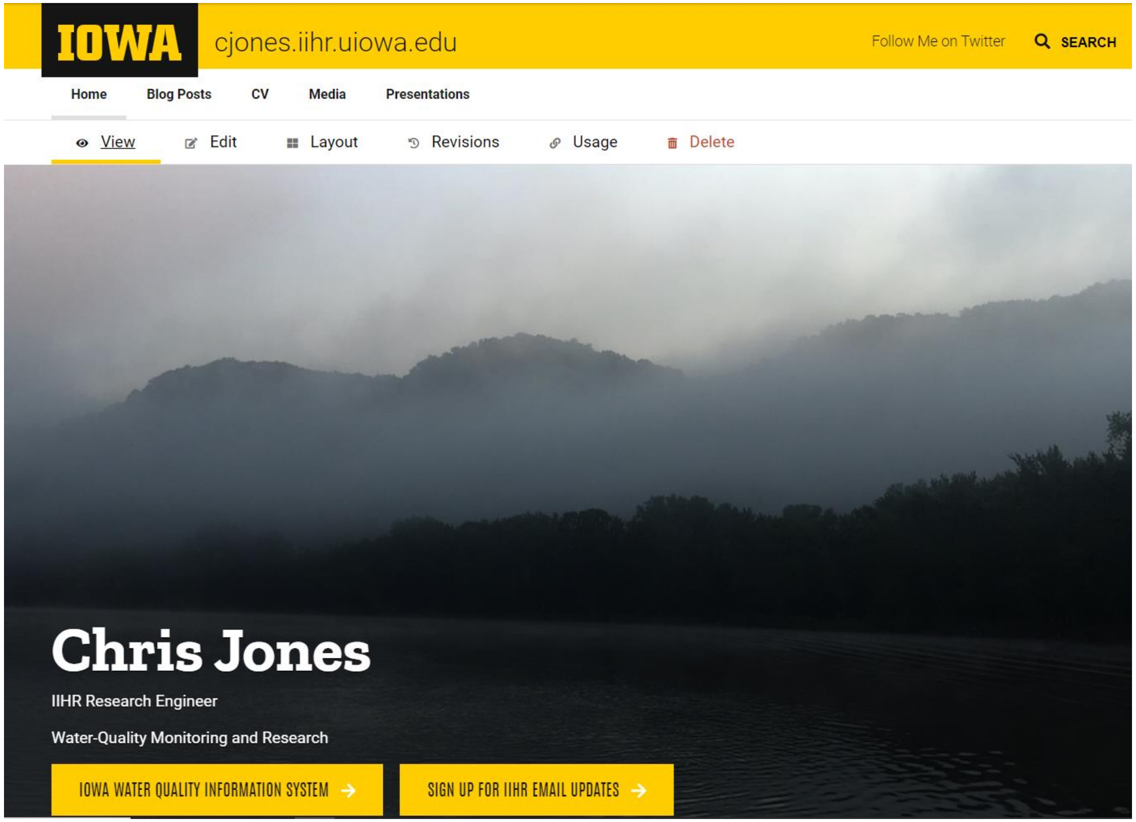
Chris Jones, Research Engineer, IIHR Hydroscience and Engineering

Proposed Water Quality Index for Iowa Streams

February 4, 2022

Slides Available at:

https://cjones.iihr.uiowa.edu/

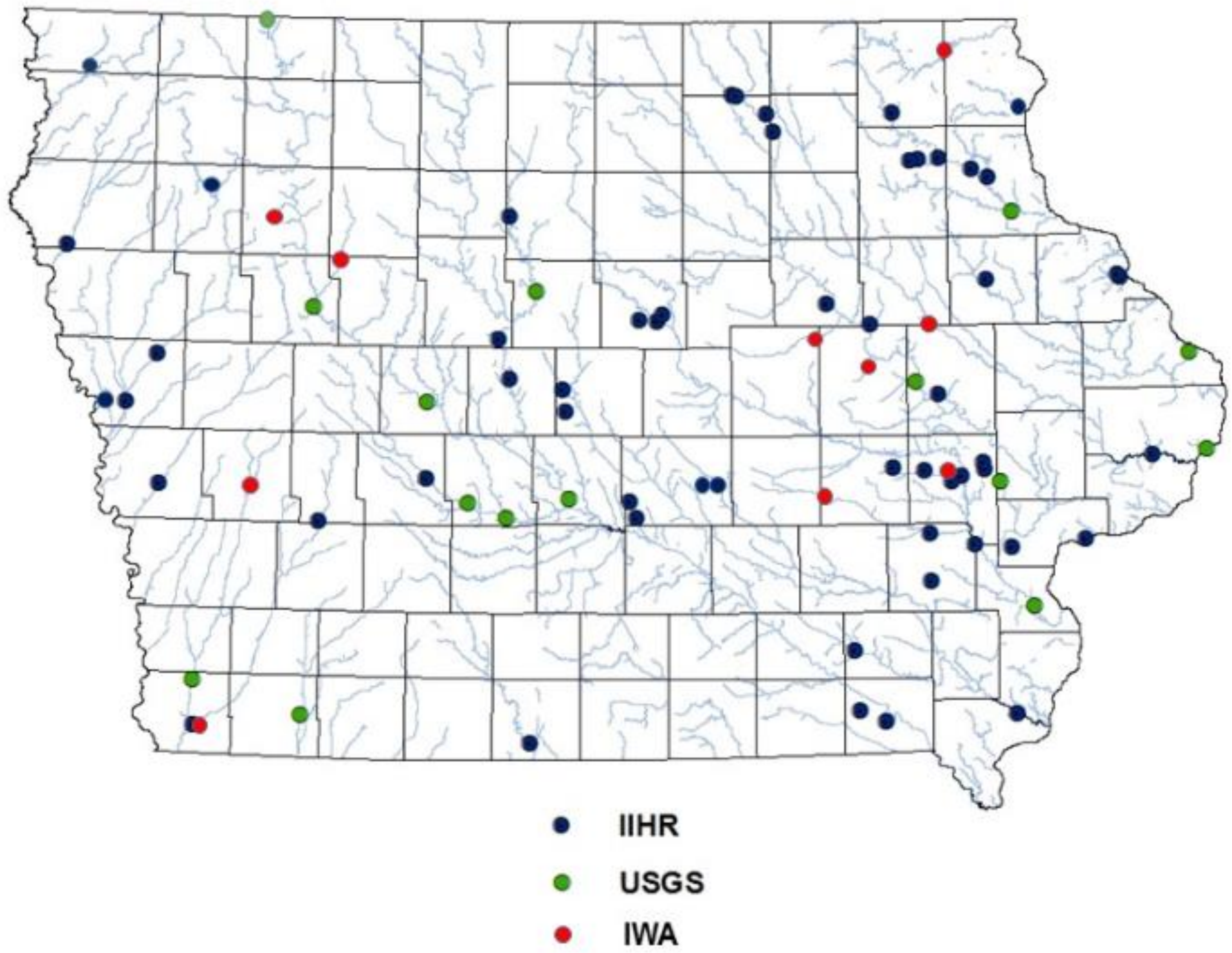


IIHR Water Quality Sensor Network

Sites

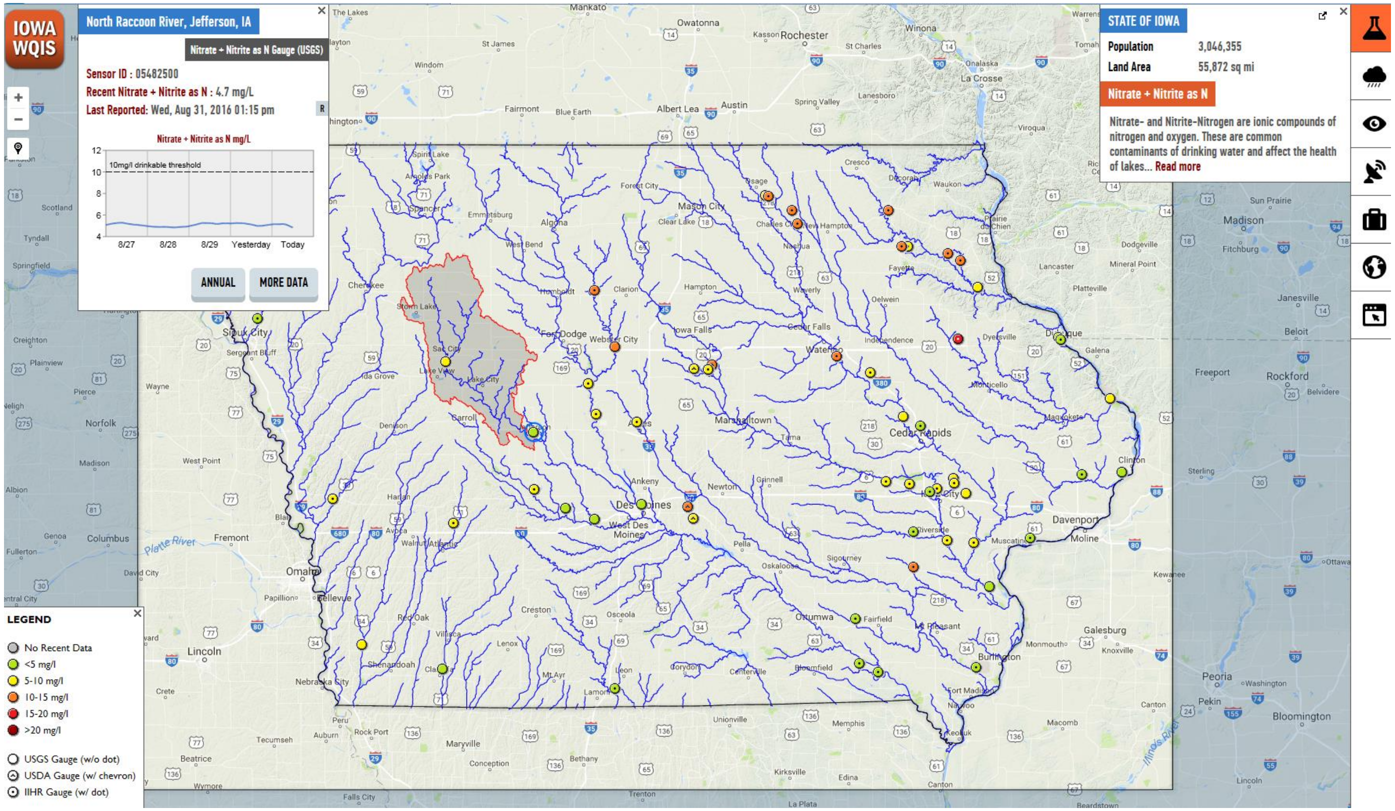
70+ sites
Nitrate-N

20-25 sites
- Temperature
- pH
- SC
- DO
- Turbidity



Site infrastructure

Iowa Water Quality Information System



iwqis.iowawis.org/

http://iwqis.iowawis.org/app/?datetime=2017-06-06T13:00

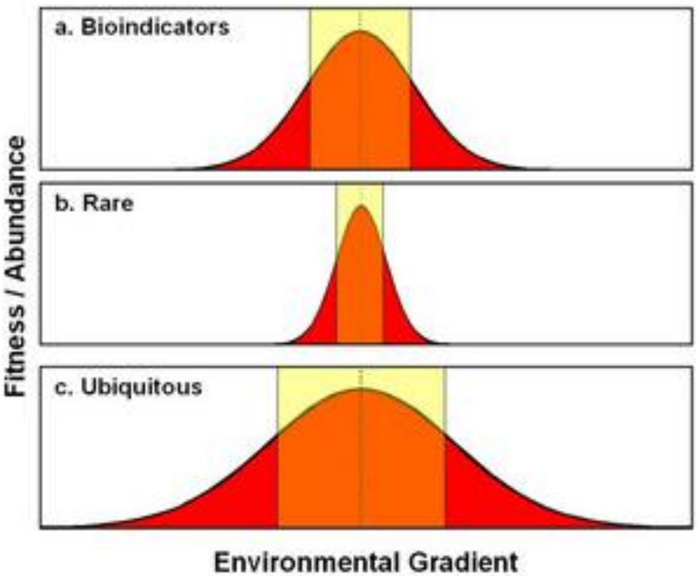
How do we define "WATER QUALITY"?

- Drinking Water
- Streams
- Lakes
- Estuaries
- Oceans
- Aquifers

Standards

- Drinking water: Maximum Contaminant Levels (MCLs)
- Wastewater: Effluent Limits
- Surface Water: Standards that protect designated uses
    - Drinking water source
    - Aquatic life
    - Recreation

Bioindicators



Biological Indicators

- IBI: Index of Biotic Integrity
- BMIBI: Benthic Macroinvertebrate Index of Biotic Integrity

MONITORING IS EXPENSIVE!

Water Quality Index

- Single value index that objectively translates a body of data into one value
- Concept dates to at least 1848

Two types:

- Water Quality Index (high #'s for good water, low #'s for bad water)
- Water Pollution Index (low #'s for good water, high #'s for bad water)

Confounding factors

n natural condition

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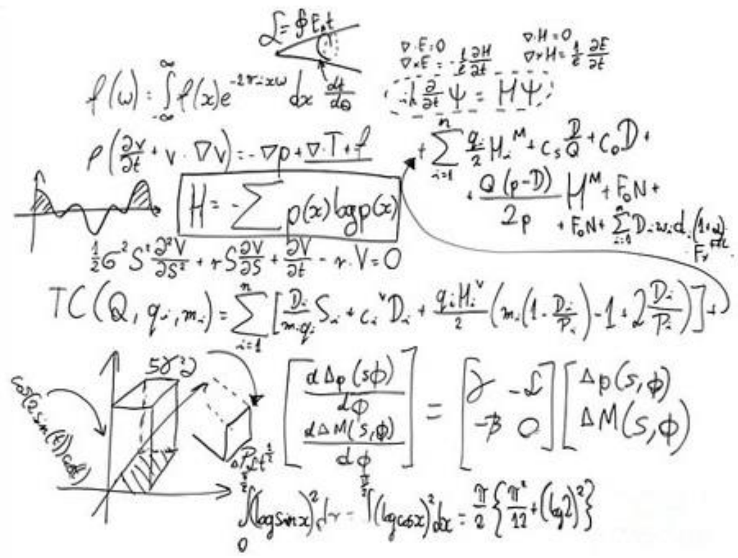
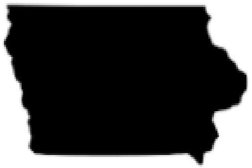
Process

- 1. Selection of water quality parameters that will determine the index value
- 2. Transformation of parameter data to common or arbitrary unit
- 3. Weighting of the parameter (not always done)
- 4. Aggregation of index values to final index score.



Iowa

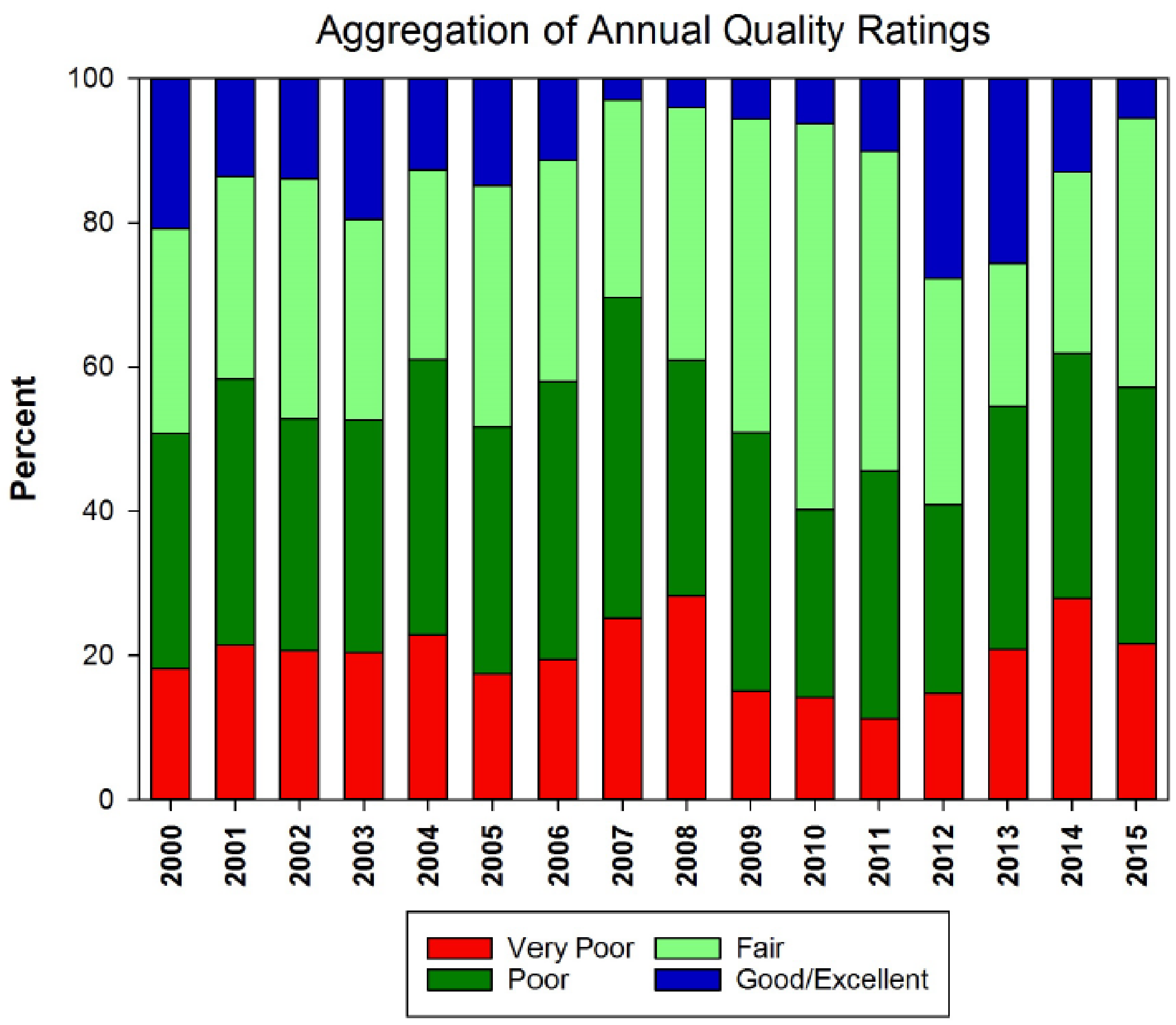


- WQI created by DNR in 2005
- Modification of WQI created by the National Sanitation Foundation

Parameter	IWQI	NSFWQI
Biological Oxygen Demand (BOD)	Yes	Yes
Dissolved Oxygen (DO)	Yes	Yes
E. coli	Yes	No
Fecal coliforms	No	Yes
Nitrate as Nitrogen (NO3-N)	No	Yes
Nitrate + Nitrite as Nitrogen (NOx-N)	Yes	No
Pesticides	Yes	No
Temperature	No	Yes
Total Dissolved Solids (TDS)	Yes	Yes
Total Phosphorous (TP)	Yes	Yes
Total Suspended Solids (TSS)	Yes	No
Turbidity	No	Yes

- Parameters in the IWQI were not weighed (NSFWQI were)
- The index was calculated by the square root of the number of parameters divided by the sum of the reciprocal of the squares of the parameter value.
- Geographically-specific subindex rating curves. For TDS, Iowa was divided into three sections: western half, the Paleozoic Plateau and the rest
- For TSS, Loess Hills, NW Iowa Driftplain, and the rest.
- IWQI rated bad waters worse and good waters better than NSFWQI.

Figure 1: Aggregate IWQI Ratings for Iowa Streams, 2000-2015



Rating	Index Value
Very Poor	10 to 25
Poor	25 to 50
Fair	50 to 70
Good	70 to 90
Excellent	90 to 100

Then 2014 happened

- -IWQI:
  - subindex of any parameter without a result to be assigned a score of 50 for that subindex.

- -In 2014, budget problems ended pesticide monitoring
- -IWQI with one subindex score of 50 and the rest at a maximum-best of 100 produced a total IWQI of 87
  - excellent rating was mathematically impossible.
- -Total pesticide levels:
  - below 1.5 parts per billion (ppb) rec
  - 1.5-3 ppm receive a 50;
  - greater than 3 ppb received a 10.
  - Historically, 90% of the Iowa sampl

Analysis of Iowa Water Quality Index

and

Proposed Alternative

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Prepared for: Iowa Department of Natural Resources

July 15, 2016

Three components of our work:

- Compare the parameters used for IWQI with those of other well-known water indices, within the context of their relevance for Iowa waters.
- Use available water quality from IDNR's water monitoring program to assess how the different indicators compare when applied to Iowa waters.
- Develop alternative(s) to IWQI that will more accurately assess Iowa waters while increasing utility of the "Index" concept for policy-makers, agencies, and lay people.

Tasks

1. Literature search and review
2. Data Aggregation
3. Apply Iowa data to existing indices
4. Develop potential alternative to IWQI
5. Reporting

Data Aggregation

Aggregated data from 12 watersheds that would be representative of the state as a whole (landforms, latitude, longitude)

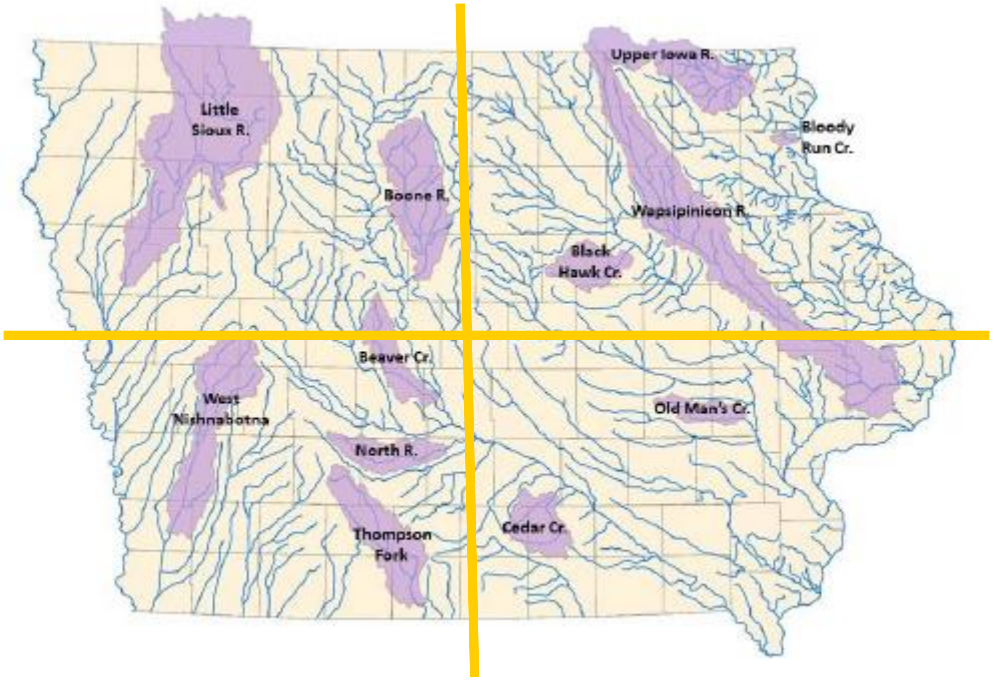


Figure 2: Watersheds of selected ambient sites.

Oregon WQI

- Ammonia
- Nitrate
- Total P
- Total solids
- Fecal coliforms
- Temperature
- Dissolved Oxygen
- BOD
- pH

- Water quality lab results are transformed into unitless subindex values ranging from 10 (worst) to 100 (best).
- These subindices are then combined to give a single WQI value ranging from 10 to 100.

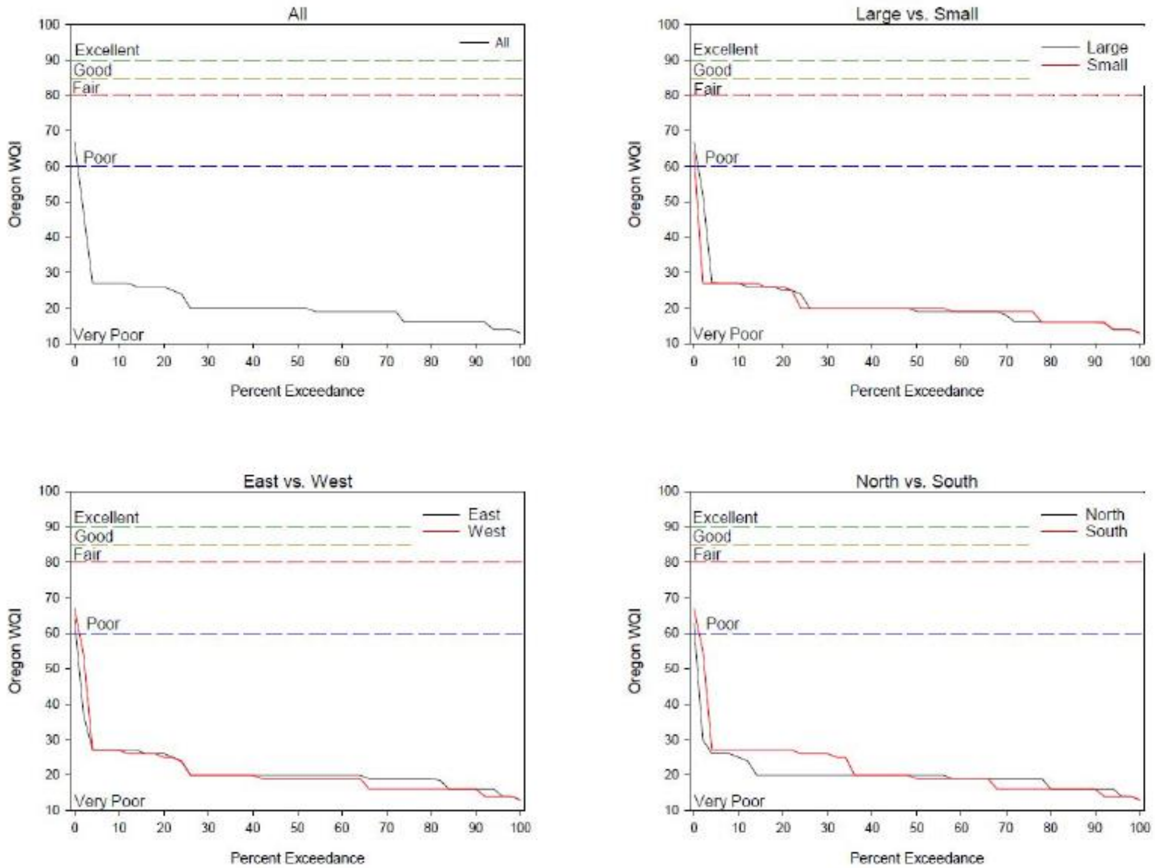


Figure 5: WQI values calculated using the Oregon WQI for 12 selected Iowa streams

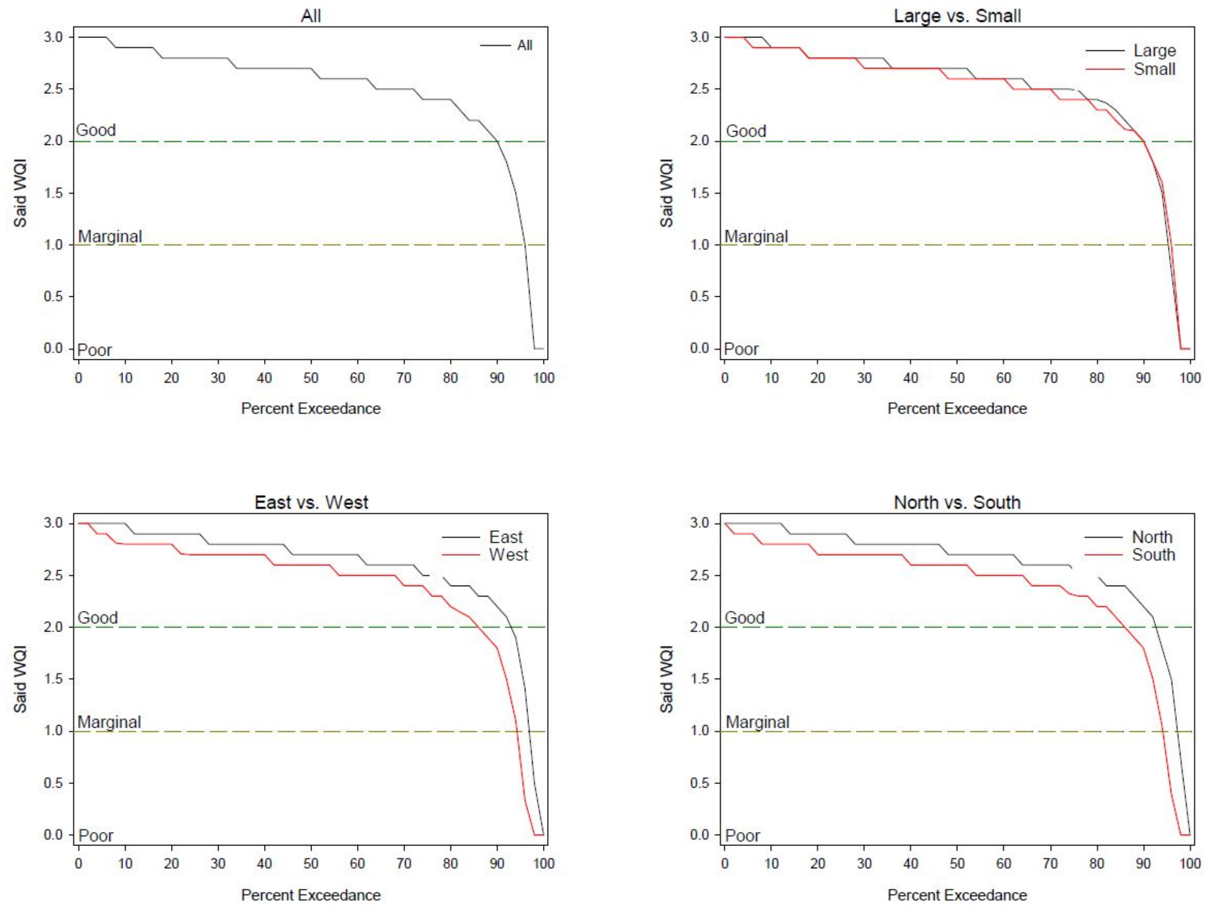
Water Quality Index of Said et al.

- DO
- TP
- Fecal Coliforms
- Turbidity
- Specific Conductance

- parameters weighted by their significance on water quality in the order of DO, fecal coliform, TP, turbidity, and SC.

- An algorithm then transformed the results to an index value ranging from 0 to 3.

- Emphasis on DO resulted in almost all Iowa streams rated ≥ good.



Alberta WQI

47 variables (metals, ions, pesticides, nutrients and related variables, bacteria).

"Performance Indicator" i.e. calculated based on the fraction of samples that meet designated thresholds.

Thresholds can be set at whatever level the user wants.

Index accommodates any number of parameters ≥ 2

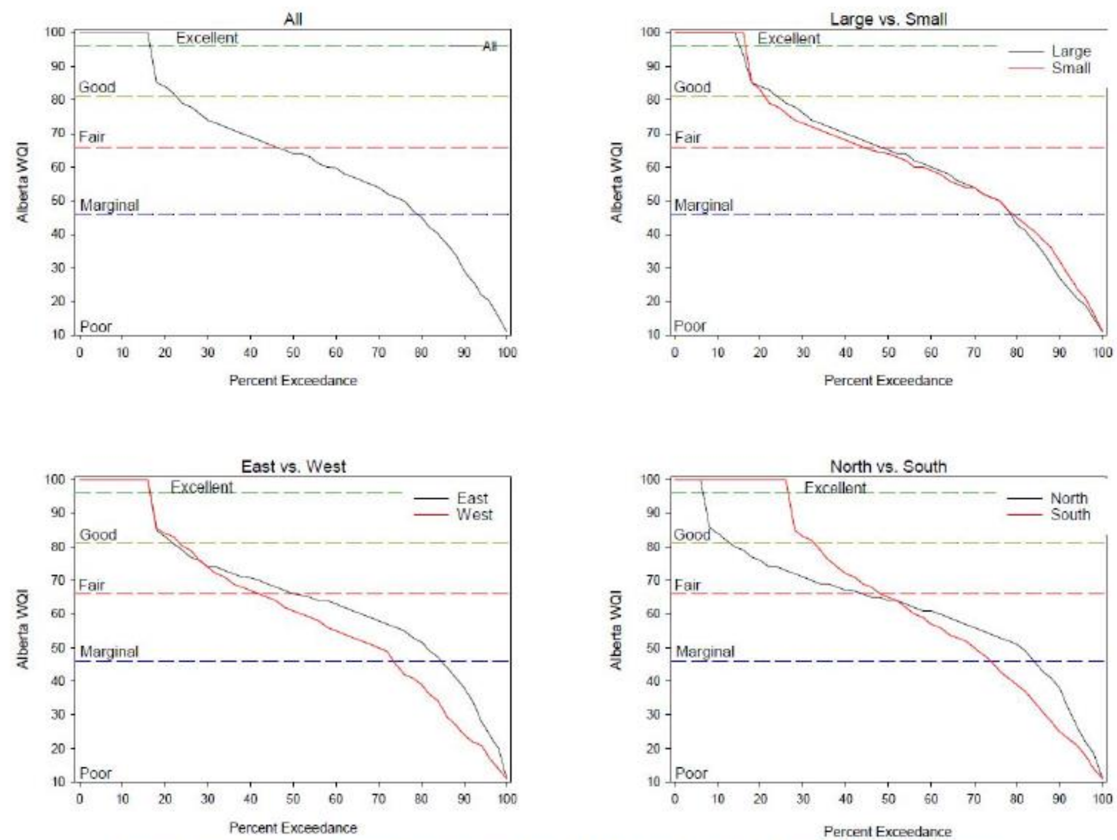


Figure 9: WQI values calculated using the Alberta WQI for 12 selected Iowa streams

Considerations

- Easy to understand by the public and policy makers.
- Focus on stressors most important to water quality in Iowa.
- Necessary monitoring is not prohibitively expensive.
- Sufficient flexibility to endure changes in budget.
- Able to allow incorporation ideas from DNR staff and scientists.
- Able to change with changing public perceptions and expectations.

The Water Quality Index Formula takes the following form:

$$Index\ Score = 100 - \left(\frac{\sqrt{F_1^{\ 2} + F_2^{\ 2} + F_3^{\ 2}}}{1.732} \right)$$

Where:

F₁ represents the number of water quality variables that do not meet objectives in at least one sample during the time period under consideration, relative to the total number of variables measured:

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}} \right) \times 100$$

F₂ represents the number of individual measurements that do not meet objectives, relative to the total number of measurements made in all samples for the time period of interest:

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \times 100$$

F₃ represents the amounts by which measurements depart from objectives. This is an asymptotic capping function that scales the normalized sum of the excursions from objectives (*nse*) to yield a range between 0 and 100:

$$F_3 = \left(\frac{nse}{0.01nse + 0.01} \right)$$

The *nse* variable represents the amount by which water quality is out of compliance. This is calculated by summing the departures of individual tests from their objectives, and dividing by the total number of tests:

What parameters are driving water quality in Iowa Streams?

What parameters can be easily and inexpensively monitored?

1. Dissolved Oxygen
2. Total Nitrogen (Kjeldahl N, Nitrate, Nitrite)
3. Total Phosphorus
4. *E. coli*
5. Turbidity

Threshold Scenarios

Scenario 1	threshold	Scenario 2	threshold	Scenario 3	threshold	Scenario 4	threshold
E. coli	235 MPN/100 ml	E. coli	235 MPN/100 ml	E. coli	235 MPN/100 ml	E. coli	235 MPN/100 ml
Total N	3.5 mg/L	Total N	3.5 mg/L	Total N	3.5 mg/L	Total N	3.5 mg/L
Turbidity	50 NTU	Turbidity	25 NTU	Turbidity	50	Turbidity	25
DO	5 mg/L	DO	5 mg/L	DO	5 mg/L	DO	5 mg/L
Total P	0.18 mg/L	Total P	0.18 mg/L	ortho P	0.1 mg/L	ortho P	0.1 mg/L

Modeled WQI for the 4 Scenarios

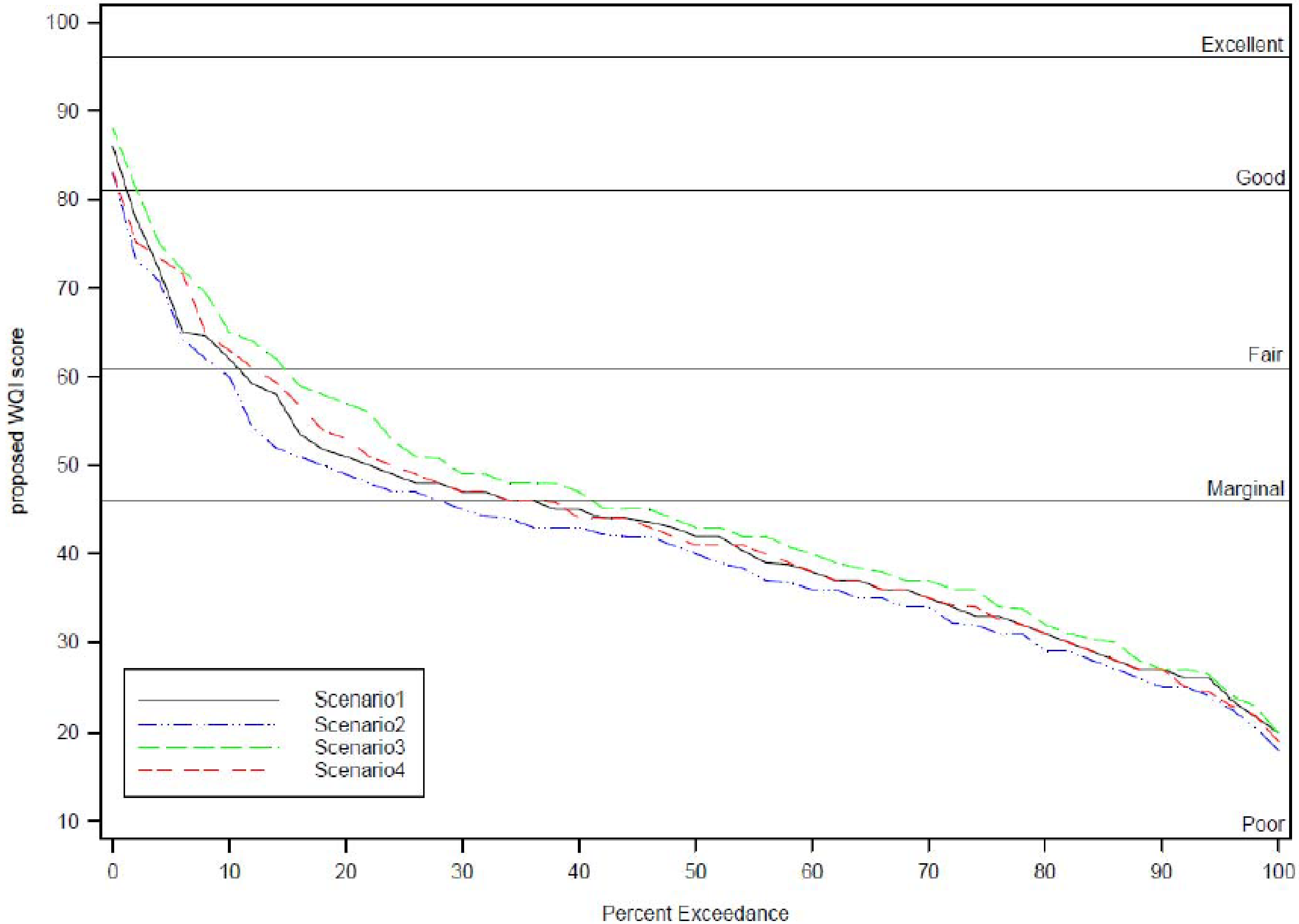
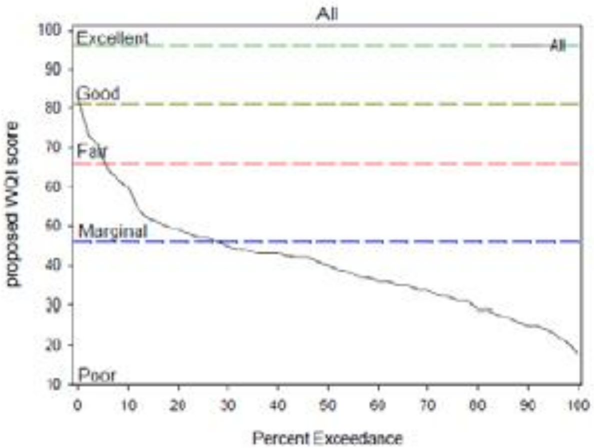
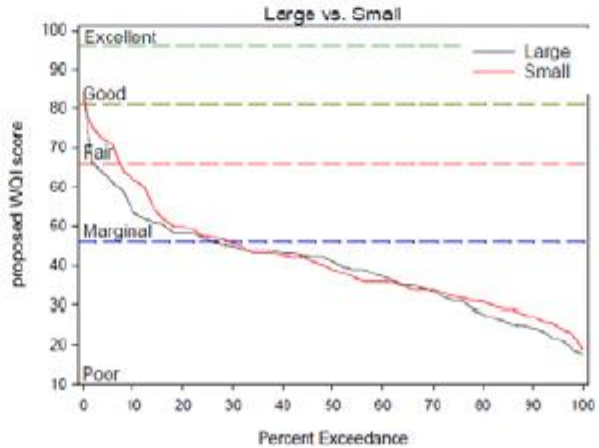
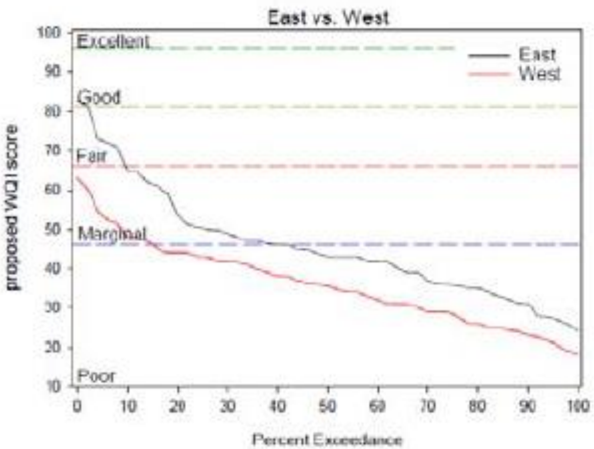
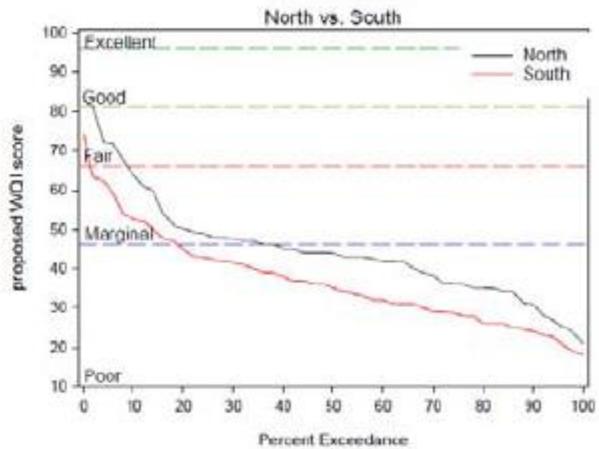


Figure 10: Scores for 12 Iowa streams using the proposed WQI under the four different threshold scenarios, 2000-2015









End of DNR project

Scenario 2	threshold
E. coli	235 MPN/100 ml
Total N	3.5 mg/L
Turbidity	25 NTU
DO	5 mg/L
Total P	0.18 mg/L

2000-2020

>96=Excellent

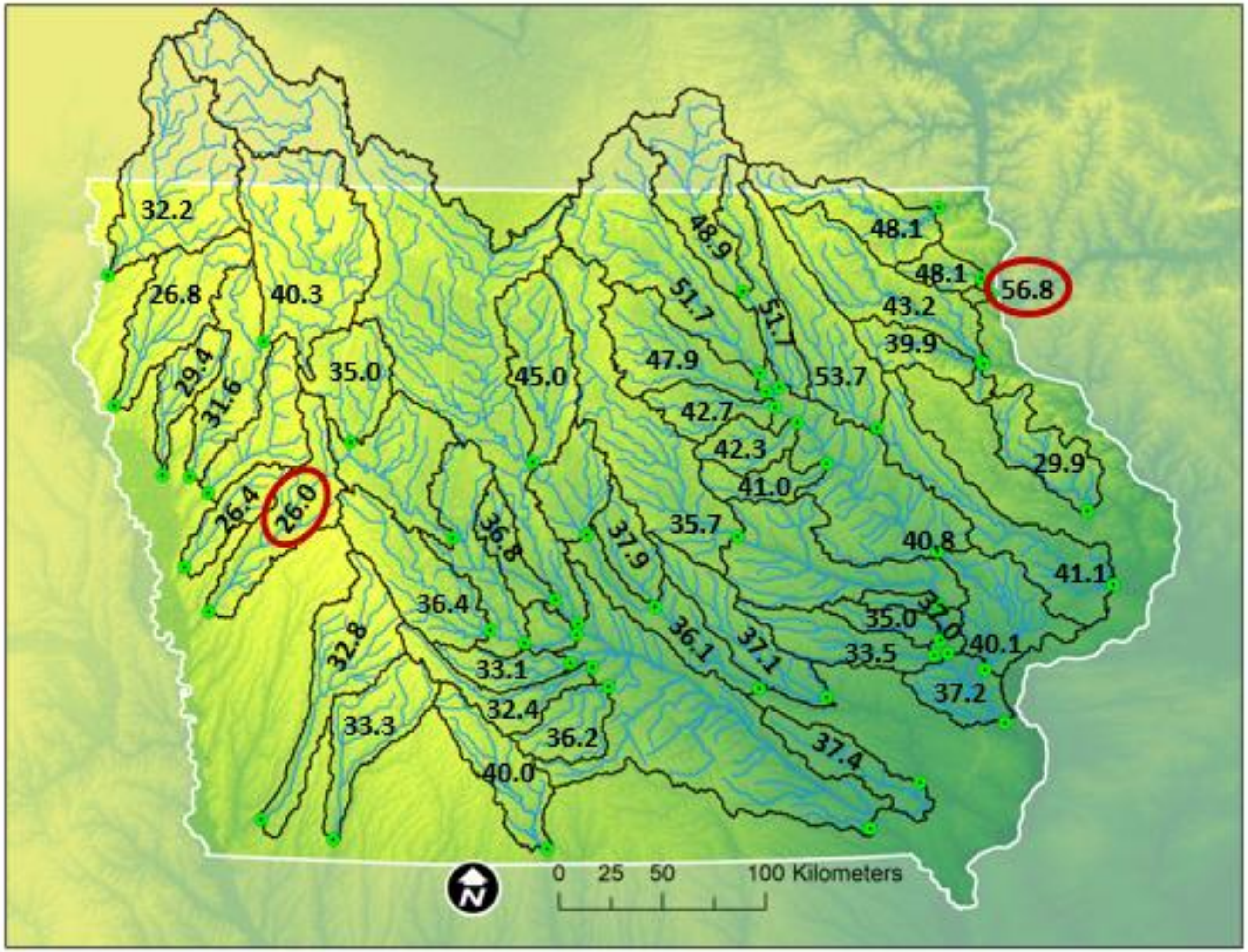
81-95=Good

66-80=Fair

46-65=Marginal

10-45=Poor

<10=Very Poor



Environment

The Battle Over Bloody Run Creek

Iowa Public Radio | By Clay Masters
Published July 1, 2021 at 5:00 AM CDT

LISTEN • 6:21

Clay Masters / IPR

2016-2020

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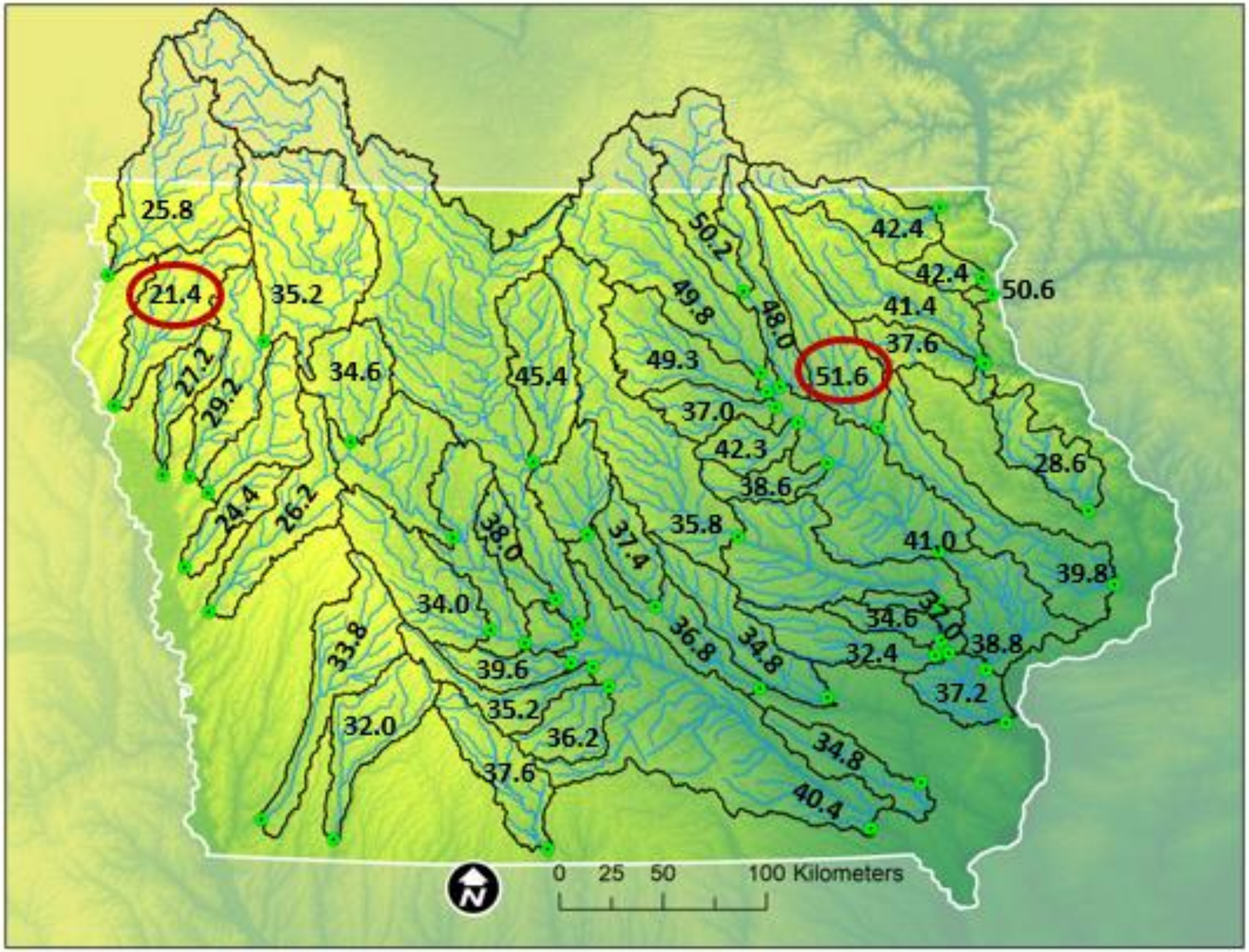


2016-2020 vs 2000-2016

wqi	water quality index
DO	Dissolved oxygen
EC	E. coli
N	Total nitrogen
P	Total phosphorus
Turb	Turbidity
	less than 5% change
	5 to 10% improvement
	10-20% improvement
	>20% improvement
	5-10% deterioration
	10-20% deterioration
	>20% deterioration

3/44 improving (>5%)

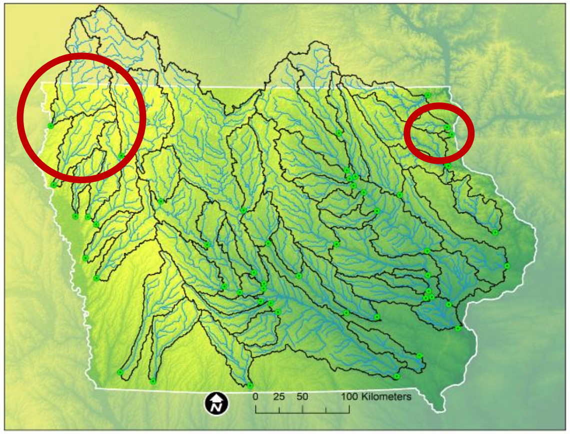
16/44 <5% change

25/44 declining (>5%)

WQI DO EC TN TP TURB

Location	group	WQI	Percent Change, 2016-20 versus pre-2016					
		2016-20	change wqi	change DO	change EC	change N	change P	change turb
Wapsipinicon River at Independence	Iowan Surface	51.6	-5.1	-1.0	31.6	12.0	50.0	18.3
Bloody Run Cr at Marquette	Paleozoic Plateau	50.6	-14.4	-1.7	111.8	18.0	62.5	198.3
Cedar River at Charles City	Iowan Surface	50.2	4.4	-1.8	-38.1	-2.6	-9.5	-0.7
Shellrock River at Shellrock	Iowan Surface	49.8	-4.8	-5.2	30.0	-2.1	11.1	-12.3
W. Fork of the Cedar River at Finchford	Iowan Surface	49.3	2.8	-4.7	55.6	0.1	21.4	0.0
Cedar River at Janesville	Iowan Surface	48.0	-11.1	-9.8	51.5	3.3	11.8	-12.1
Boone River at Stratford	Des Moines Basin Up	45.4	1.3	-4.3	-16.8	-8.0	-16.7	-13.8
Upper Iowa River at Dorchester	Paleozoic Plateau	42.4	-14.7	-8.4	-51.7	20.5	0.0	-9.3
Yellow River at Ion	Paleozoic Plateau	42.4	-17.3	-5.8	-48.7	27.6	21.1	76.5
Blackhawk Creek at Waterloo	Iowan Surface	42.2	-0.2	0.0	-5.8	-2.3	-5.9	20.4
Turkey River at Garber	Paleozoic Plateau	41.4	-5.5	-2.7	-44.3	8.8	-10.3	5.4
Cedar River Downstream of Cedar Rapids	Iowan Surface	41.0	0.7	0.9	17.6	5.9	-13.3	31.0
Des Moines River at Keosauqua	Des Moines Basin Down	40.4	-6.5	-1.8	161.9	7.8	-17.1	53.6
Wapsipinicon River at DeWitt	Iowan Surface	39.8	-5.0	-8.2	6.0	1.1	13.6	0.3
North River at Norwalk	Des Moines Basin Down	39.6	23.0	2.1	-80.6	-19.1	-24.2	-21.1
Cedar River at Conesville	Iowan Surface	38.8	-4.2	-9.4	21.5	-0.7	-5.6	-6.0
Wolf Creek at LaPorte City	Iowan Surface	38.6	-7.4	1.0	58.3	-6.3	12.5	15.4
Beaver Creek at Grimes	Des Moines Basin Up	38.0	4.4	3.8	-11.6	-16.7	43.8	-26.8
Thompson River at Davis City	Missouri River Trib	37.6	-7.8	-4.0	-32.3	0.5	10.7	-5.8
Volga River at Elkport	Paleozoic Plateau	37.6	-7.8	-3.7	-41.3	8.2	-7.4	-2.5
Indian Creek at Colfax	Iowa-Skunk	37.4	-1.8	-1.9	25.7	-20.9	3.6	25.1
Beaver Creek at Cedar Falls	Iowan Surface	37.0	-16.7	-3.6	-39.8	11.6	-7.1	13.3
South Skunk River at Oskaloosa	Iowa-Skunk	36.8	2.5	-2.8	-28.6	-29.1	-11.8	-3.7
South River at Ackworth	Des Moines Basin Down	36.0	-0.8	1.0	-35.9	0.0	3.2	18.8
Iowa River Downstream of Marshalltown	Iowa-Skunk	35.8	0.3	-0.9	-1.3	-3.5	-13.2	67.9
Middle River at Indianola	Des Moines Basin Down	35.2	7.0	-2.8	-68.7	-19.6	-16.7	-6.6
Little Sioux River at Larrabee	Missouri River Trib	35.2	-16.0	-8.0	200.0	9.2	8.0	39.9
Cedar Creek at Oakland Mills	Iowa-Skunk	34.8	-11.2	0.0	12.1	-25.0	-6.9	-13.6
North Skunk River at Sigourney	Iowa-Skunk	34.8	-7.9	0.0	12.1	-7.7	-6.9	-13.6
Iowa River at Lone Tree	Iowa-Skunk	34.8	-8.9	0.9	75.7	0.7	22.2	34.6
North Raccoon at Sac City	Des Moines Basin Up	34.6	-3.6	-2.8	87.6	-26.9	-37.5	12.9
Old Mans Creek at Iowa City	Iowa-Skunk	34.6	-1.4	-3.8	-48.7	-18.8	3.6	45.0
South Raccoon River at Redfield	Des Moines Basin Up	34.0	-8.4	-1.8	19.3	6.8	-14.3	-36.0
South Skunk River at Cambridge	Iowa-Skunk	34.0	7.3	-1.9	-24.1	-23.3	-40.0	80.5
E. Nishnabotna at Shenandoah	Missouri River Trib	33.8	2.4	-2.8	-43.8	-5.4	-19.1	-42.2
English River at Riverside	Iowa-Skunk	32.4	-5.0	1.0	-54.8	-9.4	6.3	38.9
W. Nodaway at Shambaugh	Missouri River Trib	32.0	-5.3	0.9	-15.9	-9.6	10.8	-17.5
Little Sioux River at Smithland	Missouri River Trib	29.2	-15.1	-2.8	-23.5	10.8	9.4	32.5
N. Fork Maquoketa R. at Hurtsville	Iowan Surface	28.6	-6.8	-2.8	7.7	7.7	56.3	85.1
West Fork Ditch at Hornick	Missouri River Trib	27.2	-9.6	-1.9	-22.2	17.6	21.1	8.8
Boyer River at Missouri Valley	Missouri River Trib	26.2	0.8	-6.5	70.9	-2.2	-36.6	-36.5
Rock River at Rock Valley	Missouri River Trib	25.8	-24.8	-3.8	392.8	44.7	38.5	31.4
Soldier River at Pisgah	Missouri River Trib	24.4	-10.0	0.0	-44.5	36.8	-1.9	-20.3
Floyd River at Sioux City	Missouri River Trib	21.4	-26.5	-1.0	235.9	35.2	6.8	88.4
	Iowan Surface	42.9	-4.5	-3.7	16.3	2.3	11.3	12.7
	Paleozoic Plateau	42.9	-11.9	-4.5	-14.8	16.6	13.2	53.7
	Des Moines Basin Up	38.0	-1.6	-1.3	19.6	-11.2	-6.2	-15.9
	Des Moines Basin Down	37.8	5.7	-0.4	-5.9	-7.8	-13.7	11.2
	Missouri River Trib	29.3	-11.2	-3.0	71.7	13.8	4.8	7.9
	Iowa-Skunk	35.0	-2.9	-1.0	-3.5	-15.2	-4.8	29.0

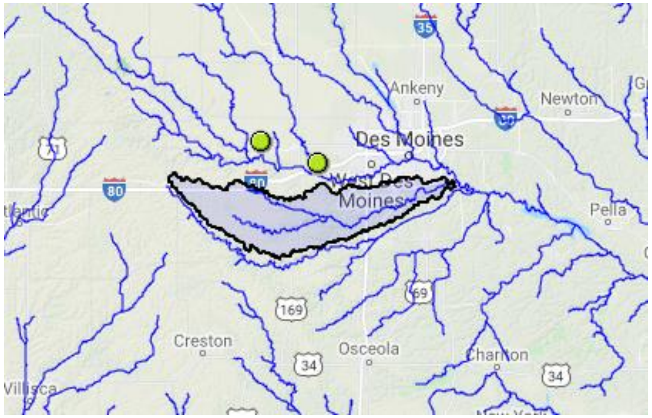
Category	Best ('16-20)	Biggest Improvement (%)	Worst ('16-20)	Biggest Deterioration (%)
WQI	Wapsi (Ind.)	North R.	Floyd R.	Floyd R.
DO	Bloody Run	Beaver Cr. (Grimes)	Thompson R.	Cedar R. (Janesville)
E Coli	Shellrock R.	North R.	Rock R.	Rock R.
TN	South R.	S. Skunk (Osk.)	Floyd R.	Rock R.
TP	Bloody Run	S. Skunk (Camb.)	Floyd R.	Bloody Run
Turb	Wapsi (Ind.)	E. Nishnabotna	South R.	Bloody Run

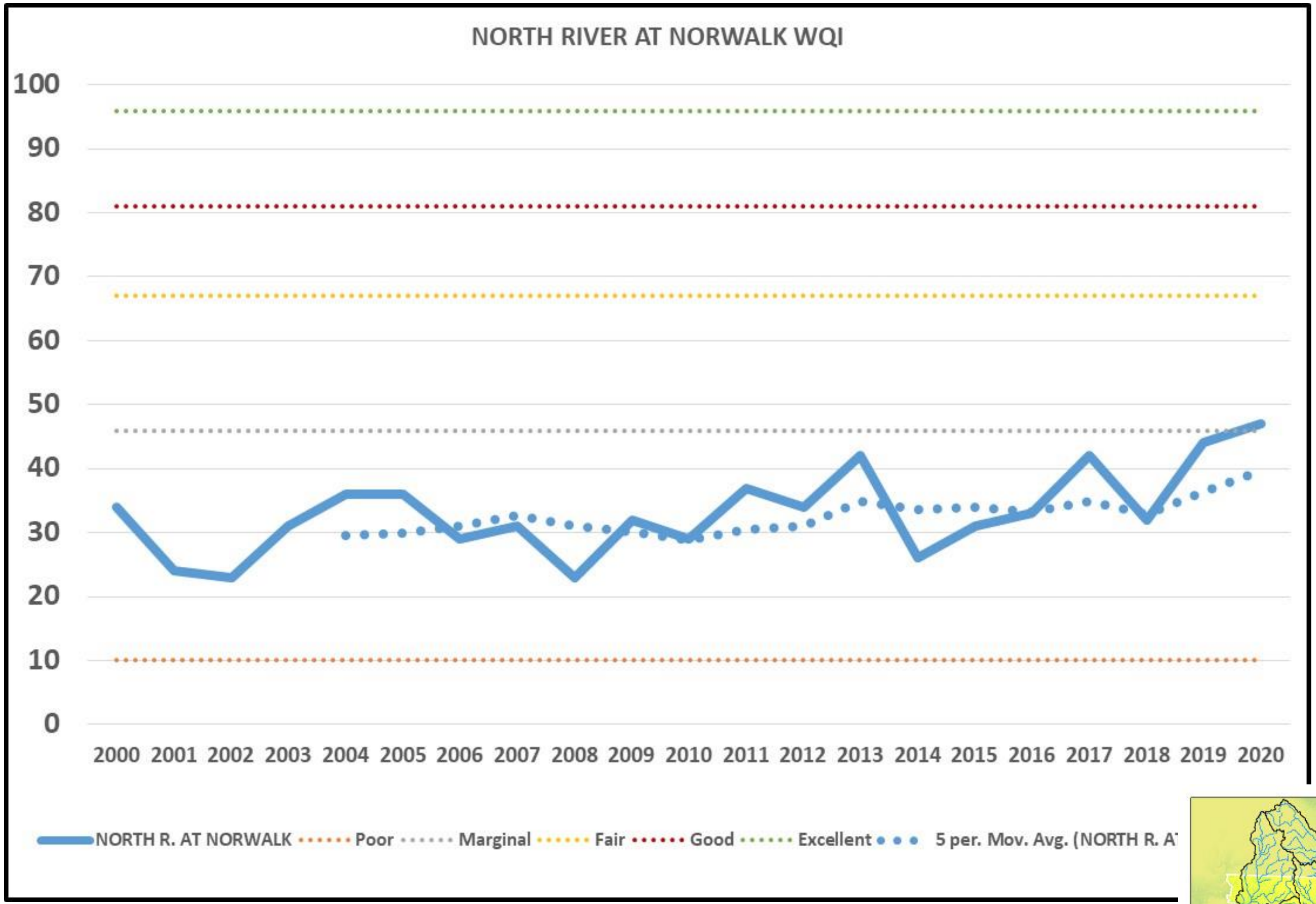


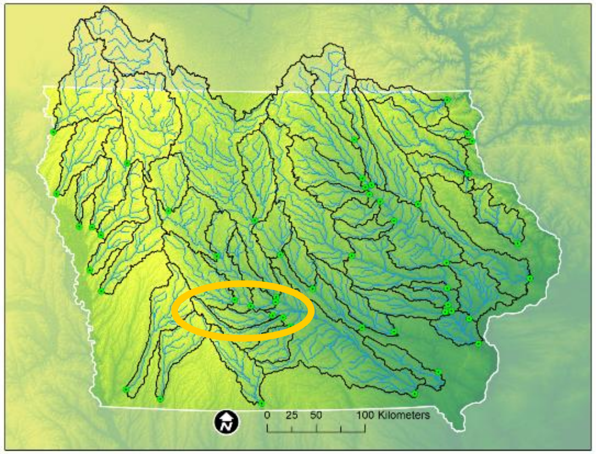
Overall Statewide Averages

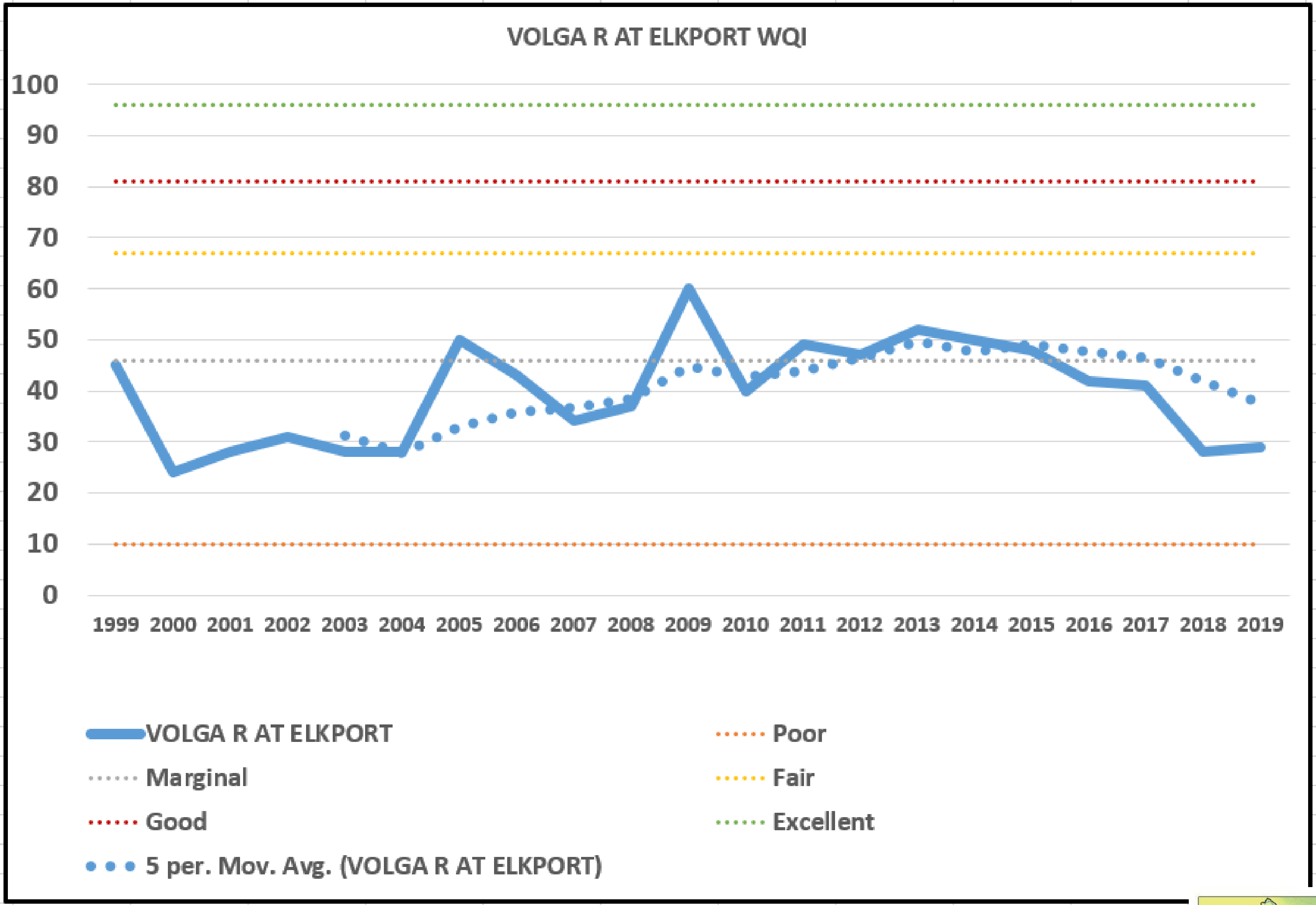
- 2000-2006: 38.1
- 2007-2013: 40.8
- 2014-2020: 37.5

One stream on continuous improvement: North River

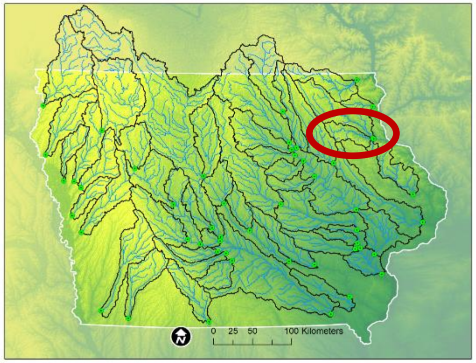


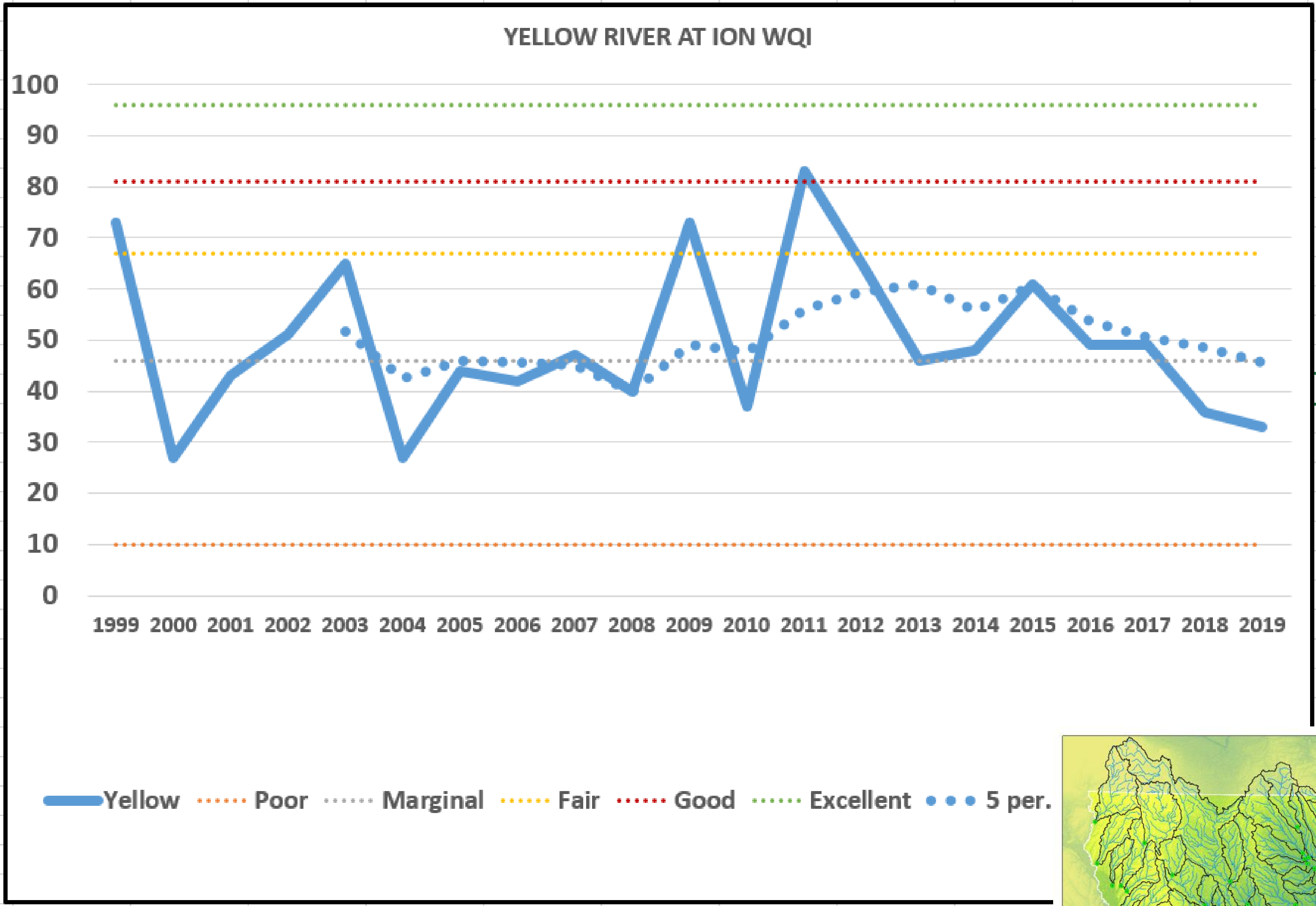

NORTH RIVER AT NORWALK WQI
100
90
80
70
60
50
40
30
20
10
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
NORTH R. AT NORWALK
Poor
Marginal
Fair
Good
Excellent
5 per. Mov. Avg. (NORTH R. A

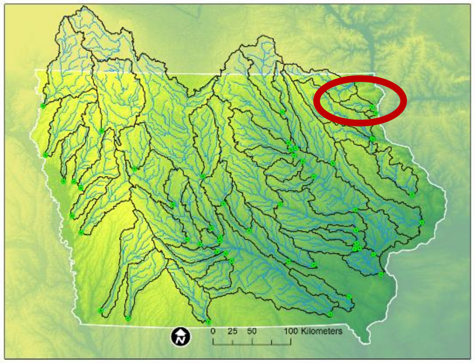

0 25 50 100 Kilometers

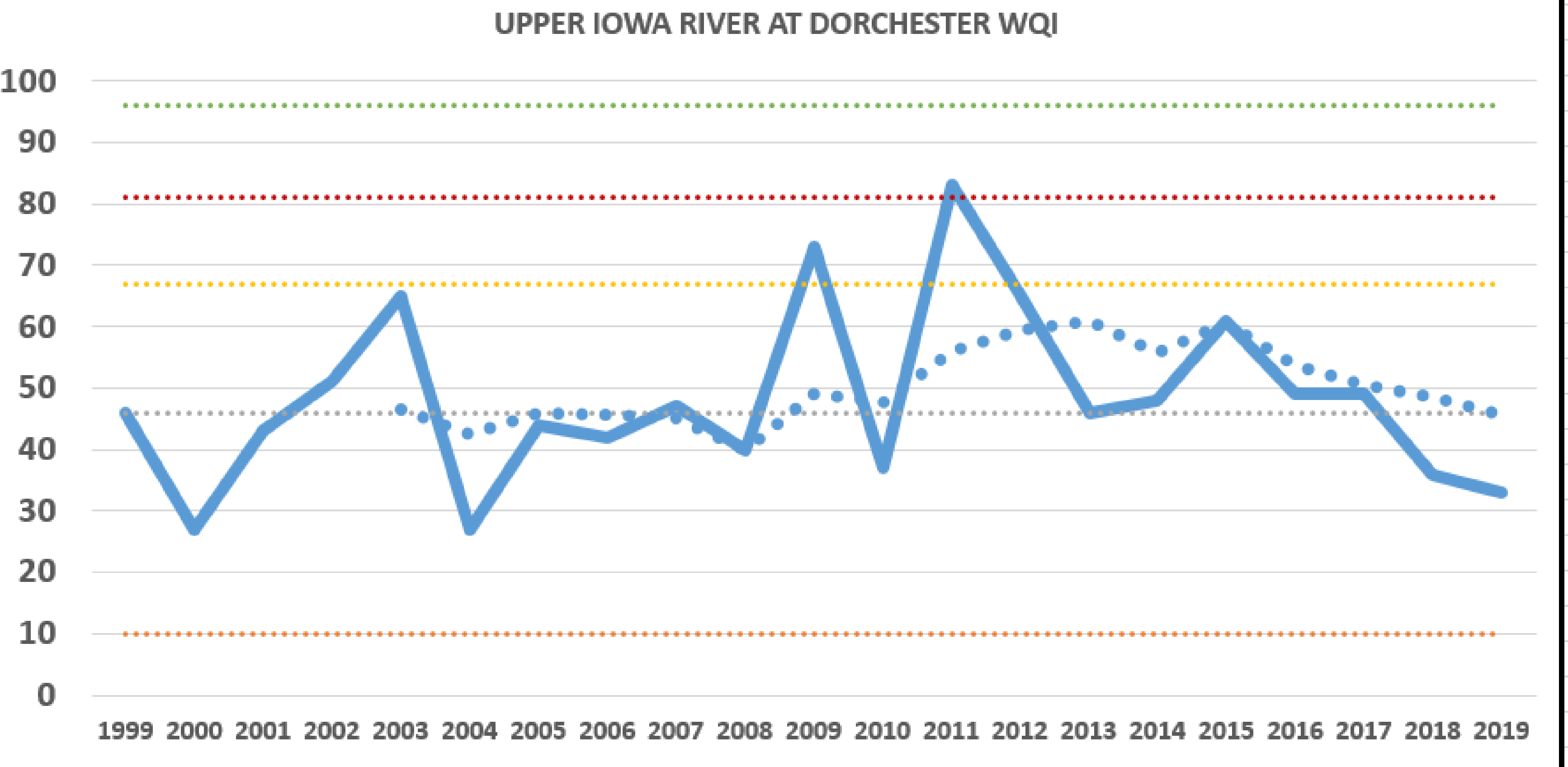


VOLGA R AT ELKPORT WQI
100
90
80
70
60
50
40
30
20
10
0
1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
VOLGA R AT ELKPORT
Poor
Marginal
Fair
Good
Excellent
5 per. Mov. Avg. (VOLGA R AT ELKPORT)

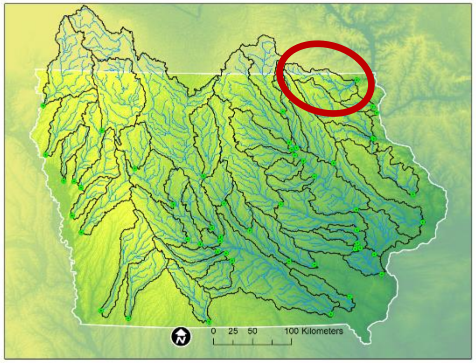


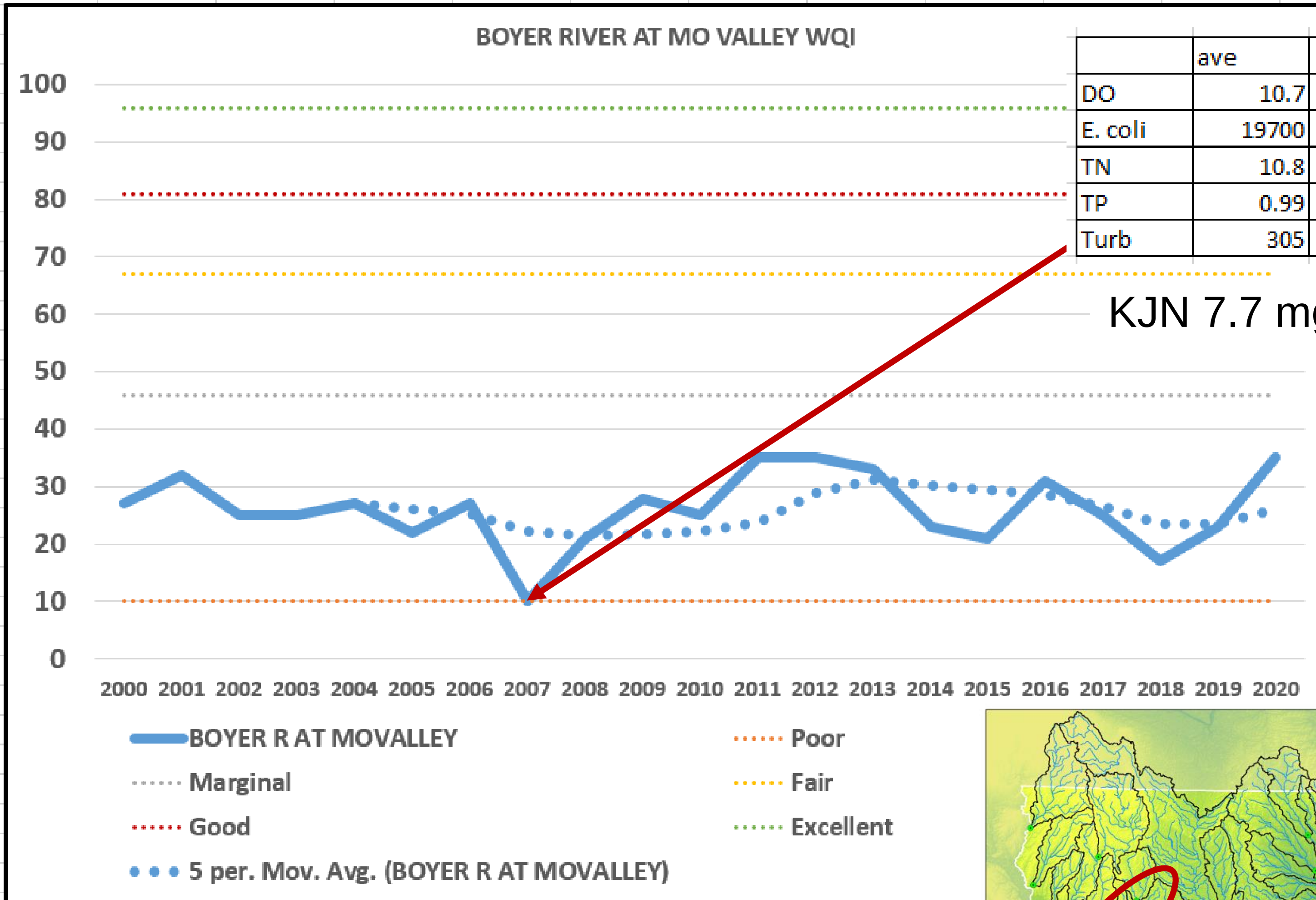

YELLOW RIVER AT ION WQI
100
90
80
70
60
50
40
30
20
10
0
1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Yellow
Poor
Marginal
Fair
Good
Excellent
5 per.


0 25 50 100 Kilometers



UPPER IOWA RIVER AT DORCHESTER WQI
100
90
80
70
60
50
40
30
20
10
0
1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
UPPER IOWA R. AT DORCHESTER
Poor
Marginal
Fair
Good
Excellent

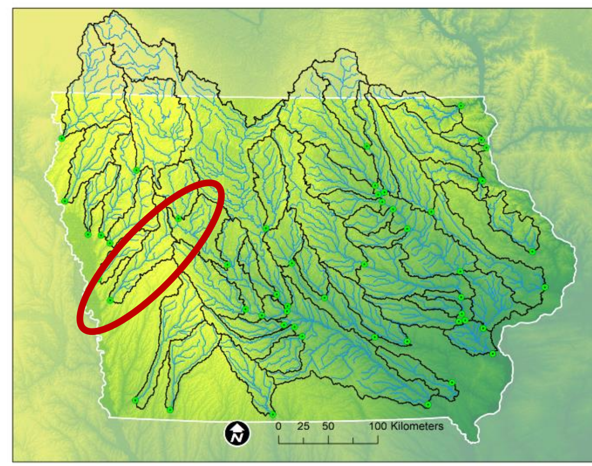




	ave	7-Aug
DO	10.7	4.7
E. coli	19700	220,000
TN	10.8	9.6
TP	0.99	5.4
Turb	305	2600

KJN 7.7 mg/L!

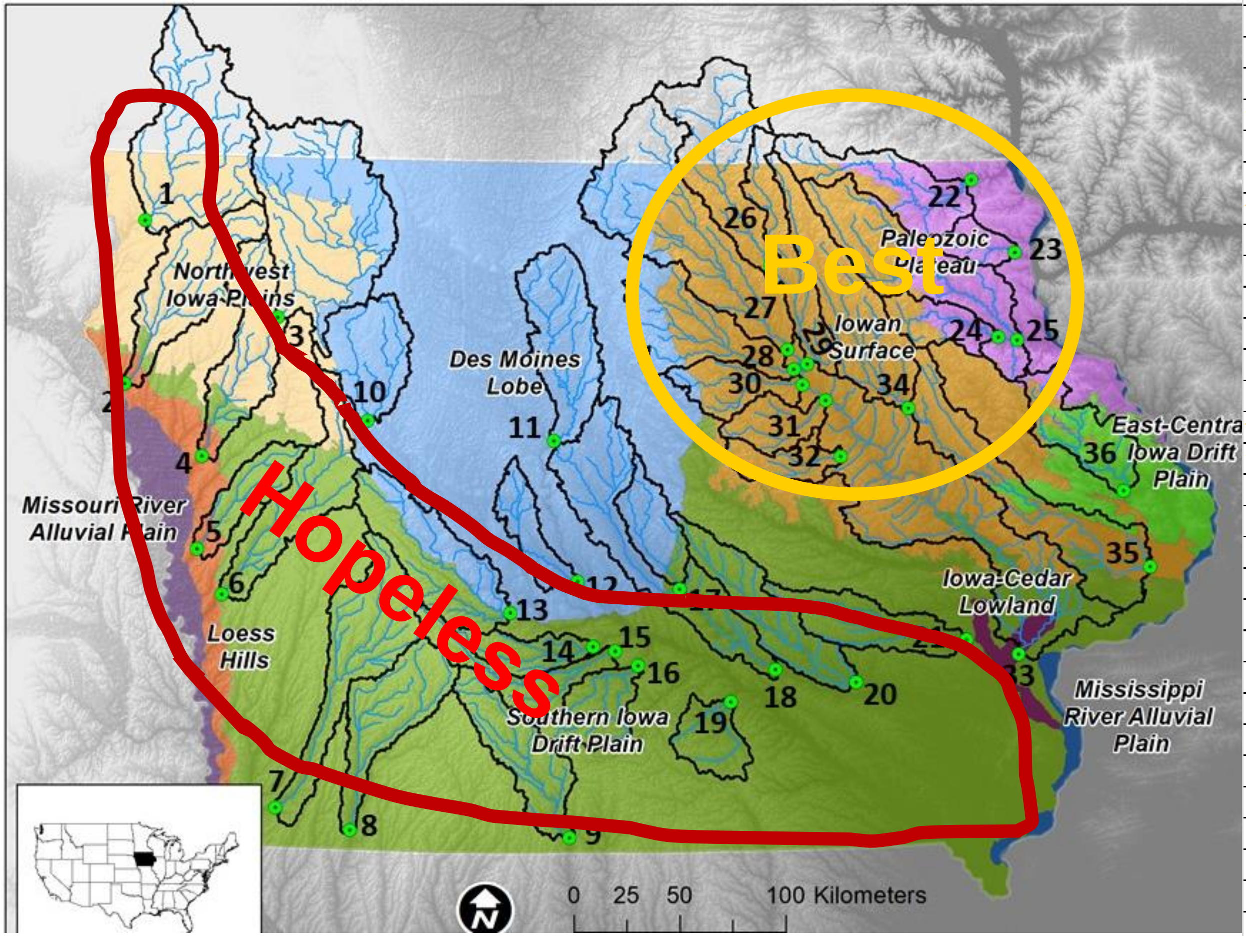
[River runner]



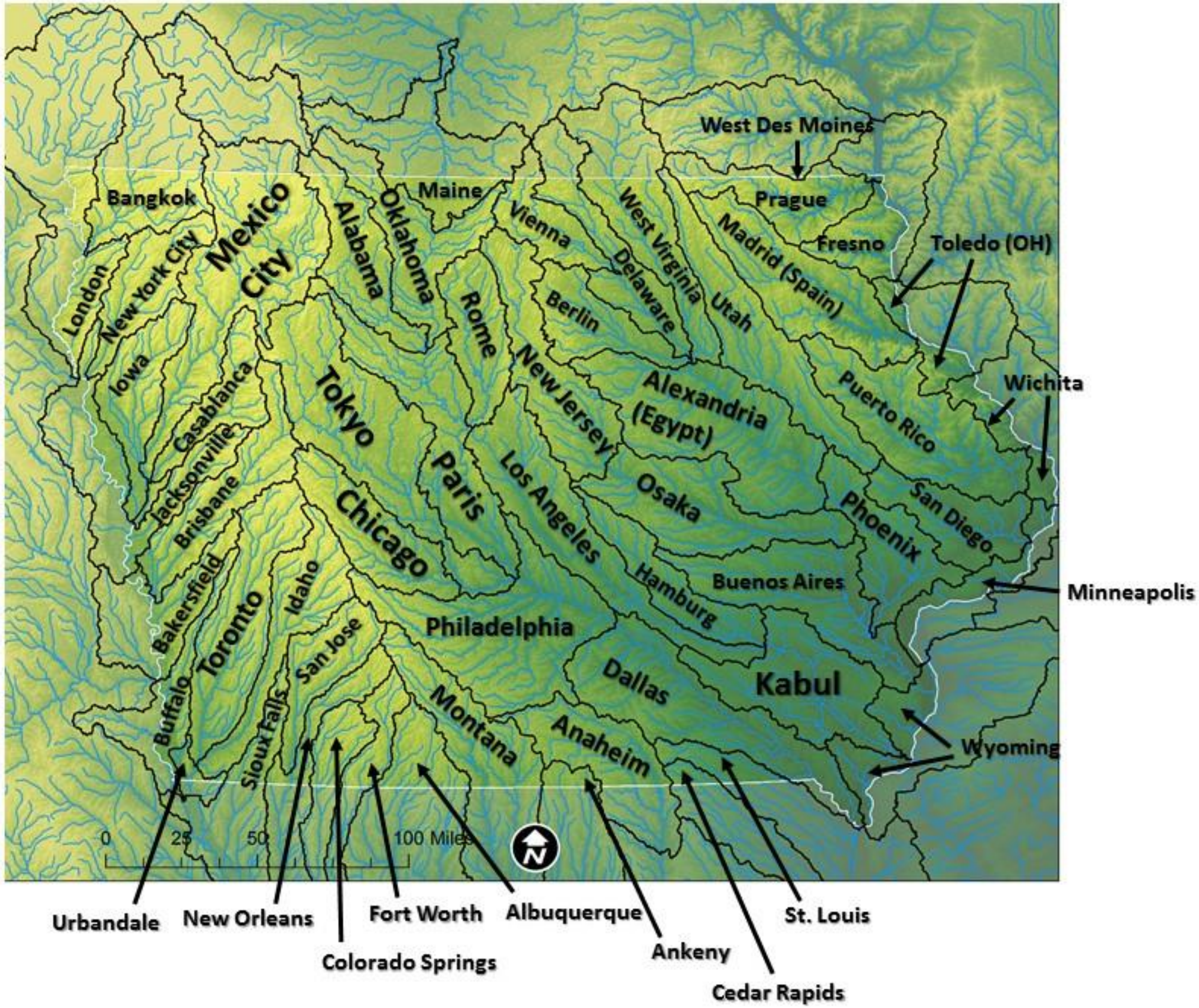
What parameter(s) are separating Iowa streams?

Parameter	%EXC	EX/TH	AVE VALUE
DO	0.04	0.03	0.24
EC	0.60	0.37	0.57
TN	0.02	0.04	0.00
TP	0.51	0.26	0.58
TURB	0.68	0.16	0.49

Table 3. R2 values calculated from linear regression equations when the percentage of samples exceeding the threshold (%EXC), the average ratio of exceedances:threshold (EXC/TH), and long term average value for the parameter are plotted versus the WQI (2000-2020).



Site	Rank	Map #	00-20
Wapsipinicon River at Independence	1	34	53.7
Cedar River at Janesville	2	29	51.7
Shellrock River at Shellrock	3	27	51.7
Cedar River at Charles City	4	26	48.9
Upper Iowa River at Dorchester	5	22	48.1
Yellow River at Ion	6	23	48.1
W. Fork of the Cedar River at Finchford	7	28	47.9
Boone River at Stratford	8	11	45.0
Turkey River at Garber	9	25	43.2
Beaver Creek at Cedar Falls	10	30	42.7
Blackhawk Creek at Waterloo	11	31	42.3
Wapsipinicon River at DeWitt	12	35	41.1
Wolf Creek at LaPorte City	13	32	41.0
Little Sioux River at Larrabee	14	3	40.3
Cedar River at Conesville	15	33	40.1
Thompson River at Davis City	16	9	40.0
Volga River at Elkport	17	24	39.9
Indian Creek at Colfax	18	17	37.9
Cedar Creek at Oakland Mills	19	19	37.4
North Skunk River at Sigourney	20	20	37.1
Beaver Creek at Grimes	21	12	36.8
South Raccoon River at Redfield	22	13	36.4
South River at Ackworth	23	15	36.2
South Skunk River at Oskaloosa	24	18	36.1
North Raccoon at Sac City	25	10	35.0
English River at Riverside	26	21	33.5
W. Nodaway at Shambaugh	27	8	33.3
North River at Norwalk	28	14	33.1
E. Nishnabotna at Shenandoah	29	7	32.8
Middle River at Indianola	30	15	32.4
Rock River at Rock Valley	31	1	32.2
Little Sioux River at Smithland	32	4	31.6
N. Fork Maquoketa R. at Hurtsville	33	36	29.9
Floyd River at Sioux City	34	2	26.8
Soldier River at Pisgah	35	5	26.4
Boyer River at Missouri Valley	36	6	26.0


West Des Moines
Prague
Bangkok
Mexico City
Alabama
Oklahoma
Maine
Vienna
West Virginia
Madrid (Spain)
Fresno
Toledo (OH)
London
New York City
Delaware
Berlin
Utah
Rome
Iowa
Casablanca
Tokyo
New Jersey
Alexandria (Egypt)
Puerto Rico
Wichita
Jacksonville
Brisbane
Paris
Los Angeles
Osaka
Phoenix
San Diego
Chicago
Bakersfield
Idaho
Hamburg
Buenos Aires
Minneapolis
Toronto
San Jose
Philadelphia
Dallas
Kabul
Buffalo
Sioux Falls
Montana
Anaheim
Wyoming
0
25
50
100 Miles
N
Urbandale
New Orleans
Colorado Springs
Fort Worth
Albuquerque
Ankeny
Cedar Rapids
St. Louis

What Can Be Done?

1. Ban cropping in the 2-year Flood Plain

2. Ban fall tillage

3. Ban manure on snow and frozen ground

4. Make farmers adhere to ISU fertilization guidelines

5. Reformulate CAFO Regulations

https://cjones.iihr.uiowa.edu/