6	29.2	504
IC - Thomas	8/9/16	10:55 AM	7.25	19.8	8.04	577	5.3	4.2	0.18	34.9	3.6	32.6	624
ICS - MV Road	5/10/16	11:15 AM	10.03	14.3	7.60	397.7	16.2	8.0	0.12	31.0	4.2	15.8	2755
ICS - MV Road	5/16/16	11:45 AM	12.13	14.3	8.01	563.9	3.3	3.8	0.07	42.5	7.7	25.0	31
ICS - MV Road	5/23/16	11:23 AM	9.30	18.0	8.11	565.3	4.7	3.8	0.08	45.3	5.4	26.5	52
ICS - MV Road	5/31/16	11:27 AM	7.68	21.6	7.77	523.7	7.5	5.7	0.22	42.9	4.8	24.0	145
ICS - MV Road	6/6/16	11:36 AM	NA	NA	7.95	553	6.1	8.0	0.21	43.7	4.1	25.6	148
ICS - MV Road	6/13/16	11:42 AM	8.85	22.3	7.98	582	10.0	15.3	0.27	38.3	5.0	24.0	230
ICS - MV Road	6/20/16	2:42 PM	8.14	27.1	8.02	588	14.1	0.0	0.21	35.7	9.8	23.2	272
ICS - MV Road	6/27/16	11:33 AM	7.97	22.7	8.01	526	50.2	67.5	0.29	32.0	7.9	23.2	2592
ICS - MV Road	7/6/16	11:00 AM	6.38	22.0	7.54	139.8	457.0	390.0	0.51	6.5	1.1	6.3	27375
ICS - MV Road	7/11/16	11:50 AM	NA	NA	6.69	444	24.5	31.2	0.23	27.0	4.8	21.0	2481
ICS - MV Road	7/18/16	11:36 AM	8.22	22.1	7.81	454	11.6	8.5	0.16	30.3	3.2	23.9	1710
ICS - MV Road	7/25/16	11:45 AM	9.07	23.3	7.95	7.95	568.0	7.0	0.22	35.2	4.9	28.0	402
ICS - MV Road	8/1/16	11:45 AM	12.18	21.8	8.12	574	2.9	3.8	0.05	40.8	2.0	28.5	146
ICS - MV Road	8/9/16	11:15 AM	7.83	21.5	8.12	605	4.8	3.5	0.16	40.1	2.2	31.5	384
McLoud Run	5/10/16	8:33 AM	9.33	13.4	7.26	617	8.3	8.8	0.07	91.7	1.7	32.1	1333
McLoud Run	5/16/16	8:46 AM	10.65	11.2	7.59	755	3.7	5.3	0.09	88.6	3.9	43.9	435
McLoud Run	5/23/16	8:43 AM	9.45	12.1	7.72	733	3.7	3.3	0.12	83.7	4.2	43.6	410
McLoud Run	5/31/16	8:50 AM	8.64	14.0	7.51	693	3.1	3.8	0.12	82.4	3.7	41.5	435
McLoud Run	6/6/16	8:50 AM	9.18	13.7	7.72	710	3.5	2.5	0.12	80.7	3.6	41.7	457

Site	Date	Time	DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO3-N	SO4	*E coli*
McLoud Run	6/13/16	8:57 AM	10.19	14.4	7.50	765	4.0	5.3	0.13	79.2	3.4	41.7	884
McLoud Run	6/20/16	8:59 AM	8.76	15.6	7.72	783	4.5	5.3	0.13	79.3	3.7	42.7	776
McLoud Run	6/27/16	8:36 AM	8.07	17.8	7.66	655	6.6	6.5	0.13	67.7	2.2	33.5	1040
McLoud Run	7/6/16	8:31 AM	7.39	20.8	7.23	296.4	69.8	57.6	0.26	28.3	0.9	18.8	16275
McLoud Run	7/11/16	8:53 AM	7.26	17.4	7.59	633	6.5	4.5	0.11	65.9	2.3	33.8	1401
McLoud Run	7/18/16	8:48 AM	8.75	16.8	7.50	630	3.5	3.5	0.08	70.9	2.8	38.6	1076
McLoud Run	7/25/16	9:00 AM	10.51	15.9	7.45	738	2.8	1.2	0.08	74.9	3.4	42.2	743
McLoud Run	8/1/16	9:08 AM	10.40	15.2	7.53	745	3.0	0.7	0.06	73.4	3.5	42.3	529
McLoud Run	8/9/16	8:52 AM	8.31	15.0	8.04	748	4.4	1.7	0.08	71.7	3.7	42.6	393
IB Rd. east tile	5/10/16	9:54 AM	NA	NA	NA	NA	NA	NA	0.04	22.4	15.1	8.7	NA
IB Rd. east tile	5/16/16	10:08 AM	NA	NA	NA	NA	NA	NA	0.05	23.1	15.8	9.1	NA
IB Rd. east tile	5/23/16	9:48 AM	NA	NA	NA	NA	NA	NA	0.07	23.5	16.2	9.7	NA
IB Rd. east tile	5/31/16	9:58 AM	NA	NA	NA	NA	NA	NA	0.06	23.1	16.5	9.5	NA
IB Rd. east tile	6/6/16	10:05 AM	NA	NA	NA	NA	NA	NA	0.07	22.5	16.0	10.4	NA
IB Rd. east tile	6/13/16	10:10 AM	NA	NA	NA	NA	NA	NA	0.01	22.8	15.2	11.5	NA
IB Rd. east tile	6/20/16	10:27 AM	NA	NA	NA	NA	NA	NA	0.07	21.0	18.0	8.9	NA
IB Rd. east tile	6/27/16	9:51 AM	NA	NA	NA	NA	NA	NA	0.08	22.2	14.5	11.2	NA
IB Rd. east tile	7/6/16	9:35 AM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
IB Rd. east tile	7/11/16	10:09 AM	NA	NA	NA	NA	NA	NA	0.07	14.7	12.3	8.5	NA
IB Rd. east tile	7/18/16	9:56 AM	NA	NA	NA	NA	NA	NA	0.05	15.4	13.6	3.4	NA
IB Rd. east tile	7/25/16	10:15 AM	NA	NA	NA	NA	NA	NA	0.06	16.4	11.8	13.3	NA
IB Rd. east tile	8/1/16	10:20 AM	NA	NA	NA	NA	NA	NA	0.09	16.6	11.2	15.2	NA
IB Rd. east tile	8/9/16	9:55 AM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
IB Rd. west tile	5/10/16	10:02 AM	NA	NA	NA	NA	NA	NA	0.05	24.7	12.4	11.1	NA
IB Rd. west tile	5/16/16	10:16 AM	NA	NA	NA	NA	NA	NA	0.05	25.2	12.1	12.1	NA
IB Rd. west tile	5/23/16	9:55 AM	NA	NA	NA	NA	NA	NA	0.08	25.6	12.2	12.1	NA
IB Rd. west tile	5/31/16	10:03 AM	NA	NA	NA	NA	NA	NA	0.07	25.2	12.6	12.1	NA
IB Rd. west tile	6/6/16	10:10 AM	NA	NA	NA	NA	NA	NA	0.07	25.0	12.2	11.8	NA
IB Rd. west tile	6/13/16	10:15 AM	NA	NA	NA	NA	NA	NA	0.07	24.7	11.1	12.9	NA
IB Rd. west tile	6/20/16	10:31 AM	NA	NA	NA	NA	NA	NA	0.08	22.8	15.0	10.5	NA
IB Rd. west tile	6/27/16	10:02 AM	NA	NA	NA	NA	NA	NA	0.07	31.2	13.7	14.4	NA
IB Rd. west tile	7/6/16	9:37 AM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
IB Rd. west tile	7/11/16	10:17 AM	NA	NA	NA	NA	NA	NA	0.07	8.3	9.8	11.0	NA
IB Rd. west tile	7/18/16	10:10 AM	NA	NA	NA	NA	NA	NA	0.06	18.2	7.9	12.9	NA
IB Rd. west tile	7/25/16	10:21 AM	NA	NA	NA	NA	NA	NA	0.07	19.1	7.0	16.3	NA
IB Rd. west tile	8/1/16	10:27 AM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
IB Rd. west tile	8/9/16	10:00 AM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Site	Date	Time	DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO3-N	SO4	*E coli*
240th	5/12/2016	10:11 AM	13.5	11.9	7.76	458	1.9	3.3	0.05	28.3	17.2	14.6	295
240th	5/17/2016	9:25 AM	11.9	10.5	7.38	464	2.1	1.8	0.06	27.7	16.7	15.0	97
240th	5/25/2016	9:37 AM	9.6	14.4	7.84	453	5.9	6.8	0.07	27.1	15.9	15.5	1274
240th	6/1/2016	9:58 AM	8.5	15.3	7.23	435	7.4	13.3	0.29	22.6	21.7	10.9	457
240th	6/7/2016	9:48 AM	NA	NA	7.55	557	5.7	8.5	0.10	25.7	21.6	12.8	341
240th	6/14/2016	10:25 AM	7.8	18.0	7.48	336	12.4	67.0	0.25	21.4	19.2	10.5	538
240th	6/22/2016	9:55 AM	6.3	18.6	7.08	289	65.5	98.0	0.87	14.3	7.9	7.4	14540
240th	6/28/2016	9:38 AM	6.5	16.7	7.84	810	6.9	9.3	0.09	21.8	20.5	14.2	538
240th	7/7/2016	9:38 AM	7.0	18.2	7.53	692	8.9	12.8	0.12	21.7	14.1	17.0	1100
240th	7/12/2016	10:38 AM	8.8	19.9	7.45	892	15.1	22.8	0.17	32.2	11.4	16.3	3106
240th	7/20/2016	9:49 AM	8.3	19.3	7.47	836	11.5	17.3	0.12	25.4	11.1	18.1	1012
240th	7/27/2016	9:43 AM	7.7	18.7	7.45	415	5.9	7.7	0.10	20.2	14.3	13.9	528
240th	8/3/2016	9:55 AM	7.6	20.2	7.64	394	8.7	7.0	0.09	21.3	11.3	18.9	845
240th	8/8/2016	10:40 AM	7.2	18.5	7.69	420	7.4	6.8	0.14	24.0	10.5	20.2	556
250th	5/12/2016	10:24 AM	9.3	11.3	7.70	452	4.6	6.8	0.05	25.4	16.7	14.1	85
250th	5/17/2016	9:36 AM	9.5	10.9	7.55	460	3.7	3.8	0.06	25.5	16.3	14.6	146
250th	5/25/2016	9:50 AM	19.6	1.2	7.95	687	6.9	7.0	0.08	24.8	15.5	14.9	404
250th	6/1/2016	10:11 AM	8.0	15.1	7.24	424	12.3	17.3	0.28	18.3	20.2	10.1	529
250th	6/7/2016	10:05 AM	NA	NA	7.61	520	8.2	11.0	0.12	23.7	21.3	12.3	135
250th	6/14/2016	10:40 AM	7.5	18.1	7.44	312	25.0	30.0	0.36	18.7	16.9	9.5	813
250th	6/22/2016	10:09 AM	6.6	18.1	7.14	335	63.2	135.0	0.50	14.8	8.7	7.9	12262
250th	6/28/2016	9:54 AM	6.8	16.8	7.84	790	8.7	11.0	0.10	19.8	19.7	13.4	991
250th	7/7/2016	9:50 AM	6.7	17.9	7.75	713	15.3	24.5	0.14	20.5	13.2	16.5	2909
250th	7/12/2016	10:46 AM	8.1	21.1	7.64	823	11.6	12.5	0.14	20.7	11.9	16.2	1226
250th	7/20/2016	9:58 AM	8.1	19.8	7.65	806	9.9	13.3	0.15	24.6	10.4	16.8	3255
250th	7/27/2016	9:56 AM	7.7	18.9	7.50	399	11.6	10.8	0.11	17.8	13.5	12.9	587
250th	8/3/2016	10:07 AM	8.0	21.9	7.91	364	13.9	9.8	0.10	18.4	9.8	16.5	504
250th	8/8/2016	10:50 AM	7.8	20.4	7.90	399	8.0	7.0	0.15	20.4	9.6	18.4	1137
Hamline	5/12/2016	11:54 AM	10.9	12.8	7.83	474	1.3	1.8	0.05	24.8	21.8	13.9	97
Hamline	5/17/2016	10:05 AM	11.4	10.8	7.77	512	1.2	1.8	0.06	24.9	19.0	15.1	256
Hamline	5/25/2016	10:26 AM	8.3	12.1	7.85	554	2.9	3.2	0.08	24.7	21.1	16.1	602
Hamline	6/1/2016	11:52 AM	9.3	15.9	7.17	495	14.7	24.0	0.19	19.3	26.2	10.7	231
Hamline	6/7/2016	10:37 AM	NA	NA	7.75	951	4.1	5.7	0.08	21.4	26.8	11.8	345
Hamline	6/14/2016	11:05 AM	8.5	18.1	7.52	362	15.8	22.5	0.17	19.9	23.7	10.3	399
Hamline	6/22/2016	11:15 AM	6.4	19.7	7.16	269	205.0	153.0	0.97	6.0	8.2	5.0	3316
Hamline	6/28/2016	10:22 AM	7.3	16.7	7.64	941	4.3	4.0	0.07	18.9	27.1	13.7	231
Hamline	7/7/2016	10:17 AM	7.3	17.4	7.62	842	5.2	7.0	0.11	18.9	19.2	18.4	801
Hamline	7/12/2016	12:25 PM	8.7	19.9	7.53	1021	5.8	3.5	0.15	18.9	20.9	16.1	1060
Hamline	7/20/2016	10:24 AM	7.5	19.8	7.57	917	6.5	5.8	0.14	19.6	14.9	22.2	1234

Site	Date	Time	DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO3-N	SO4	*E coli*
Hamline	7/27/2016	10:28 AM	8.0	19.2	7.65	489	5.4	2.8	0.09	17.1	19.8	16.3	1012
Hamline	8/3/2016	12:39 PM	14.0	22.1	7.69	445	22.9	41.8	0.11	19.6	13.1	26.6	1126
Hamline	8/8/2016	11:22 AM	7.8	19.5	7.85	488	4.0	2.5	0.14	19.1	13.3	26.1	631
290th	5/12/2016	11:44 AM	12.3	14.3	7.95	466	3.0	3.5	0.05	24.9	19.5	14.1	121
290th	5/17/2016	9:57 AM	12.7	11.7	7.86	478	2.6	2.8	0.06	24.7	18.8	15.0	213
290th	5/25/2016	10:15 AM	10.6	13.1	7.82	507	6.3	6.5	0.06	24.1	16.6	15.8	1046
290th	6/1/2016	11:31 AM	9.0	16.4	7.32	445	28.5	35.0	0.33	19.4	22.3	9.9	717
290th	6/7/2016	10:24 AM	NA	NA	7.76	556	9.3	15.3	0.10	22.5	23.0	12.2	479
290th	6/14/2016	10:52 AM	7.4	19.6	7.55	264	102.0	103.0	0.51	12.7	14.4	7.3	4884
290th	6/22/2016	11:34 AM	7.3	19.6	7.18	297	240.0	212.0	0.78	8.7	10.7	6.2	10950
290th	6/28/2016	10:10 AM	7.8	18.2	7.89	834	8.3	8.5	0.10	19.3	21.5	13.9	1354
290th	7/7/2016	10:05 AM	7.0	19.2	7.69	700	5.8	9.8	0.13	18.3	14.1	17.4	3448
290th	7/12/2016	12:08 PM	9.9	22.7	7.76	872	5.1	3.8	0.14	19.1	14.3	16.9	1818
290th	7/20/2016	10:15 AM	8.7	21.5	7.67	792	6.2	6.0	0.11	19.1	10.1	19.4	2247
290th	7/27/2016	10:16 AM	7.9	20.8	7.69	416	9.3	8.3	0.13	17.2	15.1	14.2	1291
290th	8/3/2016	12:08 PM	5.1	24.4	8.02	374	10.4	9.0	0.11	17.2	9.9	20.0	6131
290th	8/8/2016	11:07 AM	7.8	21.3	7.97	418	6.4	4.0	0.15	18.9	10.5	20.2	1565
Finley	5/12/2016	9:10 AM	12.2	12.7	7.59	480	2.6	3.8	0.04	24.9	17.5	14.8	231
Finley	5/17/2016	10:31 AM	12.3	12.6	8.07	485	2.5	3.8	0.05	24.9	16.6	15.7	364
Finley	5/25/2016	9:13 AM	7.9	18.5	7.64	472	4.8	6.3	0.07	24.6	13.9	16.4	1935
Finley	6/1/2016	9:11 AM	9.3	16.1	7.23	435	40.3	45.3	0.34	19.2	21.5	9.9	1145
Finley	6/7/2016	9:20 AM	NA	NA	7.84	629	8.9	13.0	0.12	22.9	21.4	12.6	521
Finley	6/14/2016	9:50 AM	8.3	18.9	7.80	371	40.9	14.3	0.21	20.7	21.7	11.5	2382
Finley	6/22/2016	9:34 AM	8.1	18.6	7.37	393	88.6	60.0	0.59	14.8	12.1	10.4	19608
Finley	6/28/2016	8:55 AM	10.6	13.1	7.90	940	6.8	7.5	0.12	19.3	20.5	14.0	823
Finley	7/7/2016	8:58 AM	7.3	19.8	7.50	728	8.1	9.0	0.11	19.1	12.6	16.3	3076
Finley	7/12/2016	9:38 AM	8.9	20.7	7.35	908	9.1	10.5	0.18	21.7	11.9	15.6	4494
Finley	7/20/2016	9:15 AM	9.1	20.3	7.23	867	9.2	13.5	0.11	20.1	9.3	17.7	2046
Finley	7/27/2016	9:04 AM	6.0	20.5	7.86	225	10.0	10.8	0.15	17.5	13.9	14.2	4106
Finley	8/3/2016	9:12 AM	7.7	22.1	7.83	422	6.3	3.7	0.12	19.3	9.1	18.7	4884
Finley	8/8/2016	10:00 AM	8.4	20.4	7.52	463	5.3	4.0	0.18	20.3	9.5	19.0	3255
Lime	5/12/2016	9:44 AM	11.7	13.3	7.82	486	3.2	6.0	0.06	24.6	16.8	15.2	241
Lime	5/17/2016	10:42 AM	12.3	13.0	8.03	492	3.9	5.2	0.06	24.6	15.8	16.2	168
Lime	5/25/2016	10:51 AM	12.2	14.0	8.02	537	4.4	6.7	0.08	24.3	13.3	16.9	1050
Lime	6/1/2016	9:34 AM	9.5	16.4	7.50	427	44.6	51.3	0.37	18.8	21.1	9.9	1782
Lime	6/7/2016	11:02 AM	NA	NA	7.80	876	8.4	5.5	0.13	22.6	20.6	13.0	554
Lime	6/14/2016	10:05 AM	8.1	19.4	7.64	340	57.3	82.0	0.30	16.5	18.1	11.0	3448
Lime	6/22/2016	10:53 AM	8.2	19.2	7.70	394	89.4	91.0	0.62	14.7	12.0	10.2	28272

Site	Date	Time	DO	Temp	pH	Cond	Turb	TSS	DRP	Cl	NO3-N	SO4	*E coli*
Lime	6/28/2016	9:16 AM	7.9	17.8	8.02	867	8.0	9.8	0.12	19.6	18.8	14.3	657
Lime	7/7/2016	9:12 AM	7.2	19.9	7.70	740	5.4	7.3	0.14	18.6	12.1	16.5	1296
Lime	7/12/2016	10:00 AM	8.8	20.9	7.58	915	9.3	9.5	0.16	19.9	11.8	15.4	3570
Lime	7/20/2016	9:26 AM	8.7	20.2	7.51	895	6.7	5.7	0.14	20.2	9.1	18.0	2014
Lime	7/27/2016	9:19 AM	7.5	20.9	7.76	435	10.3	10.3	0.16	17.8	13.5	14.3	2014
Lime	8/3/2016	9:30 AM	7.0	21.9	7.84	432	6.6	4.4	0.12	19.7	9.1	10.3	2723
Lime	8/8/2016	10:15 AM	8.3	20.3	7.75	469	5.2	3.5	0.18	20.9	9.3	18.9	2046

Site	Date	Time	SO4	NO3-N	Cl	DRP
Lime tile 1	4/15/16	10:15 AM	14.4	23.7	18.0	0.04
Lime tile 1	4/22/16	10:10 AM	15.7	21.6	18.0	0.18
Lime tile 1	5/4/16	10:33 AM	14.1	22.8	16.8	0.04
Lime tile 1	5/12/16	10:49 AM	15.1	21.4	18.6	0.06
Lime tile 1	5/17/16	11:00 AM	14.9	21.4	18.8	0.07
Lime tile 1	5/26/16	9:21 AM	15.8	22.1	18.9	0.08
Lime tile 1	6/1/16	10:41 AM	13.0	30.4	14.7	0.09
Lime tile 1	6/9/16	9:51 AM	13.4	30.6	15.5	0.08
Lime tile 1	6/15/16	9:31 AM	13.4	36.8	16.1	0.11
Lime tile 1	6/23/16	9:54 AM	12.7	35.9	16.6	0.08
Lime tile 1	6/30/16	9:40 AM	13.0	33.1	15.8	0.09
Lime tile 1	7/7/16	9:52 AM	16.7	27.1	16.0	0.13
Lime tile 1	7/12/16	11:13 AM	20.8	24.1	17.5	0.11
Lime tile 1	7/21/16	9:42 AM	11.9	15.4	9.7	0.26
Lime tile 1	7/28/16	9:21 AM	15.7	26.6	16.2	0.07
Lime tile 1	8/3/16	10:58 AM	18.8	25.8	18.2	0.15
Lime tile 1	8/8/16	9:39 AM	20.5	21.4	17.2	0.10
Lime tile 2	4/8/16	1:01 PM	14.4	23.3	17.5	0.03
Lime tile 2	4/8/16	12:15 PM	15.7	15.4	15.6	0.03
Lime tile 2	4/15/16	10:45 AM	15.6	15.6	16.0	0.04
Lime tile 2	4/22/16	10:20 AM	15.5	14.5	15.7	0.06
Lime tile 2	5/4/16	11:07 AM	15.5	15.6	15.6	0.04
Lime tile 2	5/12/16	11:24 AM	15.5	15.8	17.1	0.05
Lime tile 2	5/17/16	11:35 AM	15.4	15.6	17.0	0.07
Lime tile 2	5/26/16	9:56 AM	15.7	15.8	17.3	0.07
Lime tile 2	6/1/16	11:12 AM	15.7	15.0	14.7	0.09
Lime tile 2	6/9/16	10:00 AM	14.3	17.0	15.2	0.07
Lime tile 2	6/15/16	9:40 AM	0.0	0.0	0.0	0.00
Lime tile 2	6/23/16	10:31 AM	14.8	14.8	12.9	0.09
Lime tile 2	6/30/16	10:08 AM	14.6	15.6	12.9	0.08
Lime tile 2	7/7/16	10:32 AM	16.6	13.1	12.5	0.09
Lime tile 2	7/12/16	11:48 AM	17.6	11.6	12.2	0.07
Lime tile 2	7/21/16	10:15 AM	19.9	10.5	12.1	0.06
Lime tile 2	7/28/16	9:48 AM	18.6	9.5	11.8	0.05
Lime tile 2	8/3/16	11:25 AM	21.0	8.3	11.7	0.06
Lime tile 2	8/8/16	10:09 AM	21.9	7.7	12.3	0.08
Lime tile 3	4/8/16	12:05 PM	9.6	21.2	18.2	0.06
Lime tile 3	4/15/16	10:50 AM	9.8	22.2	18.9	0.06
Lime tile 3	4/22/16	10:30 AM	10.2	20.2	18.1	0.09
Lime tile 3	5/4/16	11:20 AM	9.3	21.1	16.6	0.06
Lime tile 3	5/12/16	11:32 AM	10.0	22.0	18.8	0.07
Lime tile 3	5/17/16	11:45 AM	9.8	17.5	18.5	0.09

Site	Date	Time	SO4	NO3-N	Cl	DRP
Lime tile 3	5/26/16	10:02 AM	9.2	22.7	18.0	0.09
Lime tile 3	6/1/16	11:21 AM	10.1	25.9	13.1	0.48
Lime tile 3	6/9/16	10:08 AM	11.9	19.1	18.5	0.15
Lime tile 3	6/15/16	9:45 AM	10.3	22.4	13.1	0.56
Lime tile 3	6/23/16	10:38 AM	9.3	18.9	13.7	0.25
Lime tile 3	6/30/16	10:14 AM	11.5	17.4	15.3	0.18
Lime tile 3	7/7/16	10:38 AM	16.3	12.5	12.2	0.21
Lime tile 3	7/12/16	11:57 AM	13.0	9.9	16.0	0.20
Lime tile 3	7/21/16	10:23 AM	13.8	7.1	14.8	0.16
Lime tile 3	7/28/16	9:54 AM	12.3	7.1	14.2	0.14
Lime tile 3	8/3/16	11:33 AM	13.6	11.1	14.9	0.13
Lime tile 3	8/8/16	10:17 AM	13.5	7.5	14.9	0.17
Lime tile 4	4/8/16	12:34 PM	10.1	10.6	16.5	0.08
Lime tile 4	4/15/16	10:20 AM	10.8	11.1	19.6	0.08
Lime tile 4	4/22/16	9:45 AM	18.5	9.1	15.0	0.05
Lime tile 4	5/4/16	10:45 AM	10.6	13.4	16.9	0.09
Lime tile 4	5/12/16	11:00 AM	11.2	12.6	19.1	0.09
Lime tile 4	5/17/16	11:10 AM	11.1	13.3	17.4	0.10
Lime tile 4	5/26/16	9:32 AM	11.3	19.7	17.5	0.09
Lime tile 4	6/1/16	10:52 AM	9.2	18.1	15.0	0.15
Lime tile 4	6/9/16	9:22 AM	10.7	16.7	16.2	0.25
Lime tile 4	6/15/16	9:10 AM	8.5	20.8	15.2	0.19
Lime tile 4	6/23/16	10:04 AM	8.3	22.7	16.5	0.18
Lime tile 4	6/30/16	9:50 AM	9.9	16.8	17.2	0.13
Lime tile 4	7/7/16	10:10 AM	12.6	12.9	17.7	0.13
Lime tile 4	7/12/16	11:26 AM	15.3	10.5	17.6	0.22
Lime tile 4	7/21/16	9:42 AM	11.3	13.7	18.3	0.08
Lime tile 4	7/28/16	9:33 AM	10.8	14.1	19.0	0.11
Lime tile 4	8/3/16	11:00 AM	11.1	14.2	17.9	0.07
Lime tile 4	8/8/16	9:49 AM	11.4	14.0	18.2	0.10
Lime tile 5	4/8/16	12:40 PM	18.6	8.8	15.5	0.03
Lime tile 5	4/15/16	10:30 AM	20.4	8.7	16.2	0.03
Lime tile 5	4/22/16	9:35 AM	14.0	10.5	17.2	0.14
Lime tile 5	5/4/16	10:55 AM	18.5	9.1	14.5	0.04
Lime tile 5	5/12/16	11:10 AM	19.3	9.4	16.1	0.05
Lime tile 5	5/17/16	11:20 AM	21.3	9.4	15.7	0.06
Lime tile 5	5/26/16	9:43 AM	21.5	9.5	15.1	0.06
Lime tile 5	6/1/16	11:00 AM	17.2	11.8	13.5	0.07
Lime tile 5	6/9/16	9:29 AM	18.9	11.1	14.2	0.07
Lime tile 5	6/15/16	9:18 AM	NA	NA	NA	NA
Lime tile 5	6/23/16	10:20 AM	17.0	16.2	14.7	0.08
Lime tile 5	6/30/16	9:57 AM	16.8	11.5	12.7	0.07

Site	Date	Time	SO4	NO3-N	Cl	DRP
Lime tile 5	7/7/16	10:18 AM	20.5	10.3	13.2	0.06
Lime tile 5	7/12/16	11:38 AM	21.1	9.8	13.2	0.06
Lime tile 5	7/21/16	10:02 AM	22.1	8.6	12.7	0.05
Lime tile 5	7/28/16	9:38 AM	21.2	8.3	13.1	0.05
Lime tile 5	8/3/16	11:12 AM	21.7	8.4	12.5	0.05
Lime tile 5	8/8/16	9:57 AM	24.0	6.0	13.1	0.08
Lime tile 6	4/8/16	10:46 AM	11.6	20.4	20.7	0.03
Lime tile 6	4/15/16	9:30 AM	11.7	24.4	22.4	0.03
Lime tile 6	4/22/16	9:35 AM	11.9	25.4	22.4	0.04
Lime tile 6	5/4/16	9:55 AM	12.0	19.1	20.4	0.03
Lime tile 6	5/12/16	9:33 AM	12.5	21.0	22.5	0.04
Lime tile 6	5/17/16	10:20 AM	12.4	20.8	23.2	0.06
Lime tile 6	5/26/16	8:50 AM	13.0	24.5	23.5	0.06
Lime tile 6	6/1/16	9:26 AM	12.3	19.8	22.2	0.07
Lime tile 6	6/9/16	8:58 AM	13.0	22.0	22.6	0.06
Lime tile 6	6/14/16	8:53 AM	11.7	17.5	19.7	0.06
Lime tile 6	6/23/16	9:11 AM	11.1	19.8	15.0	0.06
Lime tile 6	6/30/16	9:07 AM	12.5	17.7	16.5	0.06
Lime tile 6	7/7/16	9:12 AM	12.9	15.9	16.9	0.06
Lime tile 6	7/12/16	9:54 AM	12.3	14.7	15.7	0.06
Lime tile 6	7/21/16	9:03 AM	14.1	15.6	17.5	0.05
Lime tile 6	7/28/16	8:45 AM	14.7	15.1	17.9	0.04
Lime tile 6	8/3/16	9:21 AM	15.2	14.3	18.0	0.05
Lime tile 6	8/8/16	9:03 AM	15.1	13.2	18.5	0.08
Lime tile 7	4/8/16	11:32 AM	11.9	11.7	13.6	0.30
Lime tile 7	4/15/16	11:30 AM	12.5	11.7	14.2	0.26
Lime tile 7	4/22/16	11:11 AM	12.7	10.9	13.9	0.27
Lime tile 7	5/4/16	12:00 PM	12.5	8.7	13.5	0.31
Lime tile 7	5/12/16	12:45 PM	13.5	9.5	14.6	0.21
Lime tile 7	5/17/16	12:30 PM	13.1	10.0	14.3	0.16
Lime tile 7	5/26/16	10:42 AM	12.9	10.6	14.1	0.14
Lime tile 7	6/1/16	12:36 PM	12.8	8.2	14.0	0.29
Lime tile 7	6/9/16	10:43 AM	13.0	9.8	14.4	0.20
Lime tile 7	6/15/16	11:15 AM	9.9	11.5	18.4	0.32
Lime tile 7	6/23/16	11:23 AM	9.8	12.9	20.1	0.27
Lime tile 7	6/30/16	10:52 AM	10.9	11.3	18.5	0.31
Lime tile 7	7/7/16	11:37 AM	11.8	10.8	18.1	0.43
Lime tile 7	7/12/16	1:31 AM	11.1	11.2	19.5	0.44
Lime tile 7	7/21/16	11:06 AM	11.9	10.3	19.0	0.30
Lime tile 7	7/28/16	10:31 AM	12.6	9.8	17.0	0.21
Lime tile 7	8/3/16	1:59 AM	12.9	11.0	15.4	0.10
Lime tile 7	8/8/16	10:57 AM	14.4	9.6	18.6	0.40

Site	Date	Time	SO4	NO3-N	Cl	DRP
Lime tile 8	4/8/16	11:32 AM	7.0	10.8	10.1	0.02
Lime tile 8	4/15/16	11:20 AM	7.0	9.3	10.5	0.03
Lime tile 8	4/22/16	11:05 AM	7.3	7.5	10.3	0.04
Lime tile 8	5/4/16	11:45 AM	7.0	7.1	10.1	0.03
Lime tile 8	5/12/16	12:35 PM	8.1	5.3	10.6	0.04
Lime tile 8	5/17/16	12:15 PM	15.6	6.0	10.9	0.07
Lime tile 8	5/26/16	10:30 AM	8.1	7.5	11.5	0.08
Lime tile 8	6/1/16	12:25 PM	6.9	6.2	10.9	0.07
Lime tile 8	6/9/16	10:33 AM	6.8	6.0	11.0	0.69
Lime tile 8	6/23/16	11:13 AM	6.8	5.9	17.1	0.07
Lime tile 8	6/30/16	10:41 AM	7.1	5.2	15.7	0.07
Lime tile 8	7/7/16	10:57 AM	7.3	4.9	16.0	0.05
Lime tile 8	7/12/16	1:20 AM	7.3	5.1	16.4	0.06
Lime tile 8	7/21/16	10:54 AM	9.2	4.3	14.9	0.05
Lime tile 8	7/28/16	10:20 AM	14.7	3.3	12.1	0.05
Lime tile 8	8/3/16	1:45 AM	11.7	3.2	13.0	0.11
Lime tile 8	8/8/16	10:44 AM	17.5	2.6	10.9	0.08
Lime tile 9	4/8/16	11:48 AM	22.0	21.9	42.3	0.03
Lime tile 9	4/15/16	11:00 AM	21.4	21.1	40.6	0.03
Lime tile 9	4/22/16	10:48 AM	22.4	21.4	42.7	0.06
Lime tile 9	5/4/16	11:35 AM	20.7	23.8	43.1	0.04
Lime tile 9	5/12/16	12:23 PM	18.8	22.2	45.2	0.05
Lime tile 9	5/17/16	12:05 PM	20.1	21.1	42.0	0.07
Lime tile 9	5/26/16	10:16 AM	20.5	22.8	41.4	0.08
Lime tile 9	6/1/16	12:13 PM	20.4	31.1	46.1	0.08
Lime tile 9	6/9/16	10:25 AM	19.4	33.9	42.7	0.07
Lime tile 9	6/15/16	10:27 AM	19.8	49.6	36.2	0.10
Lime tile 9	6/23/16	11:00 AM	18.2	61.8	32.3	0.07
Lime tile 9	6/30/16	10:31 AM	18.2	56.7	28.1	0.08
Lime tile 9	7/7/16	11:14 AM	11.8	55.7	19.5	0.06
Lime tile 9	7/12/16	1:02 AM	18.5	53.8	32.3	0.06
Lime tile 9	7/21/16	10:39 AM	18.6	41.4	32.5	0.06
Lime tile 9	7/28/16	10:13 AM	18.3	39.9	30.3	0.05
Lime tile 9	8/3/16	1:12 AM	19.8	27.7	35.5	0.06
Lime tile 9	8/8/16	10:33 AM	18.2	42.2	31.1	0.08
Lime tile 10	4/8/16	1:14 PM	6.9	20.3	40.5	0.03
Lime tile 10	4/15/16	10:05 AM	6.9	20.3	39.4	0.01
Lime tile 10	4/22/16	10:00 AM	7.0	20.1	40.8	0.05
Lime tile 10	5/4/16	10:25 AM	6.8	21.7	42.4	0.03
Lime tile 10	5/12/16	10:38 AM	7.3	22.3	46.6	0.04
Lime tile 10	5/17/16	10:45 AM	7.9	22.2	45.6	0.06
Lime tile 10	5/26/16	9:11 AM	7.9	22.3	44.8	0.06

Site	Date	Time	SO4	NO3-N	Cl	DRP
Lime tile 10	6/1/16	10:29 AM	6.9	39.0	31.1	0.09
Lime tile 10	6/9/16	9:42 AM	7.0	35.0	35.1	0.07
Lime tile 10	6/14/16	9:33 AM	7.0	36.8	33.2	0.07
Lime tile 10	6/23/16	9:43 AM	6.9	41.9	27.2	0.07
Lime tile 10	6/30/16	9:30 AM	7.5	35.3	29.1	0.07
Lime tile 10	7/7/16	9:38 AM	6.0	17.2	8.8	0.09
Lime tile 10	7/12/16	11:02 AM	9.4	28.8	29.9	0.08
Lime tile 10	7/21/16	9:30 AM	8.3	21.7	30.1	0.05
Lime tile 10	7/28/16	9:12 AM	6.9	24.8	23.8	0.05
Lime tile 10	8/3/16	11:50 AM	7.7	22.4	25.2	0.05
Lime tile 10	8/8/16	9:27 AM	8.5	20.2	25.4	0.09
Lime tile 11	4/15/16	11:10 AM	4.9	3.7	14.0	0.00
Lime tile 11	4/22/16	10:35 AM	4.6	3.3	12.9	0.06
Lime tile 11	5/4/16	11:40 AM	5.3	2.8	20.0	0.04
Lime tile 11	5/12/16	12:11 PM	NA	NA	NA	NA
Lime tile 11	5/17/16	11:57 AM	NA	NA	NA	NA
Lime tile 11	5/26/16	10:11 AM	NA	NA	NA	NA
Lime tile 11	6/1/16	11:39 AM	4.9	14.6	37.3	0.08
Lime tile 11	6/9/16	10:18 AM	NA	NA	NA	NA
Lime tile 11	6/15/16	10:10 AM	4.9	28.9	44.8	0.08
Lime tile 11	6/23/16	10:48 AM	5.2	37.5	43.8	0.09
Lime tile 11	6/30/16	10:24 AM	NA	NA	NA	NA
Lime tile 11	7/7/16	10:47 AM	NA	NA	NA	NA
Lime tile 11	7/12/16	12:52 PM	NA	NA	NA	NA
Lime tile 11	7/21/16	10:34 AM	NA	NA	NA	NA
Lime tile 11	7/28/16	10:03 AM	NA	NA	NA	NA
Lime tile 11	8/3/16	12:59 PM	NA	NA	NA	NA
Lime tile 11	8/8/16	10:27 AM	NA	NA	NA	NA