ENVIRONMENTAL WORKING GROUP

DECEMBER 2012

MURKY WATERS: Farm Pollution Stalls Cleanup of Iowa Streams

by
Craig Cox, EWG Senior Vice-President for Agriculture and Natural Resources
and
Andrew Hug, EWG Analyst

www.ewg.org
1436 U Street NW, Suite 100
Washington, DC 20009

Photo by NRCS

Table of Contents

Acknowledgments

The authors would like to thank Karl Pazdernik of Iowa State University for running statistical analyses on these datasets and explaining the statistical tests. We would also like to thank Richard Langel of the Iowa Geological Survey Bureau for providing the raw data and answering numerous questions about it; Jill Sherwood and Robin McNeeley of the Iowa State University GIS Lab for early GIS analyses, and Mary Skopec of the Iowa Geological Survey for her review of the science.

We would also like to thank EWG colleagues past and present: Soren Rundquist for his extensive GIS work and assistance organizing data, Brett Lorenzen for finding data, Olga Naidenko for her encouragement and research, Taylan "Ty" Yalniz for the excellent layout and especially Nils Bruzelius for his thorough editing.

We also thank a great many others in the state who provided data, success stories or helped with interpretation of data. We thank all of you for your commitment to improving the quality of Iowa's waters.

Murky Waters:
Farm Pollution Stalls Cleanup of Iowa Streams

By
Craig Cox, EWG Senior Vice President for Agriculture and Natural Resources
Andrew Hug, EWG Analyst

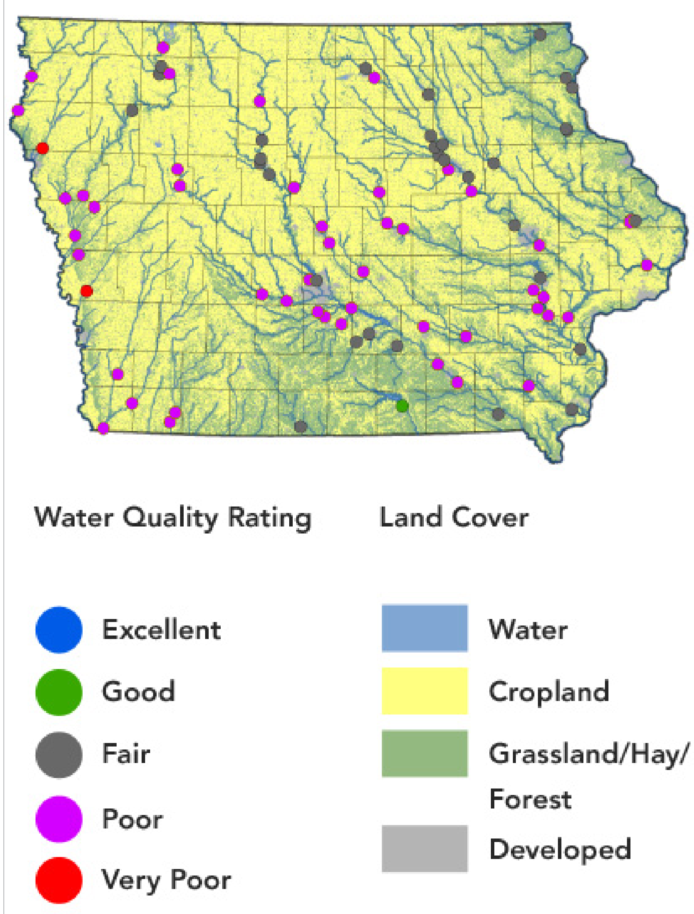
EXECUTIVE SUMMARY

Forty years after the Clean Water Act became law, the data are clear: Iowa's rivers and streams are still murky. The pollution that continues to degrade them has become a case study on the consequences of the most serious flaw in this historic and otherwise effective federal law: It does little or nothing to address agricultural pollution.

Chronic Poor Water Quality

An EWG analysis shows that from 2008 to 2011, water quality was rated "poor" or "very poor" at 60 percent of the 98 stream segments monitored by the Iowa Water Quality Index. The Index, produced by the Iowa Department of Natural Resources (IDNR), uses data from a stream-monitoring network created in 1999 to provide objective measures of how the state's free-flowing waterways are faring. EWG's analysis found that none of the sites had "excellent" water quality

Figure 2: Location and Average Condition of 83 Iowa Stream Segments, 2008-2011



during the most recent 36-month period studied, and only one was rated "good."

During the summer months, when Iowans flock to enjoy the outdoors, the Index ratings paint an even grimmer picture. Year after year, from May through August, the rankings of many more streams fall into the "very poor" or "poor" categories.

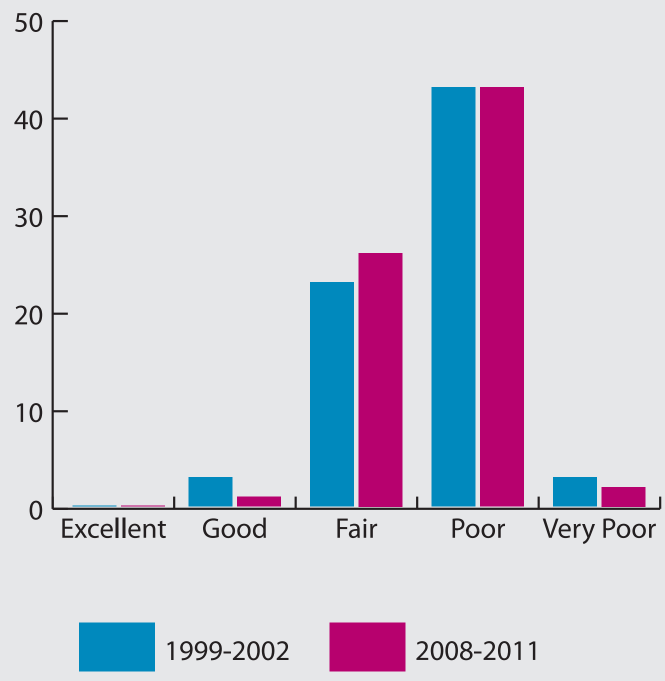
During the three summers between 2009 and 2011, fully 80 percent (66 of 83 sites with complete data) had average ratings of "very poor" (7) or "poor" (59). That was 32 percent more than the year-round averages for those years, because comparatively better wintertime scores tend to offset the very bad scores of summer. The number of monitored streams rated "fair" dropped in half during summer months, to just 16, and only one held on to its "good" rating.

The two pollutants most responsible for poor water quality ratings in the Index are nitrogen and phosphorus. In 55 percent of the monthly samples across all sites, nitrogen was the single worst pollutant, followed by phosphorus in 30 percent. Together, high levels of nitrogen and phosphorus set off a cascade of pollution problems that contaminate drinking water and damage the health of Iowa's streams and rivers.

Water Quality: Not Getting Better

EWG's analysis found no evidence that Iowa's water quality has improved since 1999. To account for variations in weather and stream flow, we averaged the ratings for the 36 months from October 1999 to September 2002 and compared them to the average ratings for the most recent 36 months (October 2008 through September 2011). Of the 72 sites that have 36 months of data for both periods, the number of stream segments rated "good" dropped from three to one, while the number rated "fair" increased from

Figure 5: Water Quality Index Ratings for 72 Monitoring Sites



23 to 26. The number rated "poor" was unchanged at 43, and the number rated "very poor" dropped from three to two.

Over the entire 12-year period, the condition of 16 sites improved, but 15 worsened. Only one – a site initially rated "good" that declined to "poor" – improved or worsened by more than one rank. The ratings of 41 out of 72 sites (57 percent) showed no change at all.

Worse yet, a statistical analysis of trends over the past 12 years predicts that Iowa's overall water quality will still be poor 10 years from now, given business as usual. Fifty percent (36) of the 72 stream segments analyzed will be in "poor" or "very poor" condition in 2021, compared to 51 percent (37) today. There still will be no stream segments ranked "excellent." Only two stream segments (3 percent) will be ranked "good," the same as today.

Overall, water quality in 68 percent of the monitored stream segments is either declining or stable. At those sites where the statistics show a positive trend, the improvement is so slow that there will be little change over the next ten years.

Table 2: Iowa water quality will still be poor in 10 years

	2011		2021	
	Number	**Percent (%)**	**Number**	**Percent (%)**
Very Poor	6	8	5	7
Poor	31	43	31	43
Fair	33	46	34	47
Good	2	3	2	3
Excellent	0	0	0	0
Total	72	100	72	100

Iowa Is Missing the Mark

According to the Iowa Department of Natural Resources, fully 92 percent of the nitrogen and 80 percent of the phosphorus – the two pollutants most responsible for the poor condition of the waterways that the Index monitors – come from non-point sources. Only 8 percent of the nitrogen and 20 percent of the phosphorus come from "municipal and industrial discharges." Yet Iowa's water quality regulation almost exclusively targets municipal and industrial discharges, while agricultural runoff remains largely unregulated.

Instead, Iowa relies on farm owners and operators to take voluntary measures to reduce pollution, and taxpayers pick up much of the cost. Iowa's towns, cities and industries don't have that choice. Under the federal Clean Water Act, they have been required to take often-expensive action to reduce pollution since 1977.

To make matters worse, the already inadequate funding for programs that pay farmers to take action to reduce their pollution is shrinking. Funding for the five programs that provide most of the money totaled only $11.5 million in fiscal year 2013, 23 percent below the $14.9 million in fiscal year 2002.

It Doesn't Have To Be This Way

Iowa's rivers and streams can be clean, but only if Iowans take concerted action to reduce the nitrogen and phosphorus overload from agricultural operations. The good news is that experience and science make it clear that concerted action does result in major improvements.

Iowa's voluntary programs could work much better if they were revamped to be more effective and were provided with a larger and more secure source of funding. The governor and the legislature must act to implement the Iowa Land and Water Legacy amendment endorsed by 63 percent of Iowans in 2010. The state's citizens voted to tax themselves to provide funding to clean up their water. It is time for Iowa's politicians to follow through. The Department of Agriculture and Land Stewardship must revamp the way voluntary programs are implemented to increase accountability, target resources to the right places, monitor and report on the farming and conservation practices used by farmers and make use of highly trained professionals to advise producers and make programs work.

Revamping the way conservation programs are implemented will produce better results more quickly. But even the most focused and best-managed voluntary programs will not be sufficient to solve the water quality problems associated with agricultural production if they remain entirely voluntary. More money will help, but even massive increases in funding will not overcome the inherent weaknesses of relying solely on voluntary action.

It is time to face facts – decades of working only with farmers who volunteer to reduce their polluted runoff has not achieved any overall improvement in Iowa's streams and rivers. This report shows that 40 years of the voluntary approach have failed to improve nitrogen and phosphorus pollution. EWG's 2011 report, "Losing Ground," similarly showed that 80 years of the voluntary approach had failed to adequately reduce pollution from sediment flowing off farm fields. The state must put in place smart and narrowly targeted regulations that curb poor farming practices. Regulations should phase out particularly risky practices such as planting crops right up to stream banks or allowing livestock unmanaged access to streams. Landowners and managers should be expected to control the ephemeral gully erosion that creates a direct pipeline for mud, fertilizer and manure flowing into streams and rivers. Many, if not most, farmers would agree that these activities are simply bad business practice and bad for agriculture's brand.

Since the boom in corn and soybean prices, simply driving across Iowa provides compelling evidence that voluntary programs must be buttressed with smart regulation to ensure that proper conservation practices don’t lapse. Conservation will have to become far more durable for there to be any hope of cleaning up Iowa’s streams and rivers.

Such regulations would establish a basic standard of care that comes along with the rights of land ownership. Voluntary programs can then be used to support those landowners and managers who meet these basic standards and want to do still more to clean up Iowa’s rivers and streams.

Precisely targeted regulation coupled with a strengthened voluntary program would set Iowa on a path toward cleaner water for our children and ourselves.

FULL REPORT

Introduction

Forty years after passage of the federal Clean Water Act triggered a nationwide cleanup of many of America's most polluted rivers, lakes and harbors, agricultural pollution remains a national embarrassment. The reason is simple. The Clean Water Act specifically exempted the fertilizer, chemicals and sediment that flow from farmland – often because of poor conservation practices – from the law's reach. While industry, sewage treatment plants, storm water drainage systems and other clearly identifiable sources of pollution have steadily, if slowly, been forced to comply with the law and stop dumping untreated waste in the nation's waterways, agriculture has faced no such requirements. Various federal and state programs have used financial and other incentives to encourage farms to clean up, but participation is entirely voluntary. The results, as this report shows, were predictable. Today, agricultural pollution is the greatest threat to water quality in the nation, and signs of progress are limited. From Chesapeake Bay to the Mississippi Basin to San Francisco Bay, runoff from agriculture fouls waterways, kills aquatic life and renders vast water bodies unsafe for recreation, fishing and drinking.

This report presents the results of EWG's analysis of 12 years of water quality monitoring conducted by the Iowa Department of Natural Resources (IDNR). In 2005, the department created the Iowa Water Quality Index to provide an objective measure of the condition of Iowa's streams. The Index is based on monthly water quality data from 98 stream-monitoring sites across the state. The water quality ratings are calculated from measurements of nine water quality parameters at each site [See Appendix A for details about the Index].

Taken together, the 12 years of data reflect a history of paralysis and inaction in Iowa, one that is almost certainly reflected in the majority of heavily agricultural areas across the nation. Water quality in the monitored streams is overwhelmingly fair, poor or very poor. It is rarely "good" and never "excellent." The passage of time has produced virtually no overall improvement, and statistical forecasts indicate that with business as usual, nothing will change over the next decade. But it doesn't have to be this way.

Environmental Working Group's Analysis

EWG researchers used Index water quality monitoring data to ask three main questions:

1. How clean are Iowa's streams and rivers today?
2. Is water quality getting better, worse or staying the same?
3. What will Iowa's water quality look like in 2021 given current trends?

We also looked at what Iowa has done over the past decade to clean up its water.

The answers we found paint a disturbing picture of Iowa's water quality today and in the future unless concerted action is taken to reduce polluted runoff from agricultural operations.

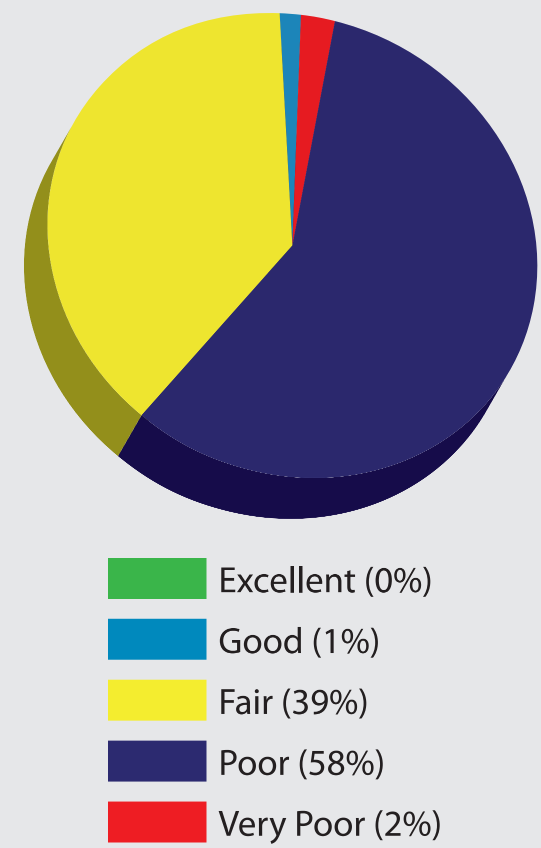
Stream Water Quality is Chronically Poor

To account for variations in weather and stream flow, the Environmental Working Group averaged the Water Quality Index data for two 36-month periods – from October 1999 to September 2002 and from October 2008 through September 2011 – for 83 sites on 52 streams that had a complete set of data for those two periods.[i]

That calculation showed that on average, 60 percent of the sites (50 stream segments) were in either "poor" or "very poor" condition. Thirty-two segments (39 percent) were rated "fair." No stream segment was rated "excellent," and only one was rated "good" (Figure 1).

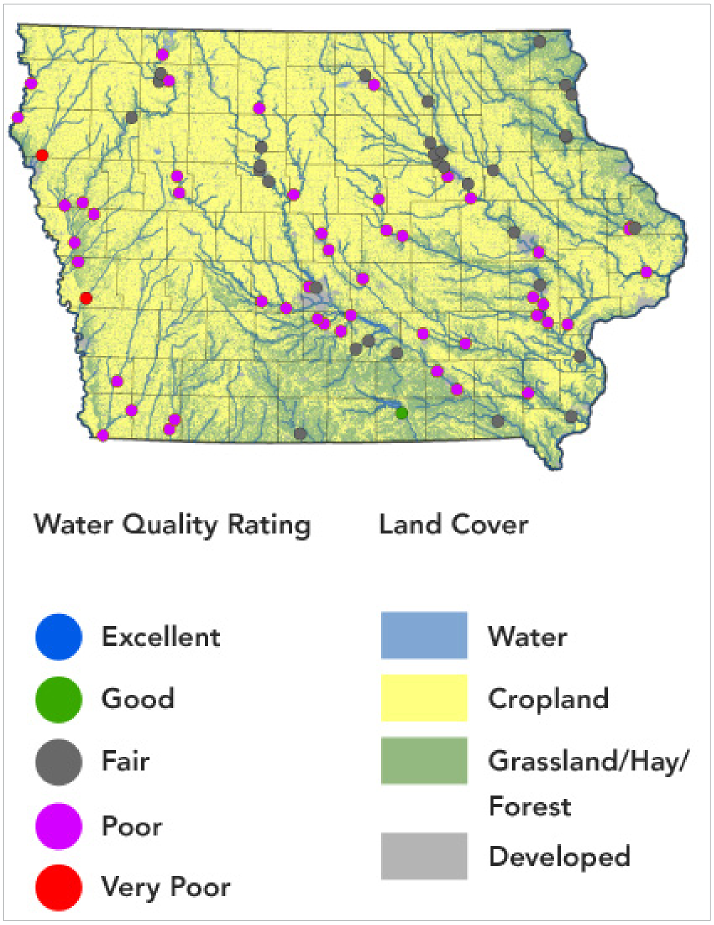
The only site that achieved an overall rating of "good" is on the Chariton River between Rathbun Lake and Centerville in far south central Iowa, where a number of unique factors apparently combine to produce good quality water. Only 38 percent of the land in the watershed draining to this site is planted in row crops, compared with an average of 64 percent elsewhere in Iowa. The watershed also has far more land covered in grass, hay and forest than most of the state. Such perennial vegetation dumps less nitrogen, phosphorus and sediment into streams than do row crops. However, even such land use differences are

Figure 1: Average Condition of Iowa Streams, 2008 to 2011



i. Due to budget issues DNR took no water quality samples for six months beginning in the fall of 2008. In order to obtain a complete data set of three years, with all seasons represented equally, EWG included data from the same months beginning in the fall of 2007. Two monitoring sites included by DNR in the first three years were not included in the last three years because even with the data supplementation described above, one had only 18 months and the other only 24 months of data. Two sites not included by DNR in the last three years were included in the first three years because data collection at a small percentage of sites had been terminated for various reasons.

Figure 2: Location and Average Condition of 83 Stream Segments, 2008-2011



likely responsible for less than half of the site's good water quality – the lake itself likely accounts for most of it. The monitoring site is only a few miles below the lake, which like any riverine reservoir significantly reduces the amount of sediment, phosphorus and nitrogen in the water downstream.

Figure 2 shows the location and water quality rank for each of the monitoring sites. Stream segments ranked "poor" or "very poor" in the Index are found everywhere in Iowa – the problem is not concentrated in just a few geographic areas.

Iowa's Water Quality is Far Worse in Summer

The Iowa Water Quality Index ratings get even worse during the summer months, when Iowans are trying to enjoy the outdoors. On average, far more streams fall into the "very poor" or "poor" categories in May, June, July and August.

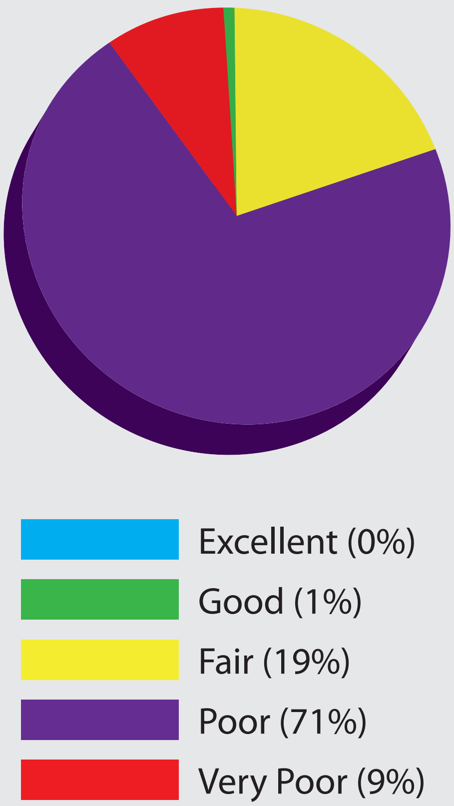
During the three summers between 2009 and 2011, fully 80 percent (66 streams) were rated "very poor" (7) or "poor" (59) on average, 32 percent more than the average for the full 36 months (Figure 3). That's because comparatively better wintertime scores tend to offset the very bad scores of summer. The number of monitored streams rated "fair" dropped in half, to just 16 streams. One was in "good" condition both in summer and year-round.

Comparing the State and Federal Water Quality Ratings

Under the federal Clean Water Act's 303(d) process, the Iowa Department of Natural Resources is required to assess the condition of the state's rivers and report those considered "impaired," which is defined as not meeting the criteria for various specific uses.

The Department uses a scientific methodology to identify impaired stream segments based on how clean the water must be to support its designated use.[1] A stream segment with a designated use of "primary contact recreation," for example, is considered impaired if a scientific assessment

Figure 3: Average Condition of Iowa's Streams in Summer, 2009-2011



concludes that bacteria levels constitute an elevated risk of swimmers becoming sick.

Iowa's designated uses[2] are divided into three categories and eight sub-categories:

Recreational Designations

- Primary contact recreational use (e.g. swimming and water skiing)
- Secondary contact recreational use (e.g. fishing and shoreline activities)
- Children's recreational use (e.g. wading or playing in water)

Warm Water Aquatic Life Designations

- Supports a wide variety of aquatic life on large rivers and larger stream segments
- Supports a resident aquatic community but not necessarily game fish on smaller perennial streams
- Supports an aquatic community in harsh conditions of intermittent streams

Cold Water Aquatic Life Designations

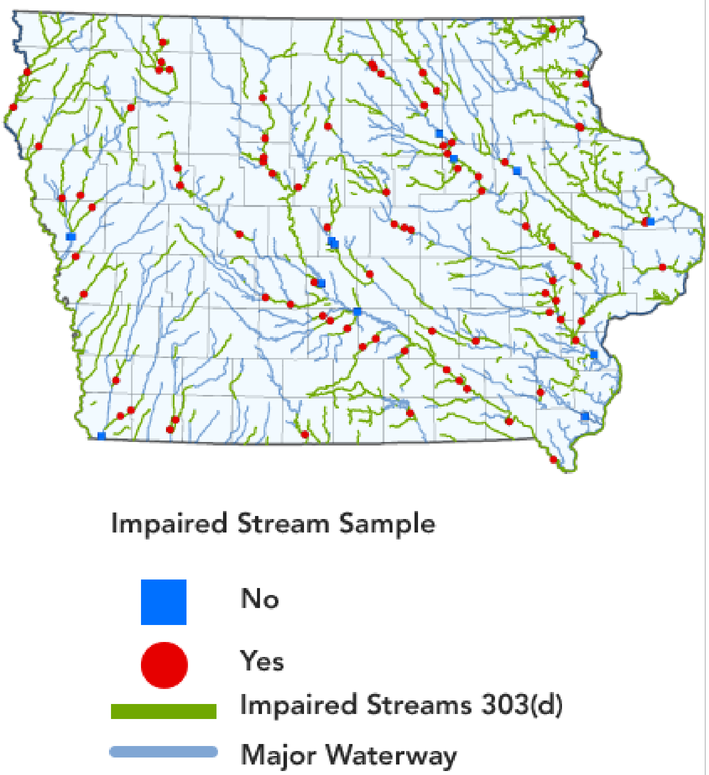
- Supports reproducing and non-reproducing trout and associated communities
- Supports cold-water aquatic communities but does not consistently support trout populations

The department currently lists 6,086 miles of the state's 26,000 miles of rivers as "impaired." But most streams have never undergone sufficient testing and evaluation to classify them under the federal system.

For the Index, the department selected stream segments for monitoring that reflected a representative cross-section of Iowa's streams and rivers. In addition, some sites were chosen as matched pairs to monitor pollution upstream and downstream of urban areas, and some were selected because they offered sampling histories that go back as far as 1986.

The Index sites were selected before the stream segments were officially designated as impaired by the Department under the Clean Water Act. In fact, the resulting monitoring data provided the information needed to officially make those designations. As of now, 87 percent of the monitored stream segments have been designated as impaired (Figure 4). When an Iowa stream is properly

Figure 4: Most Index Sites Are on Streams Designated as Impaired



monitored, some level of impairment is nearly always found.

For the most part, the Water Quality Index ratings track closely with the state agency's designations of impaired streams. However, four sites rated "poor" by the Index are not among those listed as impaired under the Clean Water Act process. The reason is simple. Even though nitrogen and phosphorus overload is the primary reason the Index rates Iowa streams "poor" or "very poor," the state has no numeric standards for pollution by nitrogen, phosphorus or sediment. As a result, those types of contamination cannot be used to designate a stream as impaired under federal law. Nevertheless, there is a high correlation between the Index's ratings and the federal "impaired" designations – despite the different criteria – because nutrient overload usually triggers contamination or conditions such as cyanobacteria blooms that meet the federal criteria for designating a stream as impaired.

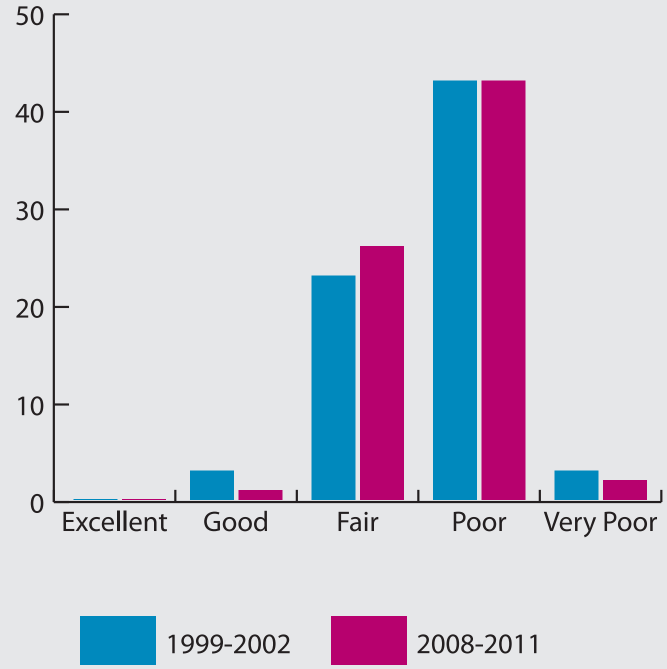
NO IMPROVEMENT SINCE 1999

Comparing data from the first 36 months of the Index condition ratings to the most recent 36 months shows that there has been no meaningful change in stream water quality since 1999. Of the 98 sites monitored by the Index, 72 have 36 months of data for both 1999-2002 and 2008-2011.[ii]

The number of stream segments rated "good" dropped from three to one over the 12-year period while the number rated "fair" increased from 23 to 26. The number rated "poor" was unchanged at 43, and

ii. Due to budget constraints, DNR took no water quality samples for six months beginning in the fall of 2008. In order to obtain a complete data set for three years, with all seasons represented equally, EWG included the data for the same months from 2007 that were missing in 2008. Two sites included by DNR over the first three years were not included in the last three years because one had only 18 months of data and the other only 24 months. Two other sites included in the first three years were not included in the last three years because monitoring at those sites had been terminated.

Figure 5: Index Stream Segments Show No Improvement in Condition Since 1999

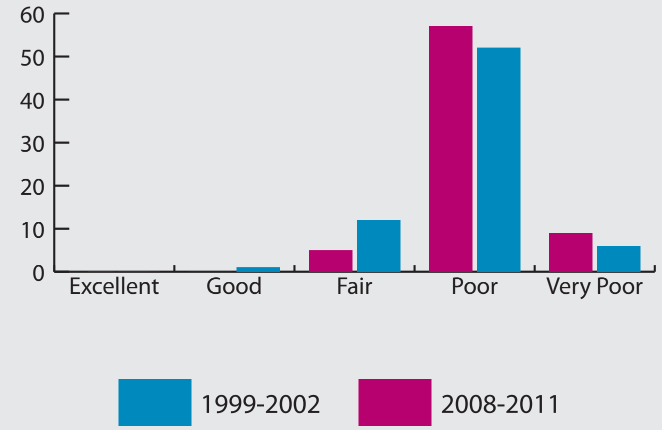


the number rated "very poor" dropped from three to two (Figure 5).

The same picture emerges from a site-by-site assessment:

- Of the three sites that started out "very poor," one is unchanged and two improved to "poor."
- Of the 43 sites that started out "poor," 28 are unchanged, 14 improved to "fair" and one deteriorated to "very poor."
- Of the 23 sites that started out "fair," 11 are unchanged but 12 fell to "poor."
- Of the three sites that started out "good," only one held on to that ranking, one dropped to "fair" and the third to "poor."

Figure 6: Summer Water Quality Has Improved Slightly since 2000



- Since the creation of the Index, no site has ever been rated "excellent."

Overall during the 12-year period, the condition of 16 sites improved and 15 worsened. Only one – a site initially rated as "good" that declined to "poor" – improved or worsened by more than one rank. The ratings of 41 out of 72 sites (57 percent) did not change.

The summer ratings paint a slightly better, but still disappointing, picture. The number of stream segments rated "very poor" or "poor" dropped by eight, from 66 to 58, while the number rated "fair" increased from five to 12. One site was rated "good" on average through all of the last three summers (2008-2011). None were rated in good condition during all of the first three summers (2000-2002) (Figure 6).

NUTRIENT OVERLOAD IS THE BIGGEST PROBLEM

The Index uses rating curves to evaluate the effect of each measured parameter on water quality. Each parameter has a unique curve that shows the quantitative relationship between the measured value and its effect on water quality. At any given monitoring location, a particular parameter is rated as "very poor" if the measured value is at levels that constitute a serious water pollution problem. Conversely, a parameter is rated "excellent" if it poses no water pollution threat. Parameters can be rated "poor," "fair" or "good" if the degree of pollution they represent falls between "very poor" and "excellent."

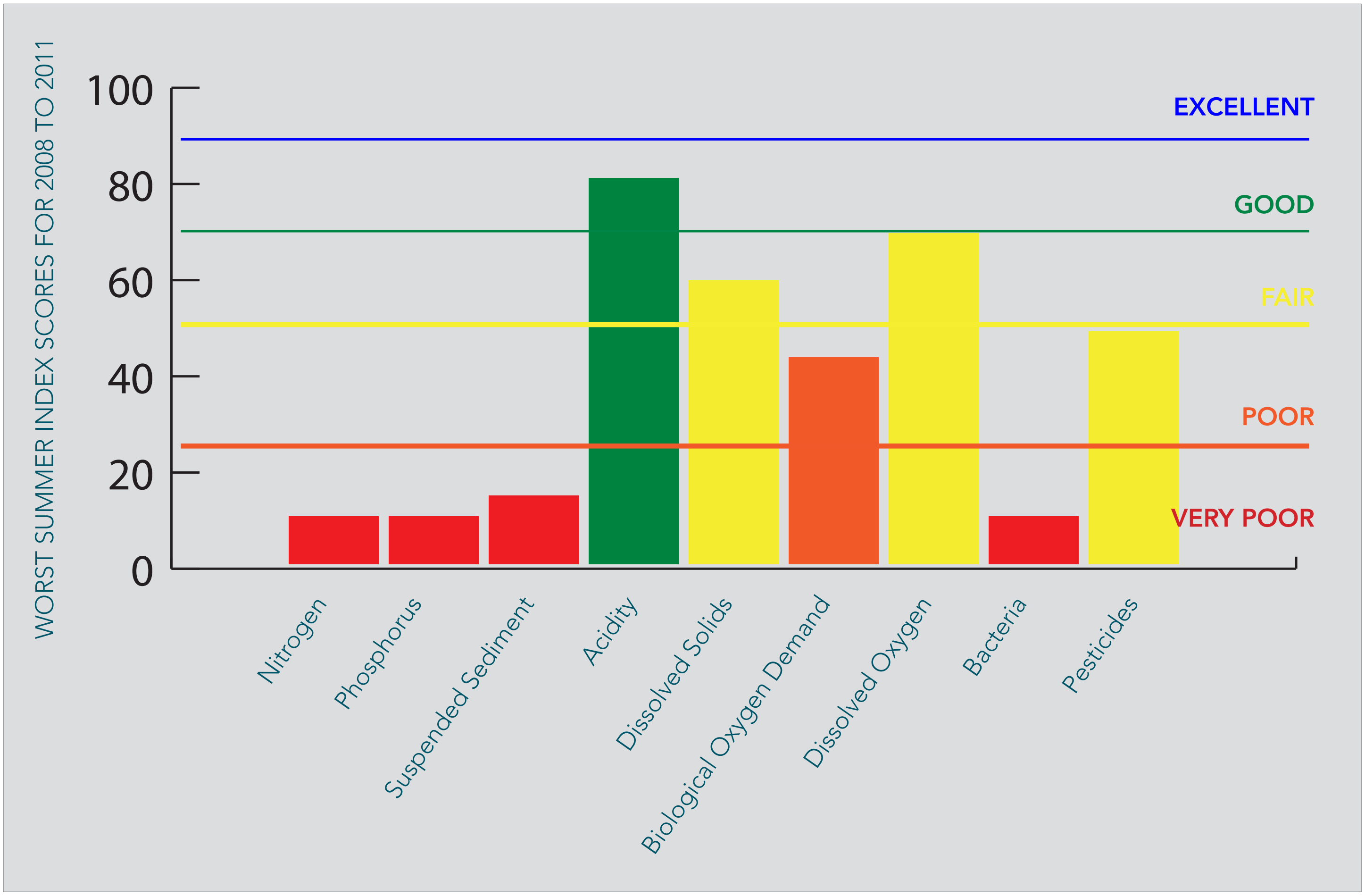
The fact that the Index tracks water quality ratings for each parameter makes it possible to determine which ones cause the worst pollution. To do this, EWG focused on 24 sites that had overall Index condition ratings of "poor" or "very poor" for all three years in the October 2008-September 2011 period. Nitrogen and phosphorus clearly stand out as the parameters most responsible for "poor" ratings (Table 1). The ratings for nitrogen ranged from "poor" to "very poor" and for phosphorus from "fair" to "very poor." None of the monitored stream sites had concentrations of nitrogen or phosphorus that were rated "good" or "excellent." This shows that nitrogen and phosphorus were causing widespread and serious pollution in all of the monitored streams. In contrast, acidity caused no water pollution problems and was rated as "good" or "excellent" in every monitored stream.

Table 1: Pollutants at Monitored Sites with Consistently Poor or Very Poor Water Quality

Year-Round Condition									
Index Ranking	**Nitrogen**	**Phosphorus**	**Suspended Sediment**	**Acidity**	**Dissolved Solids**	**Biological Oxygen Demand**	**Dissolved Oxygen**	**Bacteria**	**Pesticides**
Average	Poor	Poor	Fair	Good	Good	Good	Excellent	Good	Fair
Worst	Very Poor	Very Poor	Poor	Good	Poor	Fair	Good	Fair	Fair
Best	Poor	Fair	Excellent	Excellent	Excellent	Good	Excellent	Good	Fair

Summer Months									
Index Ranking	**Nitrogen**	**Phosphorus**	**Suspended Sediment**	**Acidity**	**Dissolved Solids**	**Biological Oxygen Demand**	**Dissolved Oxygen**	**Bacteria**	**Pesticides**
Average	Poor	Poor	Fair	Good	Excellent	Fair	Good	Fair	Fair
Worst	Very Poor	Very Poor	Very Poor	Good	Fair	Poor	Fair	Very Poor	Fair
Best	Fair	Fair	Good	Excellent	Excellent	Good	Excellent	Excellent	Fair

Figure 7: Pollutants Are Worst in Summer
(the lower the score the worse the pollution)



Nitrogen rated as the single worst pollutant in 55 percent of the monthly samples, phosphorus in 30 percent.

In summer, biological oxygen demand and bacteria (as indicated by *E. coli*) join nitrogen and phosphorus as the pollutants most responsible for worsening the condition of the water. The degree of pollution caused by bacteria varied dramatically from "very poor" (serious pollution) to "excellent" (no bacterial pollution), reflecting the episodic nature of bacterial outbreaks.

Suspended sediment pollution was the next most variable parameter, ranging from "very poor" to "good."

Nitrogen and phosphorus pollution ranged from "very poor" to "fair."

Many pollutants are at their worst in summer (Figure 7). Nitrogen, phosphorus, suspended sediment and bacteria were all rated "very poor" at some point each summer. The worst Index score for nitrogen, phosphorus and bacteria was less than 10 during the

BOX 1: HEALTH AND ECOLOGICAL EFFECTS OF NUTRIENT OVERLOAD

Nitrate, an essential nutrient for plant growth, becomes very dangerous to human health at high levels, and studies show that it presents risks even when ingested at lower levels. Fetuses and babies who ingest water with nitrate at levels above 10 mg/l are at risk of methemoglobinemia (blue baby syndrome). Lower exposures are associated with thyroid disruption, premature birth, low birth rate and brain and head abnormalities. Both adults and children exposed at lower levels are at increased risk of thyroid disruption and thyroid, colon and stomach cancer.

Streams and lakes overloaded with nitrogen and phosphorus are prone to blooms of algae and cyanobacteria that cause a number of environmental and health problems. Cyanobacteria often produce highly poisonous toxins that can injure and kill aquatic life, wildlife, livestock and people. In May 2012, 22 cattle died in Kansas after ingesting cyanotoxins.[3] In the summer of 2011, Sen. James Inhofe (R-Okla.) suffered from cyanotoxin poisoning after swimming in Oklahoma's Grand Lake, where he has a home.[4] Decaying algal blooms also create dead zones that have too little oxygen to support fish and other aquatic life. A dead zone in the Gulf of Mexico caused by nutrient overload from the Mississippi River regularly equals the size of New Jersey or Connecticut.

In addition, disinfecting water to remove algae and cyanobacteria imposes high costs on drinking water utilities. Moreover, the disinfection process creates carcinogenic byproducts that can end up in drinking water.

Source: Environmental Working Group. 2012. Troubled Waters: Farm Pollution Threatens Drinking Water[5]

summers of 2009, 2010 and 2011. The worst score for suspended sediment was 14. In combination, these pollutants can create very serious water quality problems.

Pollutants affect rankings differently

Although the Index data clearly indicate that nitrogen and phosphorus are the primary pollutants degrading water quality in Iowa, the Department of Natural Resources cites bacteria, other biological contaminants and toxic chemicals as the three primary pollutants in its required designations of impaired streams under the federal Clean Water Act. Indeed, bacteria and three other biological measures account for 82 percent of the impairments cited by the agency in its combined 303(d)/305(b) report. Each state is required to assess waters to determine if they meet designated uses. If a water body does not meet a designated use it is required to report that water body to the federal government in this report.

The discrepancy is likely driven by the fact that Iowa has still not developed specific standards for nitrogen, phosphorus or sediment in water. By law, the Department cannot list a stream as impaired by a particular pollutant if it has not set a specific water quality standard for it. The agency has acknowledged that, "Eventual adoption of numeric criteria for nutrients, chlorophyll, and/or turbidity will likely result in a substantial increase [in] the number of water bodies on Iowa's future lists of impaired waters."

BUSINESS AS USUAL WILL NOT IMPROVE IOWA'S WATER

Table 2: Iowa Water Quality Will Still Be Poor in 10 Years

	2011		2021	
	Number	**Percent (%)**	**Number**	**Percent (%)**
Very Poor	6	8	5	7
Poor	31	43	31	43
Fair	33	46	34	47
Good	2	3	2	3
Excellent	0	0	0	0
Total	72	100	72	100

EWG used two statistical tests to assess what the Iowa Water Quality Index data reveal about the direction Iowa's water quality is taking. The Kendall test detects any statistically significant trend – improving, worsening or staying the same – in the overall Index or in the rankings of individual pollutants. The Theil-Sen test estimates the magnitude of those trends. (See Appendix C for details.)

Of the 98 Index monitoring sites, 72 had data robust enough to fully meet the statistical criteria of the Kendall and Theil-Sen tests. The pesticide sub-index presented particular problems due to missing data and the use of just three possible sub-index values – 10, 50 or 100. Because of these problems, EWG eliminated the pesticide data from its statistical analysis of trends. However, we found that overall trends were generally the same with or without the pesticide sub-index.

The trend results do not include the pesticide sub-index, but we applied the statistical test to each of the other pollutants.

The results show that Iowa's water quality is stuck in neutral (Table 2). Most of the monitored stream segments will still be "poor" or "very poor" in 2021 if current trends continue. Fifty percent (36) of the 72 stream segments analyzed will be in "poor" or "very poor" condition in 2021, compared to 51 percent (37) today. There still will be no stream segments ranked "excellent." Only two stream segments (3 percent) will be ranked "good," the same as today.

Overall, water quality in 68 percent of the monitored stream segments is either declining or stable. At those sites where the statistics indicate an improving trend, the improvement is so slow that there will be little change in water quality over the next ten years.

The trends in nitrogen and phosphorus pollution – the two pollutants most responsible for poor water quality in Iowa – are particularly disturbing. In 10 years, the number of stream segments where nitrogen pollution is rated very poor will *increase* from 21 to 37 if current trends continue (Table 3).

The trend in phosphorus pollution is only slightly better. The number of stream segments where phosphorus pollution is rated good will increase from

Table 3: No Improvement in Nutrient Overload by 2021

	PHOSPHORUS CONDITION RATING			
	2011		2021	
Condition	Number of stream segments	Percent of stream segments	Number of stream segments	Percent of stream segments
Excellent	0	0%	0	0%
Good	4	6%	6	8%
Fair	26	36%	26	36%
Poor	25	35%	22	31%
Very Poor	17	24%	18	25%
Total	72	100%	72	100%

	NITROGEN CONDITION RATING			
	2011		2021	
Condition	Number of stream segments	Percent of stream segments	Number of stream segments	Percent of stream segments
Excellent	0	0%	0	0%
Good	5	7%	5	7%
Fair	1	1%	0	0%
Poor	45	63%	30	42%
Very Poor	21	29%	37	51%
Total	72	100%	72	100%

four to six by 2021. Overall, the phosphorus pollution picture will change little by 2021 if current trends continue.

Trends in individual pollutants vary. Biological Oxygen Demand, Dissolved Oxygen, *E. coli* bacteria and pH all are projected to remain almost perfectly steady through 2021, resulting in virtually no change in overall water quality. The projected nitrogen data, however, provide a clear signal of declining water quality, with the number of "very poor" sites increasing from 21 today to 37 in 2021. The decline in the number of sites rated "poor" for nitrogen might seem to indicate improvement, but since the number of "fair," "good," and "excellent" sites remains constant, it is clear that the "poor" sites are deteriorating to "very poor."

The phosphorus trend also shows deterioration, though much less so than for nitrogen. The level of Total Suspended Solids (largely eroded soil) also shows significant deterioration, with the number of sites rated "good" dropping from 54 to 41. Most are projected to decline to "fair" condition, with one moving down to "very poor."

Clearly, the key factors keeping Iowa's water from achieving any serious improvement are primarily nitrogen, followed by phosphorus.

In all, pollution from *E. coli* and total suspended solids is getting worse at 40 percent of the monitored stream segments, but the downward trends are small enough that the impact on overall water quality will be modest through 2021. Across the board, however, the number of sites showing improvement for any particular pollutant are fewer than the number where conditions are stable or getting worse for that pollutant. (See Appendix B for details on projecting trends into the future.)

IOWA POLICY MISSES THE MARK

The Federal Water Pollution Control Act Amendments of 1972 became law 40 years ago, on Oct. 18, 1972. The law, widely known as the Clean Water Act (CWA), sparked a remarkable cleanup of America's lakes, rivers and streams.[7 8 9] Despite a lawsuit and important amendments in 1977 and 1987, however, the law still suffers from one fatal flaw – it has little or no authority to address agricultural, non-point source pollution.

Iowa is a case study of the consequences of this flaw in one of the nation's most important environmental laws.

The 1972 law addressed industrial and urban sources with great specificity but excluded agriculture from its definition of the so-called "point sources" of pollution that are required to seek federal permits, the regulatory mechanism used to reduce discharges into lakes, streams and rivers:

> The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.[10]

Initially, urban storm water such as runoff from city streets was thought to be beyond the reach of the Clean Water Act, but a 1977 court ruling in response to a lawsuit filed by the Natural Resources Defense Council brought it under the law's regulatory umbrella. Agriculture, however, remained exempt.[11] In 1987, Congress amended the act to create a non-point source program (Section 319) to provide some tools to address all forms of non-point source pollution, including agriculture. The amended law instructed states to develop non-point source assessment and management programs designed to cut pollution from these unregulated sources. The law also authorized limited funding to assist with program development and implementation. If a state fails to implement a satisfactory non-point program, the Environmental Protection Agency (EPA) can cut off federal funding for the flawed program. But Section 319 provided no additional authority to regulate agricultural sources of pollution.

Iowa's non-point program relies primarily on education and voluntary programs. Federal funding for Iowa's program has fluctuated between $3.5 and $5.3 million a year for the past seven years.[12]

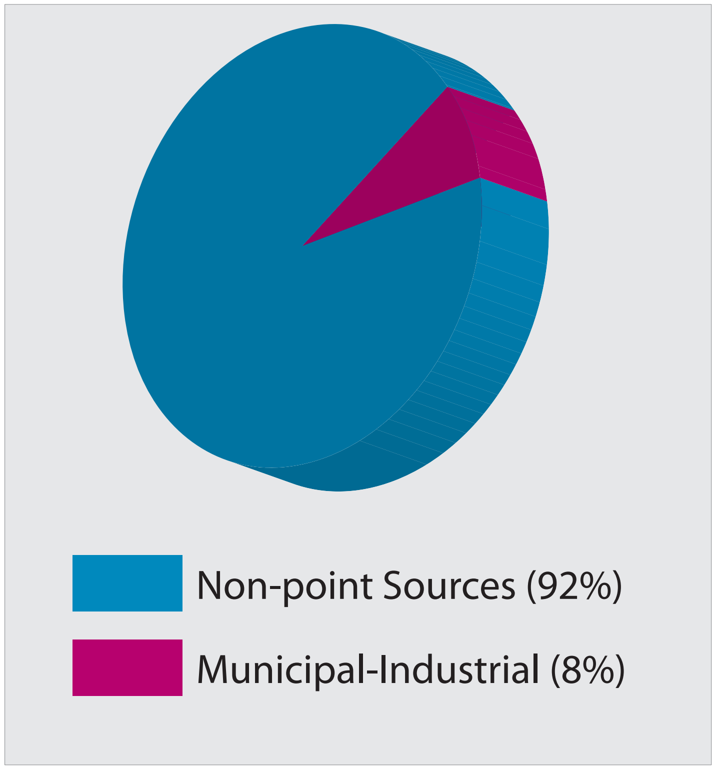
The Iowa Water Quality Index makes it clear that reducing nutrient overload is the key to cleaning up the state's streams and rivers. But in Iowa, the only farm businesses subject to direct regulatory oversight are livestock operations that confine animals in buildings or feedlots – so-called Concentrated Animal Feeding Operations or CAFOs – and farms that apply manure from CAFOs. State officials are currently responsible for enforcing water pollution regulations on CAFOs, but the federal EPA has criticized state officials for lax regulation and warned that it might take over.[13] There is no regulation of the commercial fertilizer that virtually all farm businesses apply.

As a result, most of the reduction in nutrient pollution in Iowa streams and rivers is the result of rules and regulations that apply to cities, industries and sewage treatment plants, which contribute only a small fraction of the nutrient overload. Iowa's streams and rivers will never be clean unless new and concerted efforts are taken to reduce nutrient pollution from farm businesses.

Sources of Nutrient Overload

In 2005, the Iowa Department of Natural Resources conducted a comprehensive assessment of the

Figure 8: 92 percent of Nitrogen Pollution Comes from Non-point Sources



sources of nutrient pollution in the state's waters, known as the Iowa Nutrient Budget. It showed that fully 92 percent of the nitrogen and 80 percent of the phosphorus came from non-point sources. Only 8 percent of the nitrogen and 20 percent of the phosphorus came from "municipal and industrial discharges (Figures 8 and 9)."[14]

The Iowa Nutrient Budget did not distinguish between agricultural and other sources of non-point pollution, but there is compelling evidence that agriculture is the primary culprit.

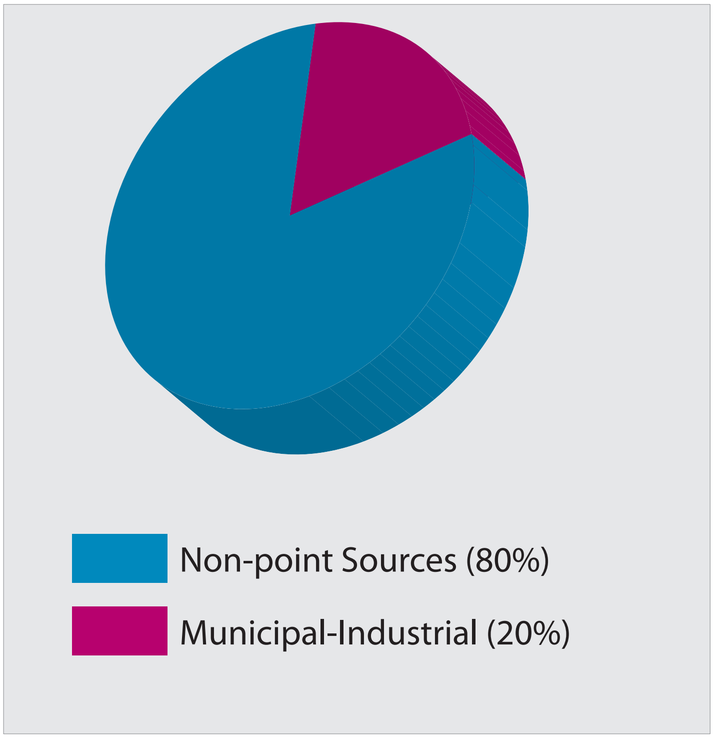
The U.S. Geological Survey (USGS) estimates that 70 percent of the nitrogen and phosphorus pouring into the Gulf of Mexico comes from agriculture. USGS also found that 66 percent of the nitrogen reaching the Gulf comes from cultivated crops, particularly corn and soybeans.[15] Iowa and Illinois, the heart of the Corn Belt, contribute 28 percent of the nitrogen reaching the Gulf.[16] That nitrogen and phosphorus pollutes Iowa's streams and rivers before flowing downstream to ravage the environment and fisheries of the Gulf.

The fact that three-fourths of Iowa's land area is planted in row crops, almost exclusively soybeans and heavily fertilized corn, is a major reason why agriculture is the primary source of nutrient overload. A 1999 University of Oklahoma study found that "over 90 percent of the nitrogen fertilizer is used for agricultural purposes, and the vast majority is applied to corn. Less than 10 percent of the [nitrogen] fertilizer is applied to non-agricultural grass (lawns, parks, general use areas, golf courses, etc.)."[17] Corn uses roughly half the nitrogen applied to it[18] and the other half remains in the environment to pollute groundwater, surface water and air. The situation is even worse in a drought year such as 2012, because a stunted corn crop is unable to take up as much nitrogen as usual, leaving huge amounts behind.

Cities and Towns Stepped Up

Although agriculture is by far the greatest contributor to nitrogen and phosphorus overload, urban sources are not free of responsibility. The Clean Water Act

Figure 9: 80 percent of Phosphorus Pollution Comes from Non-point Sources



focused attention on the largest and easiest pollution sources – pipes from factories and the like. The Act also regulated publicly owned sewage treatment plants, which also emit nitrogen and phosphorus into waterways. Since the 1977 court decision, the Act has also applied to storm water runoff from urban parking lots, streets and lawns, all of which contain nitrogen, phosphorus and animal manure, among other pollutants. These sources have long been under regulations to cut those pollution loads, and cities will soon be required to comply with even stricter storm water regulations. In addition, smaller communities originally exempted from these requirements will come under new EPA storm water regulations by 2014.[19] Still another urban source – septic systems – has been subject to increased scrutiny. Iowa clamped down on septic systems in 2009, requiring that when a property relying on a septic system is sold or transferred, that system must pass inspection or be upgraded or replaced.

Iowa's towns and cities have been legally required to reduce pollutant loading from urban runoff since 1977. They are obligated to address water pollution through actions such as:

- Separating storm sewers from sanitary sewers so that treatment plants are not overwhelmed during storms. Cities and towns across Iowa are currently under federal orders to separate sewers.
- Cleaning streets so that pollutant-laden dirt and debris do not wash into storm sewers and then enter local waterways. The city of Ames, for example, is required by federal permit to clean each street twice a year.[20]
- Upgrading sewage treatment plants in larger communities to reduce the amount of nitrogen and phosphorus they discharge. This is an important but limited step, because the plants contribute less than 1 percent of the nitrogen and about 1 percent of the phosphorus in Iowa streams.[21]
- Requiring smaller communities with un-sewered systems to install more effective treatment systems, as Conroy, Iowa did.[22] There are a total of 11,840 homes in these communities and about 10 to 15 communities a year fix the problem.[23]
- Installing porous concrete and pavement that allow rainwater to soak into the ground rather than run off to the nearest storm sewer and waterway. Charles City, Iowa, may now have the largest installation of permeable paving in the nation.[24]

Controlling pollution from storm water and other urban non-point sources presents many of the same technical challenges as cleaning up agricultural non-point sources. The difference is that for more than 30 years, federal law has required that steps be taken to control urban pollution, resulting in notable improvements as more and more communities have implemented effective practices.

Developers and Industries are Regulated

A developer who plans to "disturb" one acre or more at a construction site must file and obtain approval of a plan to promptly and properly take steps to reduce soil erosion or face fines. Inspectors regularly check construction sites to make sure the required measures are being implemented. There are no such regulations, however, for farm businesses that disturb vastly more soil.

When the state Department of Natural Resources assessed the sources of pollution in Iowa waters (the Iowa Nutrient Budget), the agency estimated that industry contributes less than one-tenth of 1 percent of the total nitrogen contamination and less than 3 percent of the phosphorus.[25] Few of Iowa's industrial operations have significant direct emissions of nitrogen or phosphorus, and the few that do are required to control those emissions under federal permits issued by EPA's National Pollutant Discharge Elimination System (NPDES).

In all, the state agency estimates that non-farm activity contributes about 16,000 tons of nitrogen a year to the environment in Iowa, an amount that is 0.41 percent of the total (0.56 percent soil mineralization of nitrogen is excluded), and 3,600 tons of phosphorus a year, which is 1.5 percent of the total. The primary point sources that emit nitrogen and phosphorus under the federal permits are sewage treatment plants. Most of the nitrogen in sewage treatment plants comes in the form of ammonia, and the permits limit the amount of ammonia the larger plants can discharge. When Iowa adopts standards for nitrogen and phosphorus under the Clean Water Act, the sewage plants will be legally mandated to control their total emissions of nitrogen (not just ammonia nitrogen) and phosphorus. Under present law, those regulations will still not apply to farm businesses.

Most Farm Businesses Escape Regulation

Most farm businesses – the main source of nitrogen and phosphorus pollution in Iowa – are under no regulatory requirements to reduce the nitrogen or phosphorus leaving their fields and polluting the public's waterways. The one exception is some farm business that include an Animal Feeding Operation (AFO). AFOs constitute just 10 percent of Iowa farm businesses.[26]

These operations are required to take steps to prevent manure from polluting Iowa's water. The specific actions required vary depending on how many animals are at the operation. The operations with more than 1,000 animal units[iii] must meet the most stringent requirements. The requirements also vary depending on the type of livestock produced, whether the business sells the manure and whether the manure is wet or dry. There are new rules that impose limited restrictions on the application of manure to land when the soil is frozen or covered with snow. Iowa officials are currently in discussions with the U.S. Environmental Protection Agency (EPA) over the possibility of implementing a new regulatory approach that would subject the larger livestock operations to the requirements of the Clean Water Act's National Pollution Discharge Elimination System (NPDES), which has applied to point sources since the 1970s.

Iowa officials have also been notified that EPA might take back responsibility for enforcing Clean Water Act regulations on livestock operations. Currently EPA directly enforces those regulations in only four states.[27]

iii. One "animal unit" is defined as one adult beef cow. Agencies then calculate how many head of another species such as chickens are equivalent. Agriculture uses AUs for a number of purposes – in this case to calculate manure production.

To reduce the likelihood that phosphorus will run off a field and pollute water, Iowa law prohibits a farm business from applying more manure than is needed to just meet a crop's requirement for this nutrient. But that same farm business faces no such restrictions on the amount of chemical phosphorus (or nitrogen) fertilizer it can apply. Beyond the limited reach of these water quality regulations for AFOs, farm businesses in Iowa are under no effective legal obligation to control the nitrogen or phosphorus running off their fields and polluting waterways.

Iowa Relies on Farmers to Volunteer

Because state and federal environmental laws and regulations impose so few requirements on farm businesses, the state's primary tool for cutting nutrient pollution from agriculture is to offer financial incentives to encourage operators to take voluntary measures. Consequently, taxpayers end up picking up much of the cost.

However, Iowa's financial commitment to such programs has been limited from the beginning.

Table 4: Iowa State Spending on Water Pollution Control is Declining

	Conservation Reserve Enhancement Program*	Conservation Reserve Program *	Soil Conservation Cost Share	Agricultural Drainage Well Closure	Resource Enhancement and Protection**	Total
(thousands of dollars, adjusted to fiscal year 2012 except fiscal year 2013)						
FY02		$1,642	$10,596	$728	$1,975	$14,941
FY03	$2,107	$0	$4,916	$0	$459	$7,482
FY04	$2,039	$2,718	$7,475	$680	$2,866	$15,778
FY05	$1,930	$2,574	$7,077	$643	$2,713	$14,937
FY06	$1,818	$2,423	$6,664	$606	$2,555	$14,066
FY07	$1,730	$2,307	$6,345	$577	$2,433	$13,392
FY08	$1,632	$1,632	$7,617	$1,610	$3,264	$15,755
FY09	$1,589	$1,589	$7,414	$1,589	$3,701	$15,882
FY10	$1,580	$1,580	$7,372	$1,580	$3,681	$15,793
FY11	$1,538	$1,333	$1,077	$1,282	$2,974	$8,204
F12	$1,000	$1,000	$6,300	$0	$2,307	$10,607
FY13	$1,000	$1,000	$6,650	$550***	$2,307	$11,507
Total	**$17,963**	**$19,798**	**$79,503**	**$9,295**	**$31,235**	**$157,794**
Change	**-53%**	**-39%**	**-37%**	**-24%**	**17%**	**-23%**

** Iowa supplements federal spending ** Soil and water component only *** Does not include $1M from the Rebuild Iowa Infrastructure Fund*

In March 2012, the non-profit Iowa Policy Project produced an analysis of water quality funding in Iowa. The Iowa Fiscal Partnership, also a non-profit, updated[28] that report[29] to include fiscal year 2013 appropriations and reported a 25 percent decline in funding since 2002 (Table 4).

The funding cuts have affected virtually all state programs that directly or indirectly provide financial support to encourage voluntary conservation, such as through local Soil and Water Conservation Districts:

- Soil Conservation Cost Share – cut 37 percent from $10.6 million to $6.7 million.
- Conservation Reserve Program state supplement – cut 39 percent from $1.6 million to $1 million.
- Conservation Reserve Enhancement Program – cut 53 percent from $2.1 million to $1 million.
- Agricultural Drainage Well Closure – cut 24 percent from $728,000 to $550,000. (Iowa has supplemented this effort for fiscal year 2013 with $1 million from the Rebuild Iowa Infrastructure Fund.)

Only the soil and water portion of the Resource Enhancement and Protection program escaped these cuts, increasing 17 percent from $1.97 million to $2.3 million over the 12 years.

Overall, funding for these five programs was slashed by 23 percent, from $14.9 million in FY 2002 (in adjusted dollars) to $11.5 million in fiscal year 2013.

The Iowa Fiscal Partnership study also cited funding cuts in four other programs that address both agricultural and non-agricultural components of water pollution:

- Watershed Protection Fund – cut 72 percent from $3.2 million to $900,00.
- GIS Info for Watersheds – cut 31 percent from $284,000 to $195,000.
- Water Quality Monitoring – cut 15 percent from $3.5 million to $2.9 million.
- Water Quality Protection – cut 29 percent from $702,000 (in FY03) to $500,000

IT DOESN'T HAVE TO BE THIS WAY

Iowa's rivers and streams can be clean, but only if Iowans take concerted action to reduce the nitrogen and phosphorus overload from agriculture. The good news is that both experience and science make it clear that concerted action can make major improvements in water quality (Box 2).

Iowa officials released a draft Nutrient Reduction Strategy on Nov. 19, 2012. If it is to make a major contribution to cleaning up Iowa's water, the strategy must include the following three components:

1. A secure, long-term commitment to increased funding for water quality programs.
2. Revamping voluntary programs to improve their effectiveness.
3. Putting in place smart and narrowly targeted regulations that discourage poor farming

BOX 2: CONCERTED ACTION WORKS

Farmers Creek

The 17-mile Farmers Creek in eastern Iowa's Jackson County was heavily polluted. The Iowa Department of Natural Resources calculated that reducing sediment and nutrients by 40 percent would bring the creek back to life. Farmers took action to fence cattle away from the stream, install grassed waterways, construct ponds and implement other conservation practices. In combination, they reduced sediment flowing into the stream by an estimated 6,827 tons a year and phosphorus by 4.5 tons per year – a 50 percent reduction in each. Aquatic life has bounced back enough that Farmers Creek has been chosen as the first Iowa stream for reintroduction of native mussels, which were decimated across Iowa over the past century.[30]

Bigalk Creek

Bigalk Creek is a spring-fed, cold-water creek in far northeast Iowa. The DNR sought to reduce the amount of sediment and livestock manure reaching the stream by 50 percent and to cut stream bank erosion by 60 percent. Landowners helped plant trees, stabilize the stream banks and keep cattle out of the stream by providing alternative sources of water. As a result, Bigalk Creek now supports a naturally reproducing trout population – one of only a handful in Iowa. One farmer reports that his cattle and calves are healthier now that they are out of the creek.[31]

Lake Icaria

Lake Icaria in southwest Iowa's Adams County is used for recreation, fishing and as a drinking water source. The 669-acre lake was suffering from excessive siltation and was officially designated as impaired in 1998. Between 1996 and 2005 state and federal agencies worked with landowners to implement erosion control practices in the watershed. These included installing stream crossings for cattle, grassed waterways and terraces, grade stabilization, animal waste management systems and changes to grazing patterns, enrolling land in the Conservation Reserve Program and building one wetland. The department estimates that these measures cut sediment flowing into the stream from 12,095 tons to 4,350 tons a year, a 64 percent improvement. Agency officials also believe that nutrient loadings were also substantially reduced. Lake Icaria now fully supports aquatic life and was removed from the impaired waters list in 2008.[32]

practices that disproportionately increase water pollution.

Long-term Funding Commitment

In November 2010, Iowans voted to establish a new dedicated fund for programs that improve the environment. The Iowa Water and Land Legacy constitutional amendment was passed twice by the House and Senate in successive legislatures and was ratified by 63 percent of the voters.[33] The amendment authorizes a three-eighths of one percent sales tax to fund the "Natural Resources and Outdoor Recreation Trust Fund," a permanent fund strictly dedicated to "protection of water quality, conservation of agricultural soils and improvement of natural areas in Iowa including fish and wildlife habitat."[34] Economists estimate the tax would provide $123.4 million a year.[35]

The ballot summary put before voters read:

"Adopts Iowa's Water and Land Legacy Amendment which creates a dedicated trust fund for the purposes of protecting and enhancing water quality and natural areas in the State, including parks, trails, and fish and wildlife habitat and conserving agricultural soils in this State."[36] (See Appendix D for the full text of the amendment.)

By their vote, Iowans clearly expressed their desire for cleaner water and a healthier environment. Even more evidence of Iowans' commitment to conservation came in the 2012 election, when 72 percent of Polk County voters agreed to increase their property taxes to pay for a Water and Land Legacy Bond.
To date, however, the legislature has failed to pass a bill to implement the sales tax increase, and there is no money in the Trust Fund.

The governor and the legislature should take swift action to pass the sales tax increase and make the Natural Resources and Outdoor Recreation Trust Fund a reality.

Revamp Voluntary Programs

More money alone, however, will not result in progress unless it is spent wisely. Revamping the way conservation programs are deployed will produce more results, more quickly.

Scientists and conservationists who have studied or worked on reducing the nitrogen and phosphorus overload problem recommend a three-pronged approach.

1. Implement measures to keep soil in place and build its capacity to hold onto nutrients and water.
2. Ensure that farmers and ranchers better manage the nitrogen and phosphorus applied to their fields in fertilizers and manure. Management plans must ensure that most of the applied nitrogen and phosphorus stays in the soil or gets taken up by crops, rather than running off or leaching into lakes, rivers, streams and groundwater.
3. Increase the amount of nitrogen, phosphorus and sediment that gets captured in wetlands, filter strips and riparian zones. These practices will also reduce and slow the amount of water running off farm fields and reduce erosion of stream banks and channels – often a large source of sediment and nutrients.

There are proven practices and systems that can effectively implement this three-pronged approach. (See Box 3)[37] So-called voluntary conservation programs that use financial incentives to encourage landowners and managers to employ those practices will help clean up Iowa's water, but only if important improvements are made to the way they operate. The most important are:

- Increase accountability by setting explicit goals and timelines and ensuring full transparency on where taxpayers' money goes and for what practices and systems.
- Focus most efforts in priority watersheds and work with groups of producers to take joint action to solve pressing problems; even heroic efforts by award-winning farmers will produce poor results if

BOX 3: SIMPLE PRACTICES – BIG IMPROVEMENT

Research shows that simple practices can dramatically reduce nitrogen and phosphorus pollution into waterways. One example comes from a study of small strips of prairie planted in strategic locations in crop fields. Researchers at Iowa State University planted 10 percent of the cropland with narrow strips in several small watersheds near Des Moines. The amount of nitrogen in the water runoff dropped by 74-75 percent, the amount of phosphorus by 79-83 percent and the amount of sediment by 92-93 percent.[38]

Iowa State University's Bear Creek project near Ames also demonstrates that planting buffers along streams can have dramatic positive effects on water quality. At Bear Creek a buffer planted with a combination of grasses and shrubs removed 90 percent of the sediment and up to 80 percent of the nutrients from runoff flowing through the buffer, and up to 90 percent of the nitrate from subsurface water flowing under the buffer.[39]

Results from the Iowa Nutrient Reduction Science Assessment[40] – a large research project that is estimating the effectiveness of various practices to reduce nutrient pollution – estimate that:

- Buffers at the edges of fields or along stream banks would cut average nitrogen losses from shallow groundwater by 91 percent and phosphorus losses by 58 percent.
- Planting a rye cover crop would cut average nitrogen losses by 31 percent and phosphorus losses by 29 percent.
- Creating wetlands to treat drainage water would cut average nitrogen losses by 52 percent.
- Shifting to no-till [planting crops directly into residue from the previous crop with no plowing or other tillage] would cut average phosphorus losses by 90 percent.

Simple practices like these can dramatically reduce loadings of agricultural pollutants. What is missing is effective policy to make sure that these practices are in place on the landscape over the long term.

neighboring producers don't work together.

- Within priority watersheds, target conservation efforts where they will do the most good to improve water quality. Often only a small portion of the agricultural land in a watershed is responsible for much or most of the nutrient overload or erosion.
- Collect, monitor and disseminate information about the farming and conservation practices farmers are using. Only rarely is real-time information available about what practices are already in place and how they change in response to market conditions and public policies such as biofuel subsidies and mandates. This information is essential for effectively directing conservation programs.
- Build the technical services and scientific support network needed to get the job done. Given current budget constraints, this will mean allocating more money for technical services and less for financial incentives to landowners and managers.

Precision Regulation

By themselves, even the most focused and best-managed voluntary programs will not be sufficient to solve the water quality problems caused by agricultural production in Iowa. More money will help, but even massive increases in funding for voluntary programs will not overcome the inherent weaknesses of relying solely on voluntary action. There are several reasons:

- The producers who volunteer are often not the ones causing the most damage.
- The actions the producers' want to take may not be the actions that actually reduce polluted runoff.
- Legislators prefer programs that provide equal opportunity for all producers, rather than programs that direct scarce funding to those producers who cause the greatest water pollution problems.

These weaknesses too often result in random conservation efforts rather than the highly focused programs needed to solve water quality problems.

The factors leading to failure of voluntary efforts were recently documented in a report published by the Soil and Water Conservation Society, "How to Build Better Agricultural Conservation Programs to Protect Water Quality,"[41] that evaluated results from 13 USDA Conservation Effects Assessment Program (CEAP) research watersheds. Chapter 8 summarized the results.[42] Among the key findings were:

- The practices applied by farmers and subsidized by the government often are only indirectly related to the most important pollution problems; in some cases the subsidized practices made the problem worse.
- Subsidized conservation practices such as nutrient management were often poorly maintained.
- Some farmers refuse to participate in voluntary programs regardless of the amount of financial support provided.
- Opportunities to increase income work against investment in conservation.

Perhaps the most compelling findings came from in-depth interviews of 90 landowners who have participated in a watershed protection project at Little Bear River, Utah, since 1990.[43] Even though the farmers thought they were doing a very good job, the interviews showed that fully 75 percent of the prescribed "management practices" designed to improve the management of irrigation water, nutrients and manure were never fully implemented. In contrast, only 13 percent of "planting practices" involving grasses, filter strips or trees and 4 percent of "structural practices" such as building fences, water storage facilities or irrigation sprinklers were not fully implemented.

Urban sources contribute only a small portion of the nitrogen and phosphorus pollution, and it will decline as ever-tightening mandatory regulations force towns and cities to spend millions to limit their polluted runoff.

Meanwhile, the well-worn voluntary path the agriculture industry lobby insists is the only way to clean up farming's pollution has achieved little. And what little progress that has been made through voluntary programs has been vulnerable to swings in market prices and changes in landownership and public policy, such as biofuel mandates.

A drive across Iowa's farmland since the recent boom in corn and soybean prices offers compelling evidence that voluntary programs must be buttressed

BOX 4: RISKY PRACTICES = EXCESSIVE POLLUTION

A handful of risky farming practices such as those documented by EWG's aerial survey of Marshall County, Iowa, in 2011 cause a disproportionate share of the pollution that keeps Iowa streams dirty. The findings of the survey, plus much more information, is available in EWG's 2011 report, "Losing Ground".

Water cuts gullies like these into poorly protected fields and carries mud, fertilizers, pesticides, herbicides and sometimes bacteria into streams. As the photos show, many gullies empty directly into streams and ditches, creating direct pipelines that carry polluted runoff into waterways.

Plowing and planting right next to stream banks greatly increases the chances that mud and farm chemicals will end up in the water. Studies suggest that much of the mud and phosphorus that ends up in Iowa rivers arrives when unprotected stream banks like this one collapse during big storms.

Simple conservation practices can prevent problems like these and would go far toward cleaning up polluted streams. EWG's survey showed that far too few farmers are using the practices that would the clean up Iowa's water.

Strategically planted strips of grass, called grass waterways, prevent gully formation. The grass protects the soil where gullies tend to form and helps filter out pollutants.

Planting grass between a crop field and a stream creates a buffer that filters pollutants out of runoff and strengthens the stream bank. Stronger banks stay intact during periods of high water flow that cause unprotected banks to collapse.

Federal and state funding has been available for decades to pay farmers and landlords to implement these practices, but too few take advantage of it. And today, some producers are responding to record crop prices by abandoning conservation measures in order to plant every acre. Farmers and landlords should be expected to take action at their own expense to safeguard vulnerable terrain that causes so much pollution. Many, if not most, farmers agree that these activities are bad business practice and bad for agriculture's brand.

with smart regulation to ensure that conservation practices stay in place over time. EWG's 2011 "Losing Ground" report showed how much damage is done to Iowa's fields and waterways when conservation practices are abandoned in order to take advantage of high crop prices.[44]

Conservation must be far more durable for there to be any hope of cleaning up Iowa's streams and rivers.

Innovative regulatory frameworks can and should be devised. But those regulatory requirements should be narrowly targeted. Rather than requiring all producers to have nutrient management plans, regulations should focus on phasing out particularly risky practices that cause a disproportionate share of the pollution and defeat a great deal of the voluntary work done by conservation-minded landowners and operators. Planting crops right up to stream banks or allowing livestock to have unmanaged access to streams, for example, should be restricted. Landowners and managers should be expected to control the ephemeral gully erosion that creates a direct pipeline for mud, fertilizer and manure to flow into streams and rivers. Many, if not most, farmers would agree that these activities are simply bad business practice and bad for agriculture's brand.

Narrowly targeted restrictions are already in place in some states and for some practices. Minnesota, for example, requires landowners – including farmland owners – to maintain or establish a 50-foot wide buffer strip of permanent vegetation along streams and lakes. In Wisconsin, the Brown County Land and Water Conservation Committee – the state's version of a local conservation district – addressed concerns about water pollution problems in Lake Michigan's Green Bay and other streams and lakes by adopting in 1991 a Shoreland Protection Ordinance that requires a 35-foot wide vegetated buffer strip along every stream. Wisconsin state officials also developed a comprehensive set of performance standards for agricultural operations. Tellingly, however, that effort has been crippled by a requirement that farmers must be paid to meet even the most common-sense standards, which ought to be part of the stewardship responsibilities that come with the rights of landownership.

Iowa has taken the first steps to restrict the risky practice of applying manure on frozen and snow-covered ground, but such restrictions are far too limited. Iowa should act to adopt the regulations proposed by the Iowa Department of Natural Resources but subsequently weakened by the legislature.

Specifically, a strengthened manure application requirement should become part of a larger set of precise and narrowly targeted regulations that:

- Restrict the use of the risky practices that cause a disproportionate share of the pollution in vulnerable locations and defeat a great deal of voluntary effort;
- Affect the fewest producers while achieving the greatest improvement in water quality;
- Push the right producers into voluntary programs;
- Level the playing field for "good actors;"
- Strike a fair and socially acceptable balance between what taxpayers should pay for and what

producers should be expected to do on their own.

Precision regulation would establish a basic standard of care expected from landowners and managers as the stewardship obligation that comes with the rights of landownership. Voluntary programs can then be used to support landowners and managers who already meet these basic standards to do more to clean up Iowa's rivers and streams.

Precision regulation coupled with a strengthened voluntary program would set Iowa on a path toward cleaner water for our children and ourselves.

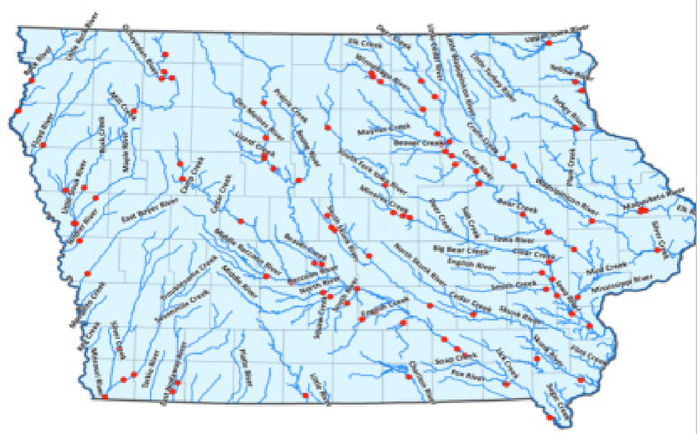
Appendix A
What is the Iowa Water Quality Index?

The Iowa Department of Natural Resources (IDNR) established the Index in 2005 to provide an objective measure of the condition of Iowa's streams. The Index is based on a long-standing model developed in 1970 by the National Sanitation Foundation, substantially modified and adapted to better fit Iowa's streams and rivers.

The Index is based on monthly water quality data from 98 stream-monitoring sites across the state that are used to assess the condition of each stream segment.

On large rivers and streams, a segment (technically known as a "stream reach"[iv]) is usually defined as a portion of the stream between confluences with two tributaries. On a small stream, the stream segment may extend the entire length of the stream. There are several Index monitoring sites along the larger rivers, including 10 Index sites along the Iowa River. The Cedar and Des Moines rivers each have nine sites. Smaller streams are monitored at only one site. Over all, the 98 Index monitoring sites rate water quality in 52 streams. Figure A-1 shows the locations of all 98 sites. The names of all monitored streams and rivers are listed in Table A-1.

Figure A-1: Location of Index Monitoring Stations



How is Water Quality Determined?

The Index combines data from measurements of nine water quality parameters taken at each monitoring site:

- Biological oxygen demand (mg/l)
- Dissolved oxygen content (mg/l) and saturation (%)
- Nitrate and nitrite as nitrogen (mg/l)
- Total phosphorus (mg/l)
- Total dissolved solids (mg/l)
- Total suspended solids (mg/l)
- *E. coli* (CFU or MPN/100 ml)
- pH (0-14 scale)
- Total pesticides (ug/l)

A "rating curve" establishes a quantitative relationship between the measured value of a

iv. "Reach. 1. The length of channel uniform with respect to discharge, depth, area, and slope. 2. The length of a channel for which a single gauge affords a satisfactory measure of the stage and discharge. 3. The length of a river between two gaging stations. 4. More generally, any length of a river." http://water.usgs.gov/wsc/glossary.html

Table A-1: Stream Segments with Iowa Water Quality Index Monitoring Sites

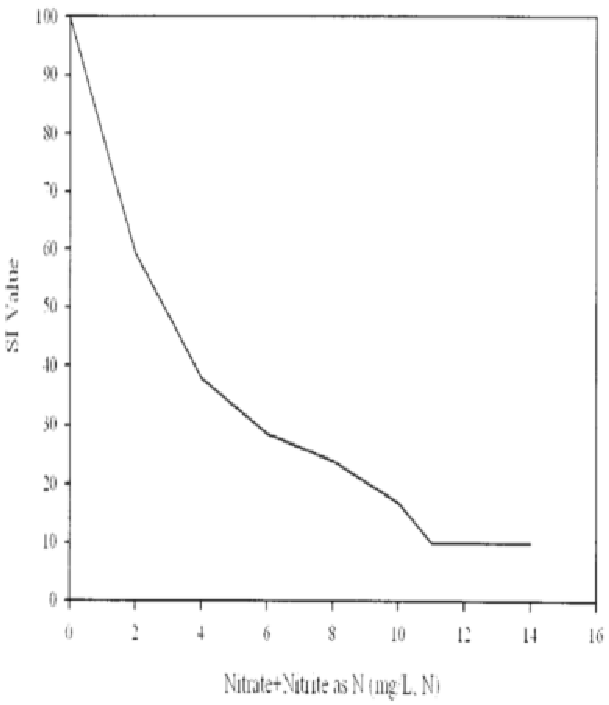
Stream or River	Number of Segments Monitored
Beaver Creek	2
Big Sioux River	1
Black Hawk Creek	1
Bloody Run Creek	1
Boone River	1
Boyer River	1
Cedar Creek	2
Cedar River	9
Chariton River	1
Des Moines River	9
East Fork of The Des Moines River	1
East Nishnabotna River	2
East Nodaway River	1
English River	1
Flood Creek	1
Floyd River	1
Indian Creek	1
Iowa River	10
Little Sioux River	6
Lizard Creek	1
Maple River	1
Maquoketa River	2
Middle River	1
Monona-Harrison Ditch	1
Nishnabotna River	1
North Fork Maquoketa River	1
North Raccoon River	3
North River	1
North Skunk River	1
Ocheyedan River	1
Old Mans Creek	1
Raccoon River	1
Rock River	1
Shell Rock River	1
Skunk River	1
Soldier River	1
South Raccoon River	1
South River	1
South Skunk River	4
Thompson Fork	1
Turkey River	1
Upper Iowa River	1
Volga River	1
Wapsipinicon River	4
West Fork Cedar River	1
West Fork Des Moines River	1
West Fork Ditch	1
West Nishnabotna River	1
West Nodaway River	1
Whitebreast Creek	2
Winnebago River	3
Wolf Creek	1
Yellow River	1
Total	98

parameter and its estimated effect on water quality. The shape of the rating curve is unique to each parameter. Figure A-2, for example, is the rating curve for nitrate. Concentrations of nitrate (horizontal axis) measured in a water sample are translated into a sub-index value ranging from 0 to 100 (sub-index value on the vertical axis).

The sub-index values for each parameter are given a qualitative condition rating based on their effect on water quality (see Table A-2). A sub-index value between 90 and 100, for example, is rated as "excellent" because the measured value does not indicate a pollution problem at that site. Conversely, a sub-index value below 25 means the measured value does indicate serious water pollution at that site; the parameter is therefore rated "very poor."

The rating curves also make it possible to compare

Figure A-2 : Index Rating Curve for Nitrate



the contribution to water quality of parameters measured in very different units. Nitrate, for example, is measured as mg/l, while pH is measured on a logarithmic scale from 0 to 14, and bacteria as the number of colony forming units per 100 milliliters of water. The rating curves make it possible to use the same unit-less sub-index value scale and the same qualitative condition rating ("very poor" to "excellent") for each of the nine parameters.

The original shape of these curves was determined in the 1970s by the National Sanitation Foundation using the Rand Corporation's Delphi technique for consensus decision-making. A panel of 142 water quality experts was assembled to develop rating curves. Each person was asked to draw a curve that associated the concentration of a parameter on the X-axis with water quality on the Y-axis. The investigators averaged all the curves. The Iowa Department of Natural Resources significantly modified the National Sanitation Foundation curves to reflect the specific circumstances of Iowa's waterways.

In some cases, the Department uses more than one rating curve for a single parameter in order to reflect important regional differences in Iowa's geology, climate and streams. Three different rating curves are used to assess Total Dissolved Solids in three different regions of Iowa – western, eastern and northeastern. Two rating curves are used to assess Total Suspended Solids – one for the Loess Hills region of western Iowa and one for the balance of the state. The other seven parameters are assessed using a single rating curve for all regions of the state.

The Department then uses an unweighted harmonic square mean to combine all nine sub-index values into a single index of water quality at each monitored site. The combined index uses a scale ranging from 10

Table A-2: Iowa Water Quality Index Rates Water Quality from Excellent to Very Poor

STREAM CONDITION	IWQI SCORE
Excellent	90.01 to 100
Good	70.01 to 90
Fair	50.01 to 70
Poor	25.01 to 50
Very Poor	10 to 25

to 100 and is given a qualitative rating ranging from "excellent" to "very poor" using the same thresholds used to rating each individual parameter except for the adjustment at the bottom of the scale since this mathematical formula cannot generate a score of zero.

For a detailed explanation of the selection of curves, selection of aggregation function and other information about the creation of water quality indexes, see:

Foreman, Katherine Lynn, The Development of a Water Quality Index for the State of Iowa, University of Iowa, 2005.

Appendix B
Trends in individual pollutants and indexes

EWG used the Theil-Sen statistical analysis to project current trends 5, 10 and 15 years into the future. Tables B-1 below presents the number of Index sites in each condition rating for each individual pollutant.

For example, Biological Oxygen Demand was rated in "very poor" condition in six Index sites in 2011. Statistical projection of current trends suggests the Biological Oxygen Demand will still be in "very poor" condition at six sites in 2016, five sites in 2021 and five sites in 2026.

Tables B-1: Projected change in condition of pollutants

Biological Oxygen Demand				
Condition	2011	2016	2021	2026
Very Poor	6	6	5	5
Poor	31	33	31	30
Fair	33	31	34	33
Good	2	2	2	4
Excellent	0	0	0	0

Dissolved Oxygen				
Condition	2011	2016	2021	2026
Very Poor	0	0	0	0
Poor	0	0	0	0
Fair	0	0	0	0
Good	2	2	2	2
Excellent	70	70	70	70

E. coli (bacteria)				
Condition	2011	2016	2021	2026
Very Poor	0	0	0	0
Poor	0	0	0	1
Fair	2	3	4	4
Good	25	26	25	24
Excellent	45	43	43	43

Nitrogen				
Condition	2011	2016	2021	2026
Very Poor	21	33	37	38
Poor	45	34	30	29
Fair	1	0	0	0
Good	5	5	5	5
Excellent	0	0	0	0

Phosphorus				
Condition	2011	2016	2021	2026
Very Poor	17	17	18	18
Poor	25	24	22	23
Fair	26	25	26	23
Good	4	6	6	6
Excellent	0	0	0	2

pH (acidity)				
Condition	2011	2016	2021	2026
Very Poor	0	0	0	0
Poor	0	0	0	0
Fair	0	0	0	0
Good	53	49	46	46
Excellent	19	23	26	26

Total Dissolved Solids				
Condition	2011	2016	2021	2026
Very Poor	0	0	0	0
Poor	1	0	0	0
Fair	2	2	3	3
Good	34	31	25	25
Excellent	35	39	44	44

Tables B-1 (cont.): Projected change in condition of pollutants

Total Suspended Solids (sediment)				
Condition	**2011**	**2016**	**2021**	**2026**
Very Poor	0	0	0	0
Poor	0	0	1	4
Fair	10	18	22	19
Good	54	46	41	41
Excellent	8	8	8	8

Iowa Water Quality Index				
Condition	**2011**	**2016**	**2021**	**2026**
Very Poor	3	2	2	2
Poor	35	40	35	37
Fair	33	29	34	32
Good	1	1	1	1
Excellent	0	0	0	0

Iowa Water Quality Index Without Pesticide Sub-Index				
Condition	**2011**	**2016**	**2021**	**2026**
Very Poor	6	6	5	5
Poor	31	33	31	30
Fair	33	31	34	33
Good	2	2	2	4
Excellent	0	0	0	0

Appendix C
Statistical Analysis for the Iowa Water Quality Index

Prepared by: Karl Pazdernik, Statistical Consultant, Iowa State University

The data consisted of values collected between 1999 and 2011 at multiple sites across Iowa where the Iowa water quality sub-index was recorded for different chemicals. The goal was to test for a monotonic trend over the time series for each combination of site and sub-index separately and produce predictions for when the sub-index will reach different categorizations. Unfortunately, since we are analyzing a time series, a simple regression analysis would violate the assumption of independence. Outliers and censored observations are also common to water quality data, so assumptions of normality are often difficult to justify. To avoid such issues, we have decided to use the more robust Seasonal Kendall and Mann-Kendall tests to determine the presence of a monotonic trend. A corresponding Theil-Sen slope and intercept estimator were used for the prediction process.

Incomplete Data

Most of the data collected at each site was not complete. In fact, there was a period between October 2008 and March 2009 where no data was collected at any site. Consequently, adjustments needed to be made. The Seasonal Kendall test does not require a continuous time series, so missing data was not directly an issue. Unfortunately, this test does use a large sample approximation to the normal distribution, and so an excessive amount of missing data will result in a small sample, thus, results may no longer be reliable.

Each of the 98 sites in Iowa can be categorized as follows.

0. There existed enough data so that all results were reliable (an average of at least 10 years).
1. There existed a substantial amount of data, however it may be too small for all results to be completely reliable (an average of at least 5 years).
2. There existed enough data to run the analysis, but not enough for any results to be reliable (at least 2 years for each month).
3. The data was so incomplete that no analysis could be run (less than 2 years for each month).

[EWG chose to work only with the highest quality data – those that fell under status "0."] The majority of sites had enough data to run a full and reliable statistical analysis. However, caution must be taken when forming conclusions based on unreliable results. The following table shows the distribution for the amount of data

Status	0	1	2	3
# of Sites	72	8	4	14

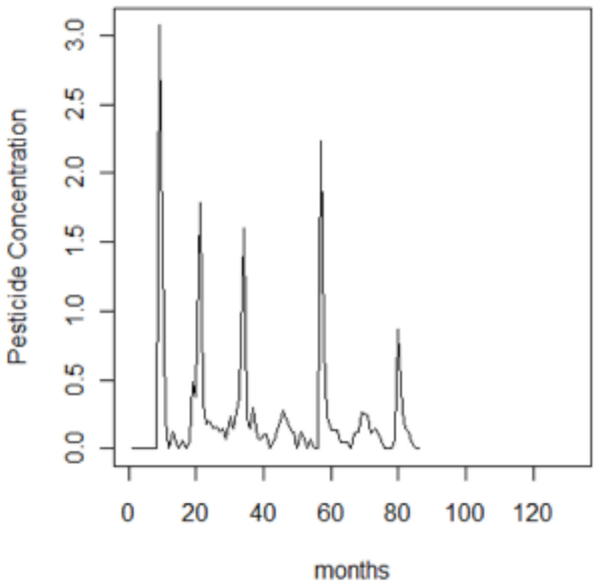
collected from each site, where "status" identifies the category.

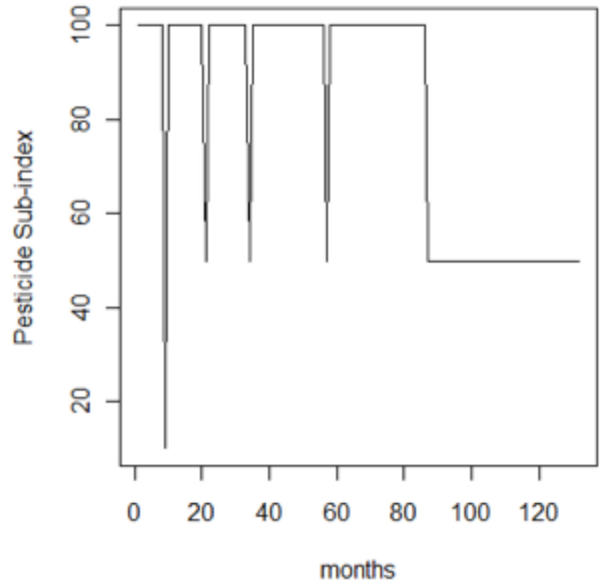
Characteristics of the Response Variables

Iowa created a water quality index (Index) as a measure of overall water quality based on nine sub-indexes: BOD, dissolved oxygen, nitrate-nitrite, total phosphate, total dissolved solids, total suspended solids, pH, total detected pesticide, and *E. coli*. Each sub-index was a score between 0 and 100 representing the quality of the water at that time and location. Note that water flow is indirectly measured in these sub-indexes, which is a factor that can greatly affect water quality.

The goal was to test for monotonic trend and obtain slope estimates over several measurements, including the overall Index, all sub-indexes individually, and the nitrate to phosphate ratio. Monotonic trend was tested and slope estimates were obtained for each site for several different time definitions including over the entire time series, over only the summer months (May through August), and for each month separately. Testing for monotonic trend over individual months required the Mann-Kendall test and testing for monotonic trend over multiple months required the Seasonal Kendall test which is a particular combination of Mann-Kendall tests. Slope and intercept estimates for individual months were calculated using the Theil-Sen estimators and the slope and intercept estimates using multiple months required the Seasonal Theil-Sen estimators. These estimates were then used to predict status change for the Index and all sub-indexes.

All chemicals could be analyzed using these methods with the exception of the total detected pesticide sub-index. This variable presented two difficulties, illustrated in the following plot.





The first issue was that the recorded value was always one of only three options (10, 50, or 100). The Mann-Kendall and Seasonal Kendall test statistics are computed by comparing a past observation to all of its future observations (for that particular month) and checking for trend (increasing or decreasing). This assumes that values are relatively unique. The total detected pesticide sub-index, having only three possible values, resulted in a large number of ties. The calculation included a correction to use a more conservative estimate of variance in the presence of ties, however, this correction was not intended for data with a prevalent amount of ties. An abundance of ties creates a similar problem for the Theil-Sen estimators.

The second issue was that the total detected pesticide concentration from which the sub-index was calculated was completely missing from all sites beginning December 2006. Therefore, as an attempt at imputation, the pesticide sub-index had a recorded value of 50 for every time point after November 2006. This improper method of imputation and the generated data resulted in a significant negative trend for almost all sites. Also, since the Index was calculated using all nine sub-indexes, results on the Index were affected as well.

To avoid this dilemma, the trend analysis was performed on the total detected pesticide concentration directly. The fact that it is a concentration (ug/L) should also account for the effect of water flow. Unfortunately, since four years' worth of data are missing, all sites received a status of 1 or higher, meaning the results are less reliable.

To correct for the negative effect the improper imputation method may have had on the Index, an additional water quality index was calculated called the Water Quality Index Minus Pesticides or WQI-P. The Index is the unweighted harmonic square mean of the sub-indexes. The WQI-P is the same unweighted harmonic square mean, excluding the pesticide sub-index from the calculation.

Theil-Sen Estimation, Interpretation, and Prediction

The Theil-Sen estimation process consists of 2 distinct parts: estimating the slope and estimating the intercept. The slope for a single month is estimated by the median of all slopes calculated between observations from that same month. The intercept is then the median of all intercepts based on the estimated slope. When the Theil-Sen estimation process was done for the entire time series or the summer season, slopes were calculated on a month-by-month basis and then the median of the set of all values was used as the slope. The intercept was then based on this estimate of slope and the entire time series.

The slope can be interpreted as the estimated increase/decrease in a chemical for a one year increase in time. The intercept can be interpreted as the estimated amount of a chemical in the landmark year, which was chosen to be 1999.

The slope and intercept together provide the equation for a line that was then used to predict when a sub-index would reach the 5 categories: very poor (0-25), poor (25.01-50), fair (50.01-70), good (70.01-90), and excellent (90.01-100). This was done for sub-indexes that had a significant slope at the alpha=.05 level.

The following sections outline the calculations and statistics used to analyze the Iowa Water Quality data.

Mann-Kendall test

The Mann-Kendall test was applied to each site, chemical, and month separately to provide monthly tests of monotonic trend. The structure of the hypothesis test is as follows:

H_0: *there is no monotonic trend*

H_A: *there is either an increasing or decreasing trend*

Let Y_{mi} be the water quality sub-index for month m and year i.

Let n be the length of the sequence (number of years).

$$S_m = \sum_{i=1}^{n} \sum_{j>i} sign(Y_{mi} - Y_{mj})$$

$$V_m = Var(S_m) = \frac{n(n-1)(2n+5) - 18T}{18}$$

This equation has a correction for tied data that results in a conservative test. Tied data occurs when $Y_{mi} - Y_{mj} = 0$. T is the number of distinct ties in the sequence. As an example, the sequence (1,3,6,2,2,2,7,4,5,5) has 2 distinct ties.

With a continuity correction, the test statistic is the following:

$$Z_m = \begin{cases} \frac{S_m - 1}{\sqrt{V_m}} & S_m > 0 \\ 0 & S_m = 0 \\ \frac{S_m + 1}{\sqrt{V_m}} & S_m < 0 \end{cases}$$

$$Z_m \sim N(0,1)$$

Z_m is then compared to a standard normal distribution to report a p-value. A p-value less than 0.01 indicates a strongly significant trend, a p-value less than 0.05 indicates a moderately significant trend, and a p-value less than 0.10 indicates a weakly significant trend.

This uses a large sample approximation, so only results with status 0 (where there is over 10 years' worth of data) should be considered reliable.

Seasonal Kendall test

The Seasonal Kendall test was applied to each site and chemical over the entire time series as well as over only the summer months (May through August). This test is essentially a sum of separate summary statistics necessary for the Mann-Kendall test calculated for each month. The hypothesis and reference distribution are exactly the same.

H_0: *there is no monotonic trend*

H_A: *there is either an increasing or decreasing trend*

Total Year Analysis:

$$S = \sum_{m=1}^{12} S_m \qquad V = \sum_{m=1}^{12} V_m$$

Summer Months Analysis:

$$S = \sum_{m=5}^{8} S_m \qquad V = \sum_{m=5}^{8} V_m$$

$$Z = \begin{cases} \frac{S-1}{\sqrt{V}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{V}} & S < 0 \end{cases}$$

$$Z \sim N(0,1)$$

Z is then compared to a standard normal distribution to report a p-value. A p-value less than 0.01 indicates a strongly significant trend, a p-value less than 0.05 indicates a moderately significant trend, and a p-value less than 0.10 indicates a weakly significant trend.

Unweighted Square Harmonic Mean

Let Y_k be the sub-index for chemical k.

$$pWQI = \sqrt{\frac{8}{\sum_{k=1}^{8} \frac{1}{Y_k^2}}}$$

Theil-Sen slope and intercept estimators

The Theil-Sen slope and intercept estimators were applied to each site, chemical, and month separately to provide monthly estimates of slope and an equation of a line that can be used for prediction. These estimates are calculated as follows:

Let Y_{mi} be the water quality sub-index for month m and year i.
Let n be the length of the sequence (number of years).

$$\beta_{1m} = median\{\frac{Y_{mi} - Y_{mj}}{i - j} : 1 \leq i < j \leq n\}$$

$$\beta_{0m} = median\{Y_{mi} - i\beta_{1m} : 1 \leq i \leq n\}$$

The equation of a line used for prediction for a given month for year i is then the following:

$$Y_{mi} = \beta_{0m} + i\beta_{1m}$$

This equation can be used to predict the response for any year; however it will be more reliable for interpolation (predicting for years within the range of the data).

Seasonal Theil-Sen slope and intercept estimators

The Theil-Sen slope and intercept estimators were also applied to each site and chemical separately over a combination of months (the summer months or all months) to provide estimates of slope and an equation of a line that can be used for prediction. These estimates are calculated as follows:

Let Y_{mi} be the water quality sub-index for month m and year i.
Let n be the length of the sequence (number of years).
Let M be the set of months to use in the seasonal estimates. So for the summer season M = {5, 6, 7, and 8} and for the full year M = {1, 2, …, 12}

$$\beta_1 = median\{\frac{Y_{mi} - Y_{mj}}{i - j} : 1 \leq i < j \leq n, m \in M\}$$

$$\beta_0 = median\{Y_{mi} - i\beta_1 : 1 \leq i \leq n, m \in M\}$$

The equation of a line used for prediction of year i is then the following:

$$Y_i = \beta_0 + i\beta_1$$

This equation can be used to predict the response for any year; however it will be more reliable for interpolation (predicting for years within the range of the data).

Prediction of Status Change

The equation of a line obtained from the Theil-Sen estimation process was then used to predict in what year each sub-index would reach a new categorization. This was done by predicting each year into the future and identifying when the predicted response would fall above (if increasing) and below (if decreasing) the given category endpoints.

Let k be the category the sub-index falls into.
Let Y_k be the value of the sub-index at the endpoint of category k. For the sub-indexes, the particular set of endpoints was {25,50,70,90}.

The year in which the sub-index reaches a new category can then be obtained by the following:

$$year_k = i \quad \text{if} \quad \beta_1 > 0 \ \text{ and } \ \beta_0 + i\beta_1 > Y_k$$

$$year_k = i \quad \text{if} \quad \beta_1 < 0 \ \text{ and } \ \beta_0 + i\beta_1 \leq Y_k$$

Appendix D
Full text of the Iowa Water and Land Legacy Amendment

Article VII of the Constitution of the State of Iowa is amended by adding the following new section:

SEC. 10. A natural resources and outdoor recreation trust fund is created within the treasury for the purposes of protecting and enhancing water quality and natural areas in this State including parks, trails, and fish and wildlife habitat, and conserving agricultural soils in this State. Moneys in the fund shall be exclusively appropriated by law for these purposes.

The general assembly shall provide by law for the implementation of this section, including by providing for the administration of the fund and at least annual audits of the fund.

Except as otherwise provided in this section, the fund shall be annually credited with an amount equal to the amount generated by a sales tax rate of three–eighths of one percent as may be imposed upon the retail sales price of tangible personal property and the furnishing of enumerated services sold in this State.

No revenue shall be credited to the fund until the tax rate for the sales tax imposed upon the retail sales price of tangible personal property and the furnishing of enumerated services sold in this State in effect on the effective date of this section is increased. After such an increased tax rate becomes effective, an amount equal to the amount generated by the increase in the tax rate shall be annually credited to the fund, not to exceed an amount equal to the amount generated by a tax rate of three–eighths of one percent imposed upon the retail sales price of tangible personal property and the furnishing of enumerated services sold in this State.

The amendment went into effect on Nov. 29, 2010.

References

1. Iowa Department of Natural Resources Iowa Geological Survey. Iowa Section 303(d) Impaired Waters Listings. http://www.igsb.uiowa.edu/wqm/ImpairedWaters/303d.html#2010

2. Iowa Department of Natural Resources. What does "Designated Use" mean? http://www.iowadnr.gov/InsideDNR/RegulatoryWater/WaterQualityStandards/DesignatedUses.aspx

3. Colburn, David. June 13, 2012. Algae linked in cattle deaths. Peabody Gazette-Bulletin. http://peabodykansas.com/direct/algae_linked_in_cattle_deaths+4338algae+416c676165206c696e6b656420696e20636174746c6520646561746873

4. Myers, Jim. July 1, 2011. Inhofe believes swimming in Grand Lake cause of his illness. Tulsa World. http://www.tulsaworld.com/news/article.aspx?articleid=20110701_335_0_hrimgs611815&subjectid=335

5. Naidenko, Olga V., Craig Cox, Nils Bruzelius. April 2012. Troubled Waters: Farm Pollution Threatens Drinking Water. http://www.ewg.org/report/troubledwaters

6. Iowa Department of Natural Resources. May 27, 2011. The Final 2010 Iowa List of Section 303(d) Impaired Waters. http://www.iowadnr.gov/Environment/WaterQuality/WaterMonitoring/ImpairedWaters.aspx

7. Committee on the Mississippi River and the Clean Water Act, National Academy of Sciences. 2008. Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities. http://www.nap.edu/catalog.php?record_id=12051

8. Clean Water Action. Celebrating the Clean Water Act. 2012. http://www.cleanwateraction.org/publication/celebrating-clean-water-act

9. G. Tracy Mehan, III, Assistant Administrator for Water, U.S. Environmental Protection Agency. Oct. 8, 2012. Testimony before the Senate Environment and Public Works Committee. http://lobby.la.psu.edu/_107th/116_WI_SRF/Congressional_Hearings/Testimony/S_EnvirPubWorks_Mehan_100802.htm

10. Federal Water Pollution Control Act Amendments of 1972. Section 502(14).

11. Natural Resources Defense Council v. Train, 396 F.Supp. 1393 (D.D.C. 1975), aff'd. by NRDC v. Costle, 568 F.2d 1369 (D.C. Cir. 1977).

12. Hopkins, Steve, Nonpoint Source Coordinator. Oct. 4, 2012. Iowa Department of Natural Resources. Personal communication.

13. Beeman, Perry. Nov. 12, 2012. EPA may take over enforcing water act in Iowa: Analyses finding DNR efforts lax prompt warning. The Des Moines Register. http://www.desmoinesregister.com/article/20121113/NEWS10/311130049/EPA-may-take-over-enforcing-water-act-in-Iowa

14. Iowa Department of Natural Resources. 2005. Iowa's Nutrient Budget: Protecting and Improving our Water: A Summary. http://www.iowadnr.gov/portals/idnr/uploads/water/standards/nbsum.pdf

15. Alexander, Richard, Richard Smith, Gregory Schwarz, Elizabeth Boyer, Jacqueline Nolan, and John Brakebill. 2008. Differences in Phosphorus and Nitrogen Delivery to the / Gulf of Mexico form the Mississippi River Basin. Environ. Sci. Technl. 42, 822-830. http://water.usgs.gov/nawqa/sparrow/gulf_findings/index.html

16. Alexander, Richard, Richard Smith, Gregory Schwarz, Elizabeth Boyer, Jacqueline Nolan, and John Brakebill. 2008. Differences in Phosphorus and Nitrogen Delivery to the / Gulf of Mexico form the Mississippi River Basin. Environ. Sci. Technl. 42, 822-830. http://water.usgs.gov/nawqa/sparrow/gulf_findings/index.html

17. Libra, R.D., C.F. Wolter and R.J. Langel. Dec. 2004. Nitrogen and Phosphorus Budgets for Iowa and Iowa

Watersheds. Iowa Geological Survey Technical Information Series 47.

18. Raun, William R and G. J. Johnson. 1999. Improving Nitrogen Use Efficiency for Cereal Production. J. Agronomy. 91:357-363. http://www.nue.okstate.edu/Index_Publications/Improving_NUE.pdf

19. U.S. Environmental Protection Agency. Proposed National Rulemaking to Strengthen the Stormwater Program. http://cfpub.epa.gov/npdes/stormwater/rulemaking.cfm

20. Iowa Department of Natural Resources NPDES Permit: City of Ames.

21. Libra, R.D., C.F. Wolter and R.J. Langel. Dec. 2004. Nitrogen and Phosphorus Budgets for Iowa and Iowa Watersheds. Iowa Geological Survey Technical Information Series 47.

22. Iowa Department of Natural Resources. 2009. Working for Clean Water: 2009 Watershed Improvement Successes in Iowa. http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedSuccesses.aspx

23. Olson, Daniel, Senior Environmental Specialist. Oct. 3, 2012. Iowa Department of Natural Resources Private Sewage Disposal Program. Personal communication.

24. Waterloo Cedar Falls Courier. May 11, 2012. Charles City adds permeable paving. http://wcfcourier.com/news/local/charles-city-adds-permeable-paving/article_48ef247c-55ff-5cb6-97ab-9c42691602e8.html

25. Libra, R.D., C.F. Wolter and R.J. Langel. Dec. 2004. Nitrogen and Phosphorus Budgets for Iowa and Iowa Watersheds. Iowa Geological Survey Technical Information Series 47.

26. The Iowa Department of Natural Resources database on animal feeding operations shows there are currently 9,379 operations in Iowa. (https://programs.iowadnr.gov/animalfeedingoperations/Reports.aspx). The Iowa Department of Agriculture and Land Stewardship's "Iowa Agriculture Quick Facts" reports that Iowa has 92,300 farms. (http://www.iowaagriculture.gov/quickfacts.asp). 9,379 divided by 92,300 equals 10%.

27. Beeman, Perry. Nov. 12, 2012. EPA may take over enforcing water act in Iowa: Analyses finding DNR efforts lax prompt warning. The Des Moines Register. http://www.desmoinesregister.com/article/20121113/NEWS10/311130049/EPA-may-take-over-enforcing-water-act-in-Iowa

28. Iowa Fiscal Partnership. June 26, 2012. Drops in Drops in the Bucket: Even Rare Boosts in Water Funding Evaporate with Inflation. http://www.iowafiscal.org/2012research/120626-IFP-water-bgd.html

29. Hoyer, Will., Brian McDonough, David Osterberg. March 1, 2012. Drops in the Bucket: The Erosion of Iowa Water Quality Funding. http://www.iowapolicyproject.org/2012Research/120301-water.html

30. Iowa Department of Natural Resources. 2011. Working for Clean Water: 2011 Watershed Improvement Successes in Iowa. http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedSuccesses.aspx

31. Iowa Department of Natural Resources. Bigalk Creek: Preserving a Treasure. http://www.iowadnr.gov/portals/idnr/uploads/water/floodplain/nonpoint/files/bigalk.pdf

32. Environmental Protection Agency. Iowa: Lake Icaria Restoration Efforts Repair a Drinking Water Source and Recreational Area. http://water.epa.gov/polwaste/nps/success319/ia_icaria.cfm

33. Iowa's Water and Land Legacy. http://www.iowaswaterandlandlegacy.org/faq.aspx

34. Iowa's Water and Land Legacy. http://www.

iowaswaterandlandlegacy.org/home.aspx

35. Otto, Daniel, Kristin Tyklka, Susan Erickson. 2012. Economic Value of Outdoor Recreation Activities in Iowa. Department of Economics, Iowa State University Extension and Outreach, Center for Agricultural and Rural Development, College of Agriculture and Life Sciences, Iowa State University.

36. Iowa's Water and Land Legacy. http://www.iowaswaterandlandlegacy.org/faq.aspx

37. Schnepf, M. and C. Cox. 2006. Environmental Benefits of Conservation on Cropland: The Status of Our Knowledge. Soil and Water Conservation Society, Ankeny, IA.

38. Helmers, Matthew J., Xiaobo Zhou, Heidi Asbjornsen, Randy Kolka, Mark D. Tomer. Dec. 2011. Water Quality Benefits of Perennial Filter Strips in Row-cropped Watersheds. 2011 Proceedings of the 23rd Annual Integrated Crop Management Conference, Iowa State University. http://www.aep.iastate.edu/icm/proceedings.html

39. Natural Resources Conservation Service. Success Stories: Buffer Bonus from Bear Creek. http://www.ia.nrcs.usda.gov/news/successstories/successstories.html

40. Helmers, Matt, Tom Isenhart. Sept. 2012. Iowa Nutrient Reduction Science Assessment. Iowa State University. Presentation to the 23rd meeting of the Mississippi River Gulf of Mexico Watershed Nutrient Task Force. https://sites.google.com/a/swcs.org/taskforce-fall2012/materials-ii

41. D.L. Osmond, D.W. Meals, D.K. Hoag and M. Arabi (eds). 2012. How to Build Better Agricultural Conservation Programs to Protect Water Quality: The National Institute of Food and Agriculture – Conservation Effects Assessment Project Experience. Soil and Water Conservation Society, Ankeny, Iowa. http://www.swcs.org/en/publications/building_better_agricultural_conservation_programs/

42. Osmond, D.L, D.W. Meals, D.L.K. Hoag, M. Arabi, A.E. Luloff, G.D. Jennings, M.L. McFarland, J. Spooner, A.N. Sharpley and D.E. Line. 2012. Synthesizing the Experience of the 13 National Institute of Food and Agriculture – Conservation Effects Assessment Project Watershed Studies: Present and Future. Chapter 8 in How to Build Better Agricultural Conservation Programs to Protect Water Quality: The National Institute of Food and Agriculture – Conservation Effects Assessment Project Experience. D.L. Osmond, D.W. Meals, D.K. Hoag and M. Arabi (eds). Soil and Water Conservation Society, Ankeny, Iowa. http://www.swcs.org/documents/filelibrary/conservation_programs_to_protect_water_quality/Chapter8_F663E50742ED2.pdf

43. Osmond, D.L., D.W. Meals, A.N. Sharpley, M.L. McFarland and D.E. Line. 2012. Conservation Practice Implementation and Maintenance: National Institute of Food and Agriculture – Conservation Effects Assessment Project. Chapter 3 in How to Build Better Agricultural Conservation Programs to Protect Water Quality: The National Institute of Food and Agriculture – Conservation Effects Assessment Project Experience. D.L. Osmond, D.W. Meals, D.K. Hoag and M. Arabi (eds). Soil and Water Conservation Society, Ankeny, Iowa. http://www.swcs.org/documents/filelibrary/conservation_programs_to_protect_water_quality/Chapter3_74CE726788F1F.pdf

44. Cox, Craig, Andrew Hug, Nils Bruzelius. 2011. Losing Ground. Environmental Working Group, Washington, DC. http://www.ewg.org/losingground/

Notes: