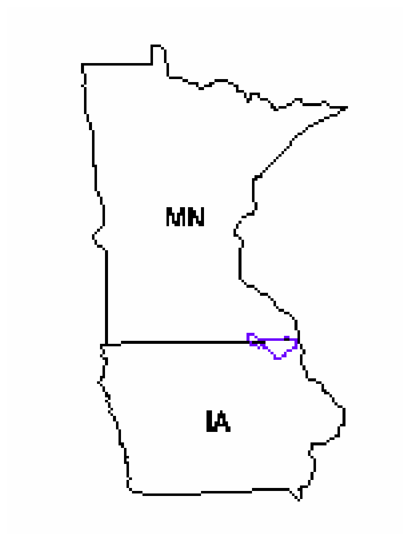
Project Report

Project Title: UPPER IOWA RIVER ALLIANCE



A PROJECT DESIGNED TO IMPROVE THE WATER QUALITY
OF
THE UPPER IOWA RIVER

Project was supported through a Watershed Assistance Grant (WAG) from the River Network. It represents a pilot project funded by the Environmental Protection Agency (EPA) as communities work to protect and restore their watersheds.

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THE UPPER IOWA RIVER WATERSHED

The Upper Iowa River originates near the small town of Taopi in the glacial drift plains of Mower County, Minnesota. It drains an area of approximately 2,683 ha (102 sq miles) from southeastern Minnesota (in Mower, Fillmore, and Houston Counties), and an area of approximately 23,780 ha (903 sq miles) of northeastern Iowa in Howard, Winneshiek, and Allamakee Counties. The Upper Iowa River drops about 222 m (728 ft) in elevation during its 205 km (127 miles) journey, yielding an average stream gradient of about 1.1 m/km (or 5.8 ft/mile). It flows in a southeasterly direction (with a gradient of about 1.2 m/km) until it reaches Decorah, Iowa, and then angles to the northeast for its last 80 km (at a reduced gradient of about 0.9 m/km) before discharging into the Mississippi River just south of New Albin, Iowa.

There have been at least six human alterations to stream flow on the Upper Iowa River. Downstream from where the Little Iowa River empties into the Upper Iowa River a low head dam associated with a grist mill was constructed in the 1850's; this impoundment is now known as Lake Louise, and is located just east of LeRoy, Minnesota. Another low head dam, constructed in the 1920's, impounds the streams' water at Lime Springs, Iowa, and prior to that there were small hydroelectric dams, which currently have little impoundment capacity, constructed at about 6.5 km (4 miles) and 11.3 km (7 miles) downstream from Decorah. In the late 1940's, the Dry Run flood control project by the U. S. Army Corps of Engineers confined the river channel between levees as it passes through Decorah, and the lower 11 km (6.8 miles) of the Upper Iowa River was channelized as part of a 1958 flood control project by the U. S. Army Corps of Engineers.

The majority of the Upper Iowa River transects a portion of the state bypassed by the last continental glacier, accounting for the more rugged topography of the area when compared to other sections of Iowa. The limestone bedrock of this driftless region (Cedar Valley to Decorah formations) is subject to being dissolved by slightly acid rain water and an intricate network of solution chambers, caves, springs and sinkholes have formed in this karst region. Karst is a Yugoslavian word used to describe an assemblage of geomorphic features related to carbonate rock formations and hydrology. The Karst topography of this watershed results in a fairly constant supply of groundwater being discharged through springs and seeps into the streambed. These ground water discharges into the streams of this basin help maintain summer water temperatures cool enough so that 29 streams are designated as coldwater streams, and 23 of these streams are part of the Iowa DNR's trout stocking program. However, it is also true that in areas of Karst topography the surface waters and the contaminants they may carry can reach the groundwater without being filtered or diluted. As a consequence, carbonate aquifers are highly susceptible to contamination by infiltration of soluble mobile chemicals (including nitrates), surface runoff from agricultural land, and waste disposal or surface spills of various kinds.

The two basic methods by which karst-carbonate aquifers are recharged with water are described by Hoyer and Hallberg (1984) as infiltration (diffuse percolation through the soil) and direct flow (runin of surface water into sinkholes). They point out that although in the past much attention has been directed at the influence of sinkholes, the largest mass and highest concentrations of soluble mobile chemicals, including nitrates, are delivered to groundwater by infiltration, not by direct runin from sinkholes. However, the runin component is thought to be primarily responsible for the delivery to groundwater of large loads and high concentrations of relatively insoluble chemicals, including pesticides, during short periods of peak runin. Peak runin occurs during periods of very heavy rainfall or thawing when the recharging of aquifers by direct runin for precipitation exceeds that from infiltration. These periods are usually characterized by peak turbidity and sediment loads, and peak loads of organic matter and pathogenic organisms.

A variety of aquatic organisms have been associated with the waters of the Upper Iowa River. Howe (1984) noted 101 species of fishes in Allamakee County, with many of them having distributions in the Upper Iowa River limited to downstream from the Lower Dam (about 7 miles downstream from Decorah); the Iowa DNR reports about 63 species of fishes in the watershed (Bill Kalishek, personal communication). Twenty-two species of fishes were noted from smaller tributary streams within the watershed during a 1974 summer study (Scherpelz and Eckblad 1974). During the summer of 1999, ten different species of freshwater mussel were noted for the Upper Iowa River (Ostby and Eckblad 2000); three of the species are classified as threatened in Iowa (Creek heelsplitter, Creeper, Ellipse). More extensive coverage of the characteristics and organisms of this region can be found in the proceedings of a symposium in April, 1983, and then published the following March (Smith 1984; Hallberg et al 1984; Bounk and Bettis 1984; Glenn-Lewis et al 1984; Howe 1984; Eckblad and Coon 1984; Roosa 1984).

WATER QUALITY STUDIES OF THE UPPER IOWA RIVER WATERSHED

Since the early 1970's a variety of studies have been conducted on the water quality characteristics of the Upper Iowa River. Sampling from 10 sites over a 12-month period gave mean BOD_5 of 2.38 mg/L, and it was determined that BOD_5, fecal coliform numbers, and most nutrients reached a maximum during periods of high flows while dissolved oxygen was at a minimum during these periods (McMullen 1972). Nitrate+nitrite nitrogen mean values were 2.22 mg/L during summer samples, 1.91 mg/L for winter samples, and values for any one sampling date were relatively similar over the entire length of the river. McMullen (1972) concluded that the water quality of the Upper Iowa River was "superior" to that of several other Iowa rivers.

During the months of June and July of 1972 and 1973 a group of 12 Luther College students studied some of the biological and chemical characteristics of the Upper Iowa River and its tributaries. Thirty sampling stations were selected; nine in the Canoe Creek watershed, eight in the Ten Mile Creek watershed, three in the Bear Creek watershed, and the remaining ten from the mainstem of the Upper Iowa River. Aquatic macroinvertebrates representing 113 different genera were identified; Chironomidae midges were most abundant, followed by Baetidae mayflies and Hydropsychidae caddisflies. Overall macroinvertebrate diversity was generally lower in locations with higher numbers of Chironomidae midges. Thirty-five species of fish were identified in this study, with the most widespread and common species being the Common shiner and the Johnny darter. Fecal coliform bacteria ranged from 360 to 610,000 per 100 ml, and all coliform values increased after heavy rainfalls (Klemme 1973).

During June and July of 1974 a study was conducted by Luther College students in which sampling was conducted upstream and downstream from seven small feedlots (30-50 head of cattle) draining into streams in Winneshiek County (Scherpelz, and Eckblad 1974). In general, rainfall influenced both upstream and downstream sites, but upstream and downstream sites were not significantly different ($p>0.05$) for a variety of water quality characteristics. These sampling sites were located in 5 different smaller watersheds of the Upper Iowa River basin (Upper Iowa, Decorah; Trout Run; Ten Mile; North Bear Creek; Silver Creek) and the Nitrate+Nitrite-N levels and Total-P levels from 1974 can be compared to levels during the July 1999 samples of the present study.

A study conducted about the same time by the University Hygienic Laboratory (UHL) concluded that the "overall chemical water quality of the stream was very good" (Geary and Morris 1975). This report also suggested that "the quality of the macroinvertebrate community was high and any limitations on colonization by aquatic organisms were primarily a function of substrate availability and not a reduction in water quality." Unfortunately, this sweeping conclusion was based upon only 11 taxa collected from 6 stations. A slightly more comprehensive biological survey was conducted by the U. S. Environmental Protection Agency in 1978 between August 8 – 10 in which a total of 79 benthic macroinvertebrate taxa were identified, including 26 taxa of chironomids, but again from only 6 different sampling stations. In their report they concluded that both the biology and water quality of the Upper Iowa River were in good condition (USEPA 1979).

During two sampling periods (21-23 April and 14-16 July) in 1980 the University Hygienic Laboratory (UHL) conducted a benthic macroinvertebrate survey from 14 Upper Iowa River mainstem locations and 6 tributary sites. This survey demonstrated the effect of the metropolitan area of Decorah, and especially the impact of the effluent from the old Decorah Wastewater Treatment Plant (DWTP). This was a trickling filter plant located near the river at the east edge of the city. At sites immediately downstream from the DWTP there was a substantial decrease in mayfly and caddisfly population density, along with the presence of two indicators of poor water quality; *Psychoda* sp. (moth flies) and the sheath-bacterium *Sphaerotilus* (Meirhoff and Prill 1982). Eckblad (1974) had also reported the impacts from DWTP on the benthic fauna of the Upper Iowa River previously. A new activated sludge treatment facility in Decorah was placed on-line in November of 1985.

A variety of studies on the Upper Iowa River and its tributaries dealing with abiotic features, algae, invertebrates, and fish of this stream were considered in a review of streams of the Iowa Driftless Region (Eckblad and Coon 1984). Since this review, many of the studies in this region have focused on stream systems believed to have lower water quality than the Upper Iowa River. For example, comprehensive studies of Sny Magill Creek (Birmingham et al 1995; Seigley et al 1994; Seigley et al 1996) and the Maquoketa River (MRA 1998). One difference between the Upper Iowa River and these other streams, noted by Eckblad and Coon (1984), is the heavy recreational use of the river by canoeists; over 6,500 canoeist-days during three summer months (Seitz 1974). The Iowa DNR has estimated that fishing trips to the streams of the Upper Iowa River watershed exceed 300,000 per year (anglers 16 years and older), which amounts to over 4 % of all fishing trips to inland streams of Iowa, and has an economic activity stimulated by angler expenditures of over 29 million dollars (Bill Kalishek, personal communication).

A variety of state and federal agencies continue to collect data related to the water quality of the Upper Iowa River. The Iowa DNR (and earlier the Iowa Conservation Commission) conduct periodic sampling (e.g. ICC 1986, IDNR 1990). They have measured several physical and chemical characteristics of streams in their surveys, but the primary emphasis has been on fish populations and water quality capable of supporting recreational game fishing. The Minnesota DNR has sampled the portion of the watershed in Minnesota, with the primary emphasis on suitable fish habitat. For example, Haugstad and Haugstad (1983) found that primary fishing pressure occurred in the Lake Louise Reservoir (fishing for crappies and bullheads) with some angling for smallmouth bass in the Little Iowa River. They noted that the Lake Louis Dam may prevent smallmouth bass movement upstream which is needed to replenish populations after low-water years. Two federal agencies gathering water quality data are the Environmental Protection Agency (EPA), and the United States Geological Services (USGS).

The EPA maintains its own water quality database system referred to as the STOrage and RETrieval (STORET) system which is intended as its principal repository for marine, freshwater and biological monitoring data. A modernized version was released in September of 1998, and literature produced by EPA indicates it is free to users, easy to use, flexible enough to go anywhere you can take a laptop and requires quality assurance information for data credibility. The new modernized STORET system is designed to meet the current and future needs of all of the agency's partners and stakeholders including federal agencies, states, tribes, local governments, academic groups and citizen volunteers involved in the collection of water quality data. The original STORET was developed in the 1960s and operated for 33 years. Modernization of the system took seven years and involved a wide range of stakeholders. Copies of the CD ROM for STORET (compatible with Windows 95/98/NT) are available free of charge from EPA (call 1-800-424-9067 or e-mail STORET@epa.gov). Data within STORET has been accessible to the public on the Internet since early in 1999.

Data retrieved from STORET for the Upper Iowa River indicates the analysis of 874 samples during the period from the mid 1960's to 1998. These samples come from 38 different stations within the watershed, some sites were sampled on a single date, while others were sampled over several months or years. For example, 131 samples taken from the Hwy 26 bridge near New Albin have been analyzed for ammonia-nitrogen during the period from July, 1974 to December, 1998. Over the entire watershed, 304 samples were analyzed for Nitrate+Nitrite-Nitrogen (between Sept, 1973 and Dec, 1998) and the mean value was 4.37 mg/L, with values that ranged from a low of 0.2 to a high of 12.0 mg/L . A number of these were samples from special effluent situations (e.g. the creamery at Granger, MN) and may not represent typical surface water conditions of the watershed.

Data from water quality studies under the supervision of the USGS are also available over the internet. One example of interest is based upon the periodic sampling being done near the mouth of the Upper Iowa River before it empties into Pool 9 of the Upper Mississippi River (Table 1). If the summer Nitrate+Nitrite-N mean of 2.22 mg/L (McMullen 1972) is compared with the recent mean of 3.56 mg/l (from Table 1) it suggests that there has been about a 38% increase in the mean Nitrate+Nitrite-N over the 25-year period. Dr. John Tjostem, microbiologist at Luther College, and his students have reported similar increases in surface water nitrogen (Mariano et al 1998), with less of an increase in ground water samples.

THE UPPER IOWA RIVER ALLIANCE PROJECT

The overall goal of this project is to form a collaborative alliance that will work together over the next ten years to improve the water quality and enhance the recreational activities associated with the river and its' watershed. Participants in this alliance include the Iowa DNR, U.S. Fish & Wildlife Service, RC&D, cities in the watershed, Soil Conservation Districts, Iowa Dept of Agriculture, County Conservation Boards, Luther College Department of Biology, the Nature Conservancy, Minnesota DNR, Houston, Fillmore and Mower counties Minnesota Soil and Water Conservation Districts and Water Quality Planners, Upper Iowa River Partnership of Mower and Fillmore Counties Minnesota, Iowa Geological Survey Bureau, IOWATER, the Northeast Iowa Forest Advisory Committee, One Stop Forestry, Lime Springs Fish and Game Association, Pheasants Forever, Ducks Unlimited, Hawkeye Fly Fishing Association, County Conservation Boards of Winneshiek and Allamakee counties, Iowa State Extension, Minnesota State Extension, Prairie Visions, the U.S. Forest Service, Upper Explorerland Regional Planning Commission, and Fred Carlson Company, Inc.

In order to determine portions of the Upper Iowa River watershed with the most serious water quality problems, 30 separate sampling stations (Fig. 1) were selected to represent the drainage from 26 sub-watersheds (Fig. 2) plus the mainstream of the Upper Iowa River. The sampling sites represented locations in which water drained from sub-watersheds with surface areas that ranged from 10.6 square miles to 118 square miles (Table 2). A sampling scheme was designed that would enable all 30 water samples to be taken on the same date and a variety of individuals and agencies collaborated in this effort. The intent was to identify at least three separate sampling periods that might represent the variety of stream flow and run-off conditions experienced during a typical year. The first set of samples was taken on 21 July, 1999 shortly after a period of recent heavy rainfall and relatively high stream flows and associated high run-offs. The second set of samples was taken on 6 October, 1999 following a period of several weeks without much rainfall and stream flows and run-offs were relatively low. The third set of samples were taken on 24 February, 2000 during a period of late winter warming with snow melt contributing to increasing stream flows.

With each sampling event the time was noted, mid-stream water depth was measured (when possible), a water sample was retrieved from mid-stream near the surface, and descriptive notes were added to the sampling data sheets. Water samples were analyzed for turbidity at the Decorah Siewer Springs Fish Hatchery using a (Hach model 2100P portable turbidity meter), and the remaining analysis was completed at the Hygienic Laboratory at the University of Iowa. The analysis included a determination of the ppb of Atrazine (detection limit > 0.05 ppb), numbers of membrane fecal coliform colonies per 100 mL, mg/L of Nitrate+Nitrite as N (detection limit > 0.1 mg/L), mg/L of Ammonia Nitrogen as N (detection limit > 0.1 mg/L), and mg/L of Total Phosphate as P (detection limit > 0.1 mg/L). A copy of the <u>Upper Iowa River Water Sampling Protocol</u> sheet is included at the end of this report.

RESULTS OF SAMPLING FROM UPPER IOWA RIVER SUB-WATERSHEDS

We will first consider, for each of the parameters estimated, the variation and central tendency for the 30 different sampling stations and the 3 different sampling dates. Water depths were variable between stations and between sampling dates (Fig. 3). The median stream depth for the 30 sampling stations was 3.6 ft, 1.0 ft, and 2.0 ft, respectively, for the three sampling dates. Would be expected with the higher stream flows on the first date, lowest flows the second date, and intermediate flows on the third sampling date. The association of higher turbidity with higher flows is also evident from the greater turbidity at almost all sites on the first sampling date (Fig. 4). Median turbidity was 168 NTU the first date, about 3 NTU the second date, and about 40 NTU the third sampling date. On each of the three sampling dates the standard deviations in turbidity were higher than their means, and the means exceeded median values; this would be expected with a small number of very large turbidity values as was true for Dry Run Creek site (21 July), Trout Run site (21 July), Unnamed Creek, Minn (6 Oct), Thomas Robert's Pond site (6 Oct), Canoe Creek site (24 Feb), and Mouth of Upper Iowa site (24 Feb). Sampling notes indicate that Dry Run Creek was at "bankfull" on 21 July, Trout Run was "very turbid" on 21 July, Unnamed Creek, Minn had "no flowing water in channel" on 6 Oct, Thomas Robert's Pond was "2' - 3' below outlet pipe" on 6 Oct, Canoe Creek was "muddy with foam" on 24 Feb, and the Mouth of Upper Iowa site was "1/2 full" on 24 Feb.

Concentrations of Atrazine in stream waters were over three times higher on the first sampling date, with median values of 0.335 ppb, 0.090 ppb, and 0.100 ppb, respectively, for the three sampling dates (Fig. 5). Fecal coliform bacteria numbers were lowest on the second sampling date (median of 210 colonies per 100 ml), were higher by almost a factor of 10 on the third sampling date (median of 1950 colonies per 100 ml), and were higher by over a factor of 100 on the first sampling date (median of 28,500 colonies per 100 ml) (Fig. 6). The four parameters considered thus far (stream water depth, Turbidity, Atrazine concentration, and Fecal Coliform numbers) were directly correlated with higher stream flow conditions. This is, larger magnitudes were associated with the samples of 21 July, smaller numbers associated with the samples of 6 Oct, and intermediate values associated with the samples of 24 Feb. The story is more complex for the three remaining measurements (Nitrate+Nitrite Nitrogen, Ammonia Nitrogen, and Total Phosphate).

The highest median concentrations of Nitrate+Nitrite Nitrogen were noted on the date with the lowest stream flows (Fig. 7). The five most upstream sites in the watershed didn't follow this trend, but overall the median concentration was 3.8 mg/L, 5.0 mg/L, and 2.75 mg/L, respectively, for the three sampling dates. Investigations elsewhere have noted that the effect of dilution (especially following periods of rainfall) may result in a lowing of the inorganic nitrogen concentration in a streams surface waters while its overall transport of inorganic nitrogen within the system is rising (Horn and Goldman 1994). When compared with the 5 sub-basins also studied in 1974 (Sherpeltz and Eckblad 1974) the Nitrate+Nitrite Nitrogen means were 3.91 mg/L in 1974, and a mean of 3.51 mg/L in 1999 (using the 21 July 1999 sample data).

Ammonia Nitrogen levels were highest during the late winter (24 Feb) sampling period with a median concentration of 0.7 mg/L, and very low (median <0.1 mg/L) during both the first and second sampling period (Fig. 8). One exception to this was the very high level (13.0 mg/L) noted from the 6 Oct sample at Unnamed Creek, Minn; this sample also had unusually high Turbitity, Fecal Coliform counts, and Total Phosphate. The total phosphate was also highest during the late winter sampling period with a median concentration of 0.8 mg/L, also relatively high during the mid-summer sampling period (median of 0.5 mg/L), and very low (median < 0.1 mg/L) during the autumn sampling period (Fig. 9). When compared with the 5 sub-basins also studied in 1974 (Sherpeltz and Eckblad 1974) the Ammonia Nitrogen means were 0.18 mg/L in 1974, and a mean of <0.2 mg/L in 1999 (using the 21 July 1999 sample data). Total Phosphate in the 5 sub-basins had a mean of 0.169 mg/L in 1974 and a mean of 1.06 mg/L in 1999 (using the 21 July 1999 sample data).

Although higher Turbidity levels and Atrazine levels were both associated with higher stream flow, there was not a significant linear relationship ($p>0.05$) between turbidity and Atrazine on any of the three sampling dates (Fig. 10). Likewise, there was not a significant relationship ($p>0.05$) between Total Phosphate and Atrazine on any of the three sampling dates (Fig. 11). In contrast, there was a highly significant relationship ($p<0.001$) between Nitrate+Nitrite Nitrogen and Atrazine on the mid-summer sampling date (Fig. 12), but not a significant relationship ($p>0.05$) on the other two sampling dates.

It appears that as one moves in a downstream direction a general decrease was observed in the concentration of Atrazine (Fig. 5), Nitrate+Nitrite Nitrogen (Fig. 7), and in total phosphate (Fig. 9), at least on one or more of the sampling dates. With only data from three sampling dates, it is probably unwise to extend the analysis to consider all possible comparisons. A principal goal of this study was to try to identify which sub-watersheds contribute the most to the loss of water quality and that will be the focus in the remaining portion of this analysis.

The entire set of sample data is displayed in Table 3, and means (based upon the 3 sampling dates) for each parameter at each site are summarized in Table 4. Descriptive statistics were reported for each column of data, giving the sample mean, the sample standard deviation, the minimum value, the value below which 25% of the observations lie (First quartile), the value below which 50% of the observations lie (Median), the value below which 75% of the observations lie (Third quartile), and the maximum value. The loss of water quality, in general, would be associated with higher values for the six parameters considered (Turbidity, Atrazine, Fecal Coliform, Nitrate+Nitrite Nitrogen, Ammonia Nitrogen, and Total Phosphate). To provide a relative assessment of each sample site (and the drainage area they reflect), a tally was made of the number of times a value for a measurement at a site was at or above the Third quartile for that parameter. This tally appears in Table 3 in the fourth column from the right margin. The column immediately to the right of this contains the percentage of the measurements, out of 18, (6 parameters x 3 sample dates) that are equal to, or greater than, the Third quartile. The column second from the right margin includes a rank (calculated from potential ranks of 1 to 30) based upon this percentage. Sites with ranks closest to 30 indicate that, other things being equal, are the likely candidates to contribute the most to the loss of water quality for the Upper Iowa Watershed. The top seven candidate sites (in rank order) are: Ten Mile Creek, Upper Iowa River, Decorah, Trout Run, Silver Creek, Cresco, Coldwater Creek, Trout River, and Coon Creek. Six of these seven sites also represent sub-watersheds, ranging in size from about 20 to 51 square miles; the site named Upper Iowa River, Decorah is from the main river just downstream from the entrance of Trout Run and would not represent a separate sub-watershed.

A slightly different, but related, approach is to focus on the means for each site (based upon the three sampling dates) for each of the six parameters (Table 4). A similar suite of descriptive statistics appears at the bottom of this table, only in this case the calculations are based upon mean values within the table. The right-most column in this table contains a tally of how many of the six means for particular site are at or exceeds the value of the Third quartile. Only three sites, Ten Mile Creek (5 out of 6 means) and Trout Run and Dry Run Creek (4 out of 6 means) had more than half of their estimated parameters that were in the top quarter of the means calculated. To help clarify which sub-basins may contribute the most to reduced water quality, a listing of only the Third quartile sites for each of the 6 parameters measured is included (Table 5). Fifteen different sub-basins are represented in the listing of Third quartile sites, plus two sites from the mainstream of the Upper Iowa River. If rank scores are assigned to the Third quartile sites for each parameter (7 = highest, 1 = lowest), and then those scores summed for each site, the five sites with the highest ranking are: Trout Run, Dry Run Creek, Ten Mile, Silver Creek, Cresco, and Unnamed Creek, MN.

CONCLUSIONS and RECOMMENDATIONS

The attempt to characterize the water quality of the Upper Iowa Watershed based upon single samples from 30 sub-basins at three different sampling dates has been at least partially successful. Water quality parameters showed considerable variation between the three sampling dates. Much of this can be attributed to the stream flow conditions on the sampling dates, as has been described in the previous section. This sampling effort has probably been most successful in identifying a set of sub-basins that appear to have relatively high water quality characteristics. The 13 sites that do not appear in Table 5 were sites that had none of their mean values for the six water quality parameters in the top quartile.

Recall that sites were characterized in three different ways: (1) means of the three sampling dates for each of the six water quality parameters were used and the number of these means that are in the top quartile was determined (maximum possible is six, see Table 4); (2) the number of times that a site had any of the six water quality in the top quartile of values over the three sampling dates was noted (maximum possible is 18, see Table 3), and (3) order the sites in the top quartile were placed in rank order based upon the mean for the three dates, for each of the six parameters and then a rank sum value for the site was calculated (maximum rank sum possible is 42, see Table 5). Only two sites appear in the top five by all three methods (Ten Mile Creek and Trout Run), and two more (Dry Run Creek and Silver Creek, Cresco) appear in the top five in two of the three methods (Table 6).

Without the ability to estimate the variability within a sub-basin on a sampling date, as only one sample was obtained and analyzed per sub-basin per sampling date, it is difficult to adequately characterize the relative water quality for many of the sub-basins. However, I believe we have sufficient information to narrow the list for further consideration to no more than the 15 sub-basins that appear in Table 5. With approximately the same sampling effort (i.e. about 30 samples on each of three additional sampling dates), but with a focus on a smaller number of sub-basins, it should be possible to get more than a single sample from within each sub-basin. This additional sample data would provide the opportunity to separate the between sub-basin variability from the within sub-basin variation. The result should be a more objective decision concerning the selection of sub-basins that contribute the most to the overall degradation of water quality of the Upper Iowa River.

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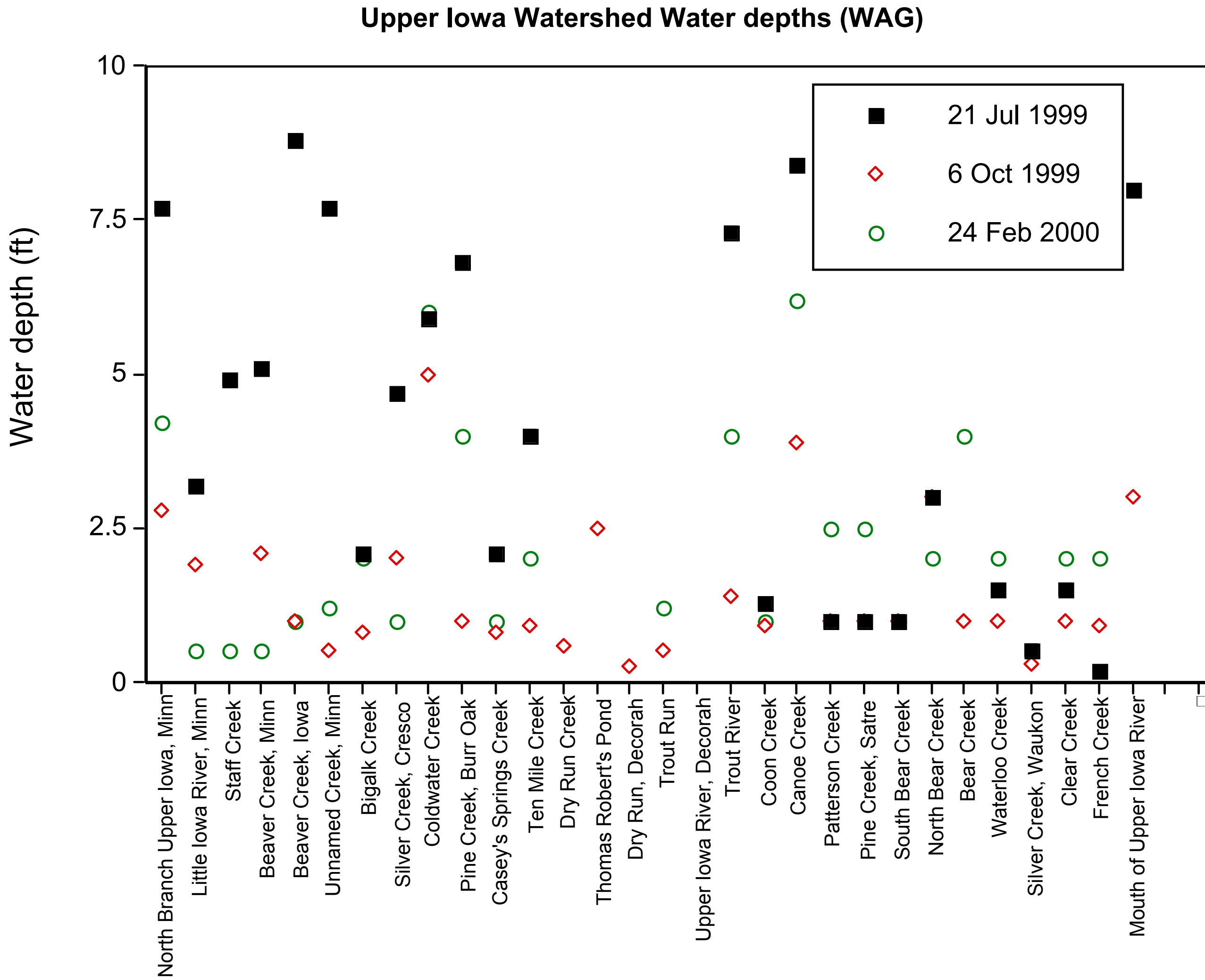

Figure 3. Water depth at 30 stations sampled during the Watershed Assistance Grant (WAG)

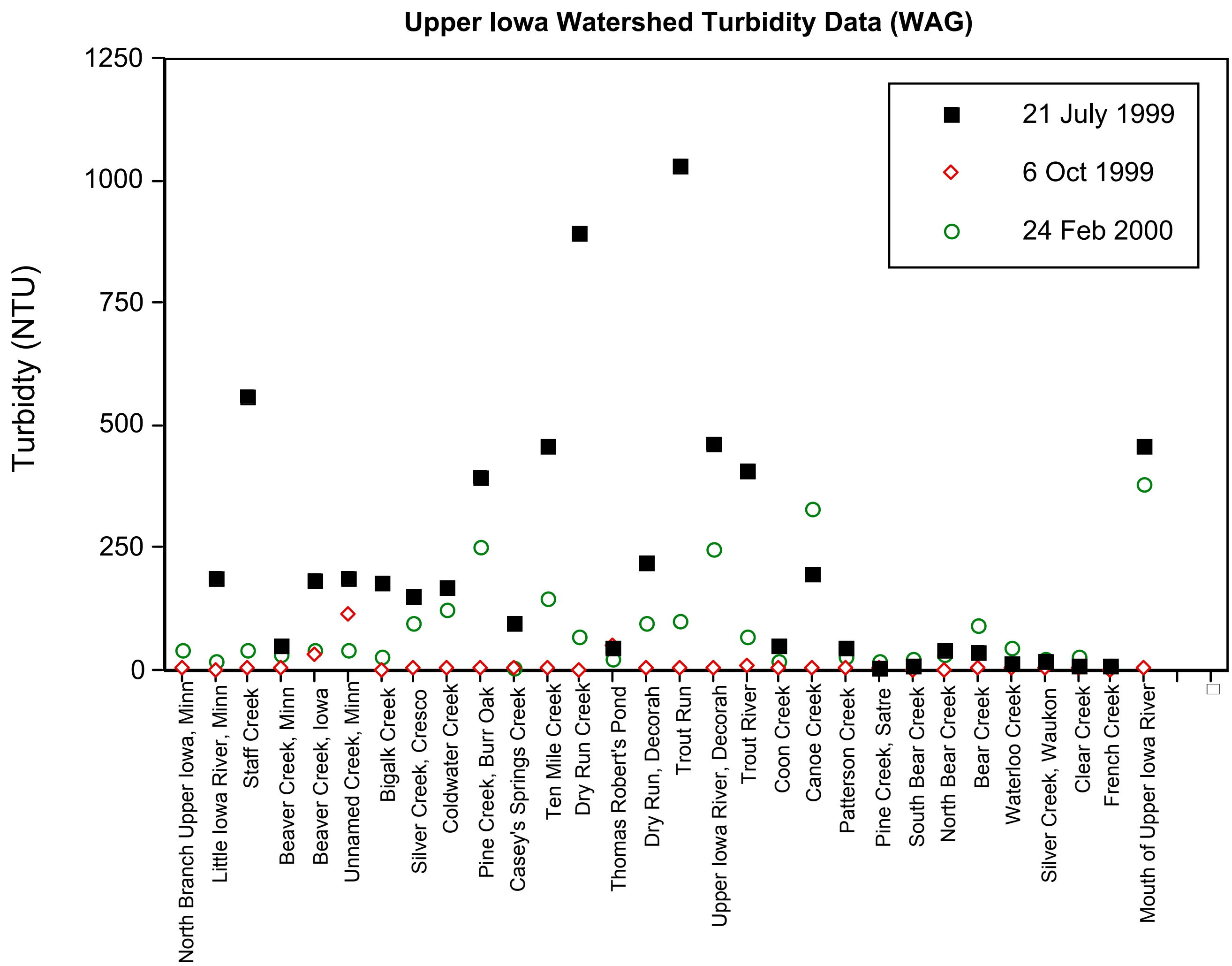

Figure 4. Turbidity at 30 stations sampled during the Watershed Assistance Grant (WAG)

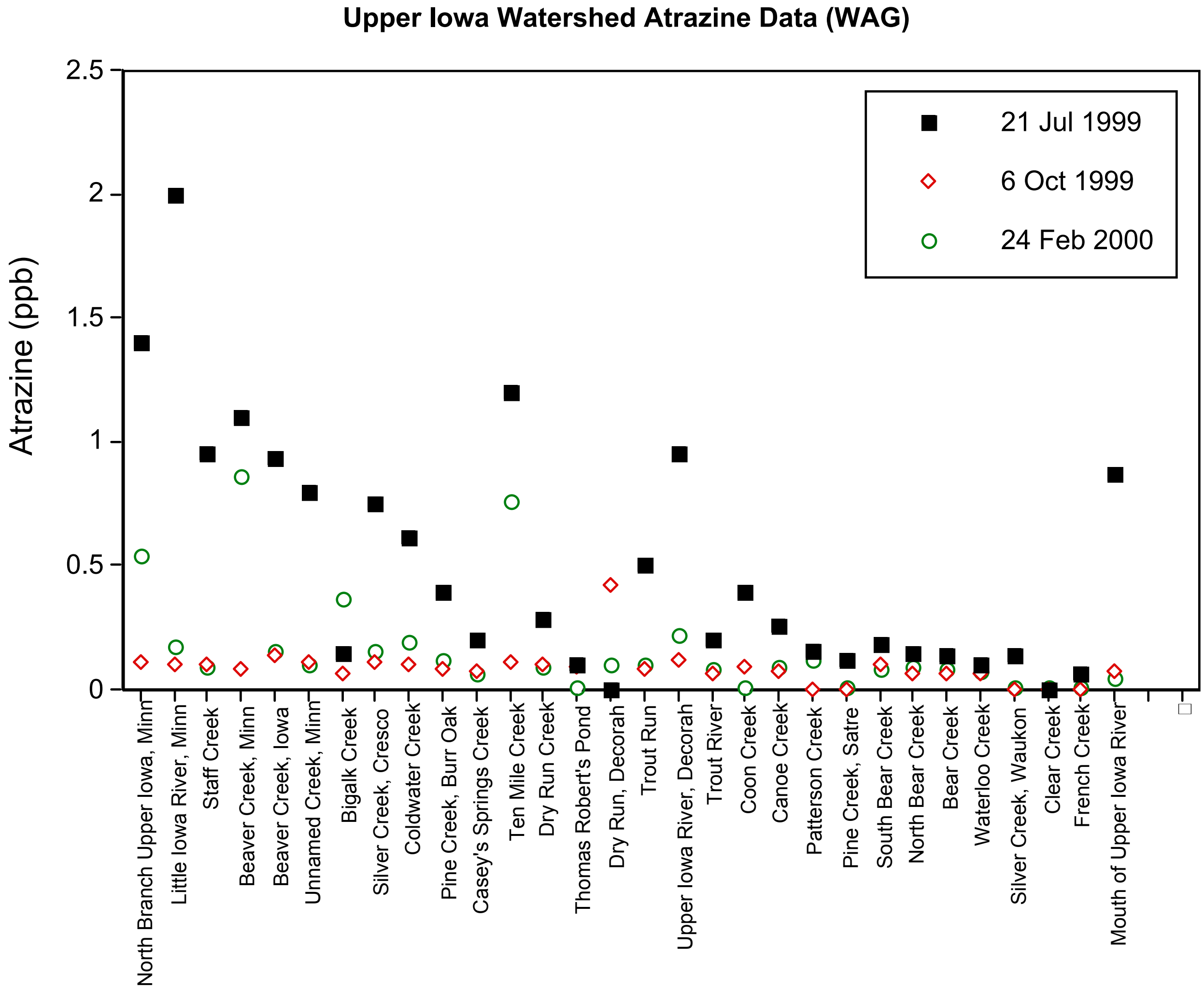

Figure 5. Atrazine at 30 stations sampled during the Watershed Assistance Grant (WAG).

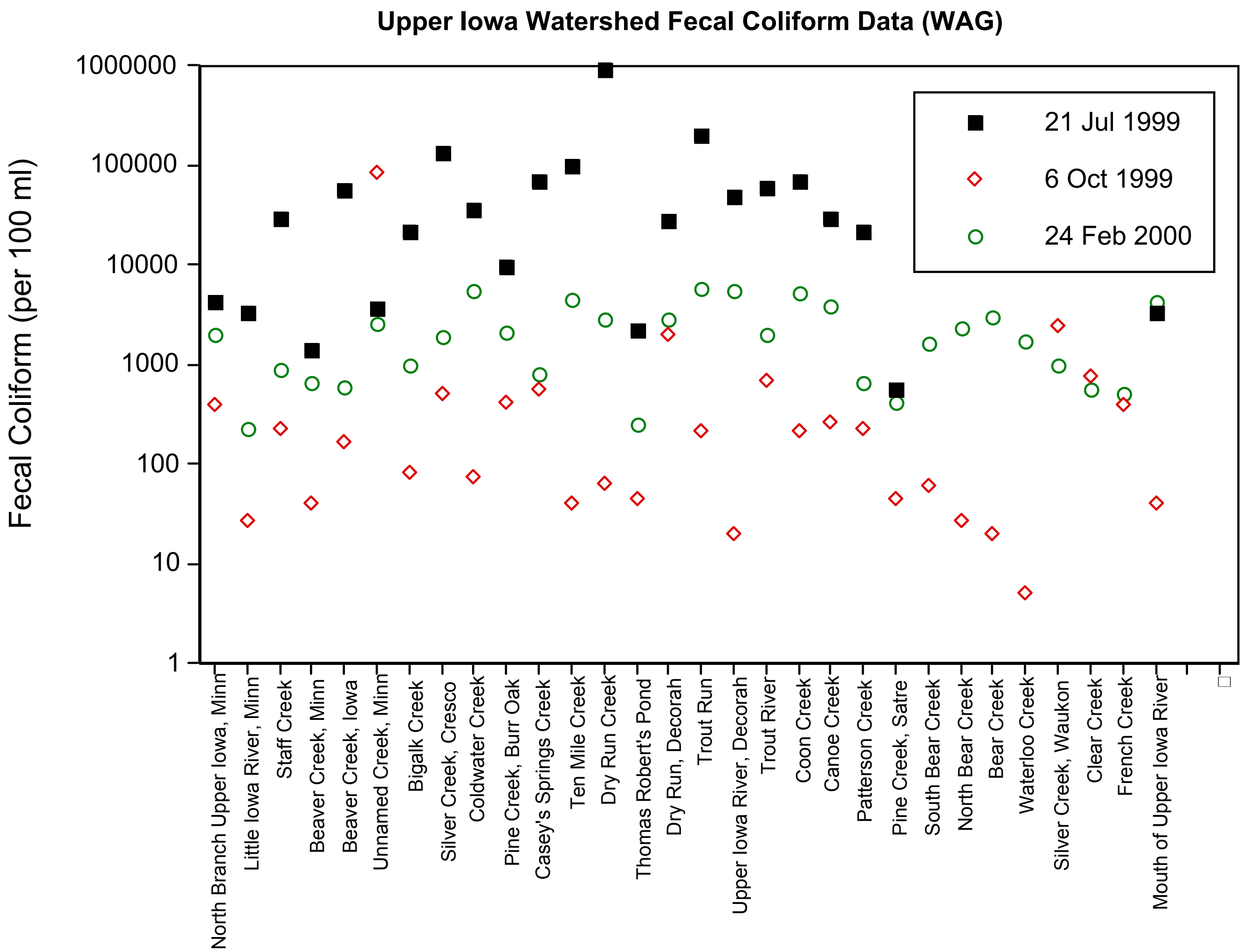

Figure 6. Fecal coliform at 30 stations sampled during the Watershed Assiatance Grant (WAG).

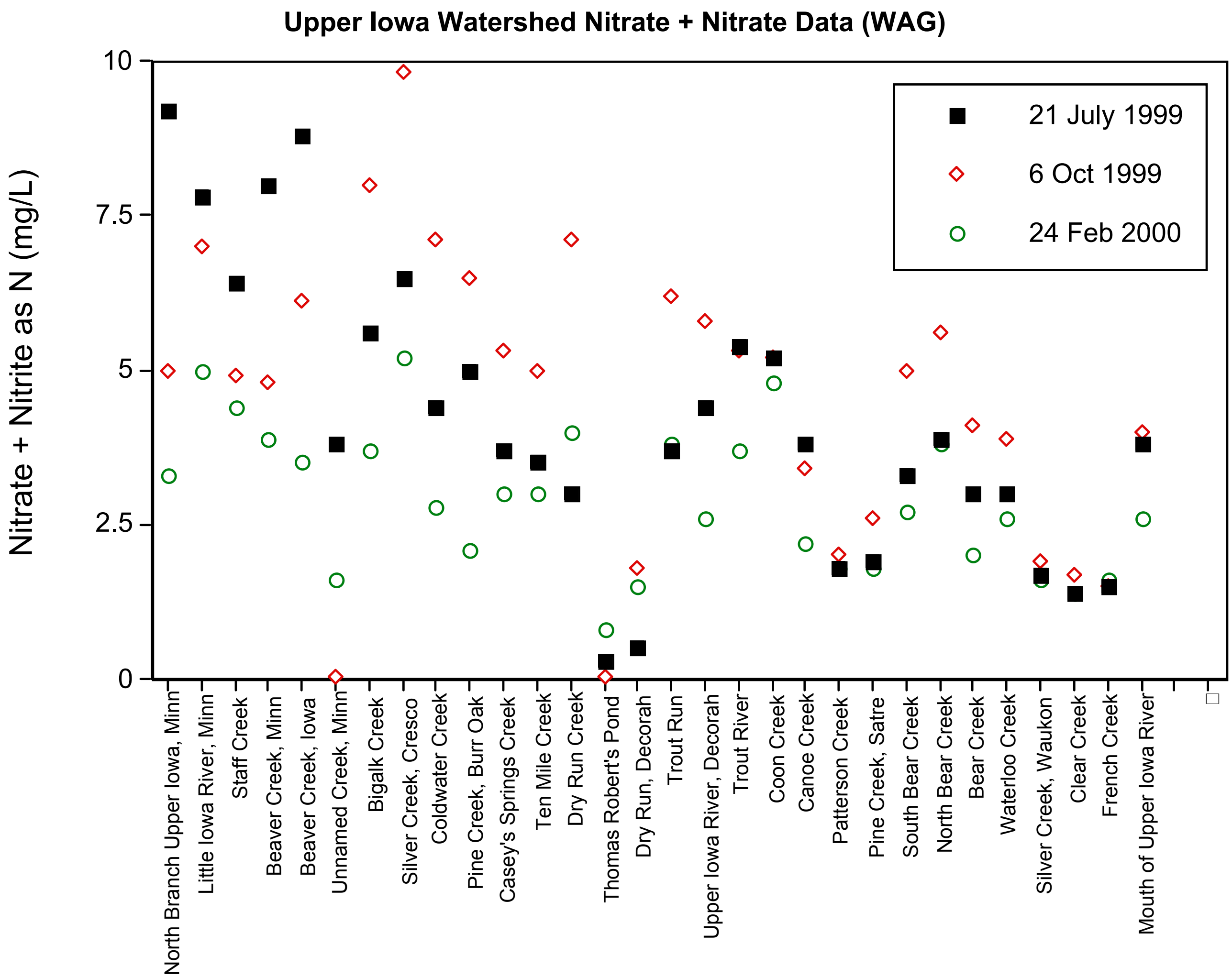

Figure 7. Nitrate+Nitrite Nitrogen at 30 stations sampled during the Watershed Assistance Grant (WAG)

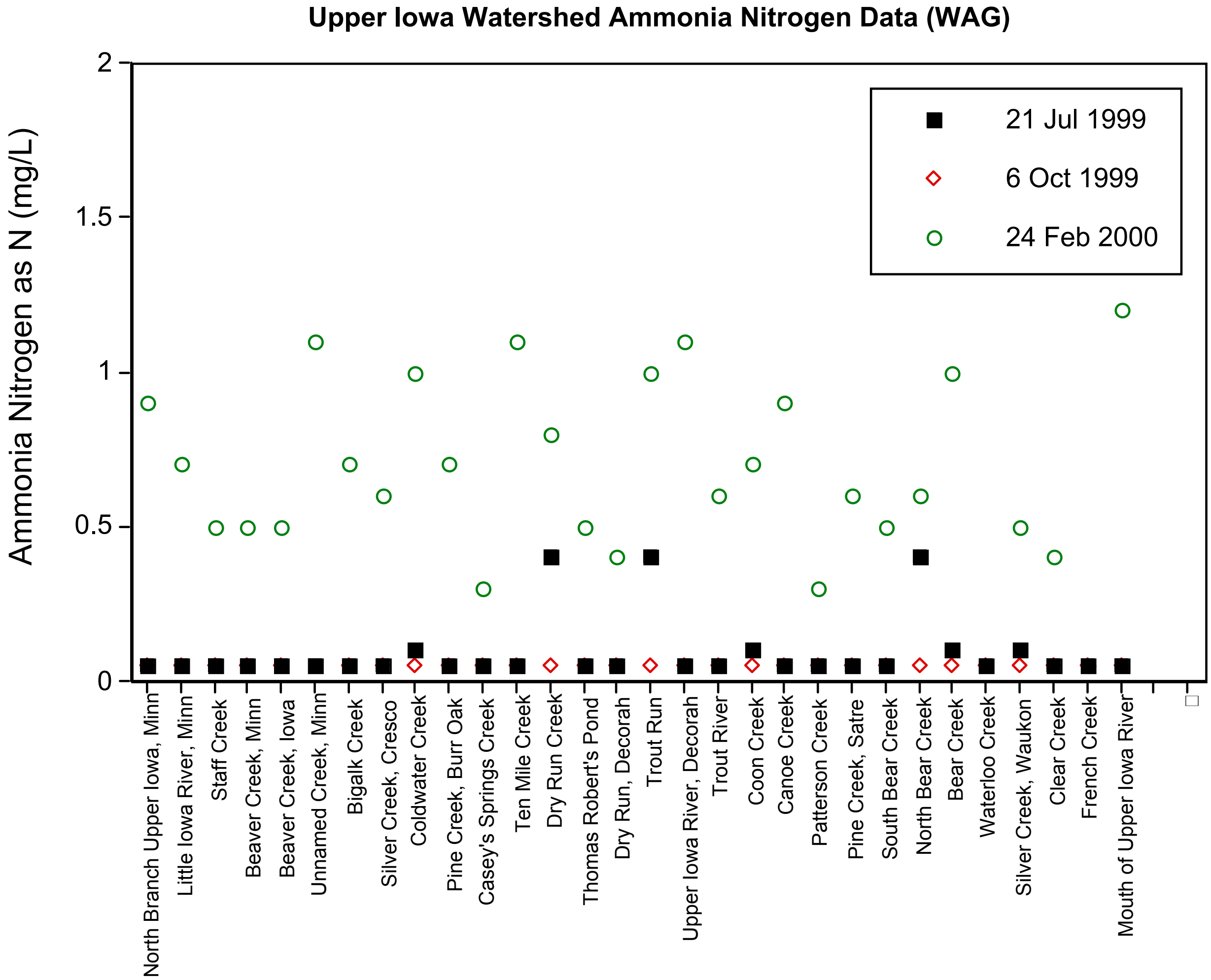

Figure 8. Ammonia Nitrogen at 30 stations sampled during the Watershed Assistance Grant (WAG). Not displayed is the value of 13 mg/L at Unnamed Creek, MN on 6 October, 1999.

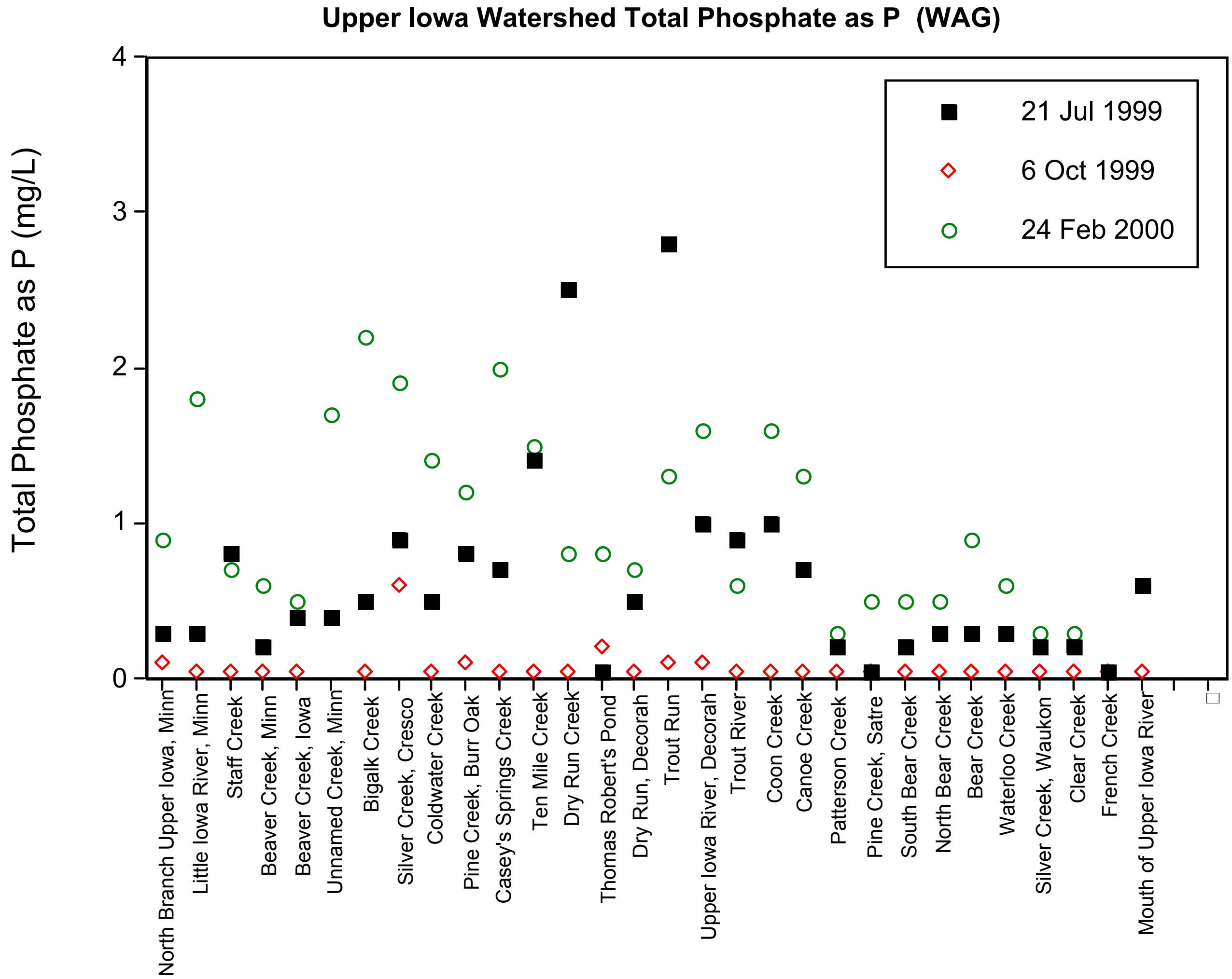

Figure 9. Total Phosphate at 30 stations sampled during the Watershed Assistance Grant (WAG). Not displayed is the value of 7.2 mg/L at Unnamed Creek, MN on 6 October, 1999.

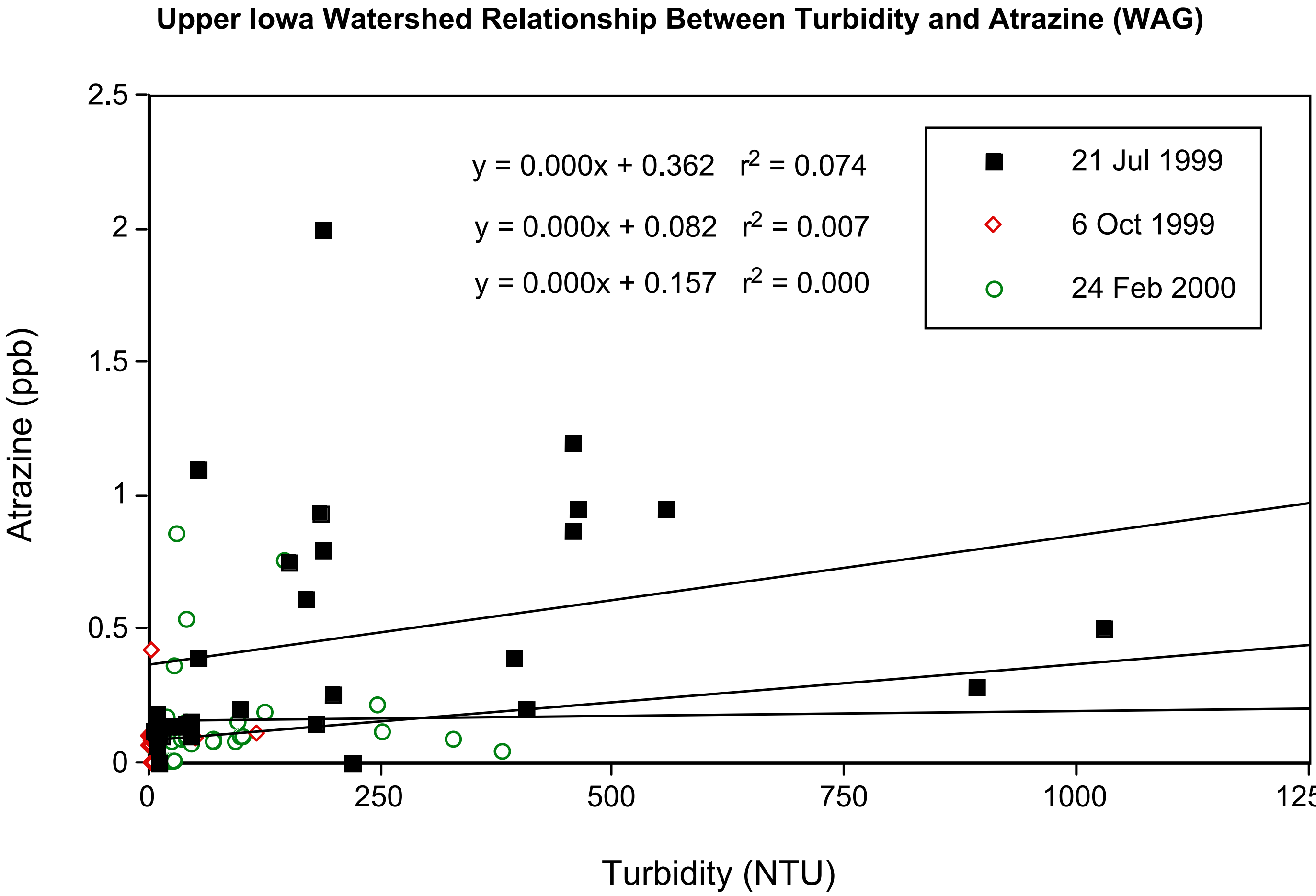

Figure 10. Relationship between turbidity and atrazine at 30 stations sampled during the Watershed Assistance Grant (WAG).

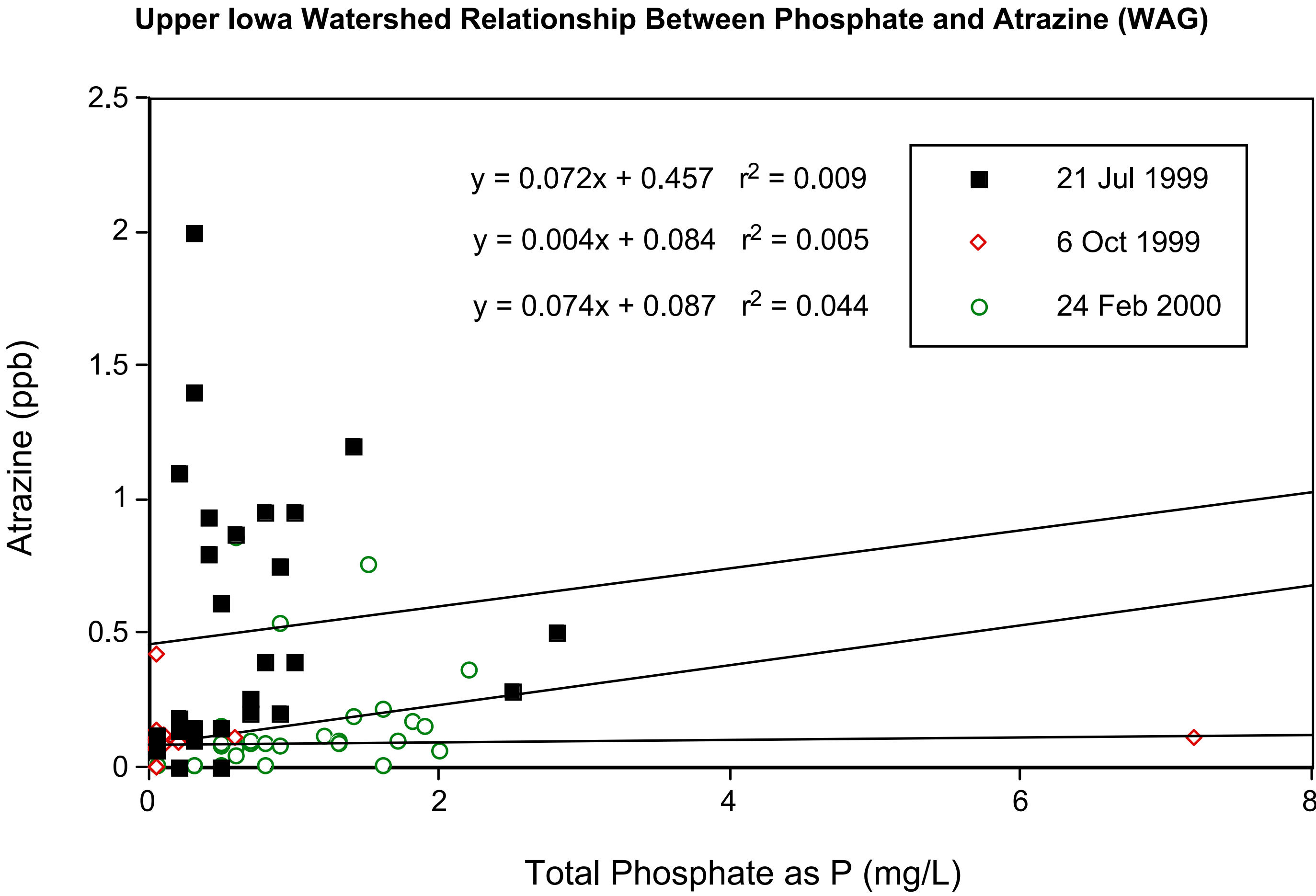

Figure 11. Relationship between phosphate and atrazine at 30 stations sampled during the Watershed Assistance Grant (WAG).

Upper Iowa Watershed Relationship Between Nitrate and Atrazine (WAG)

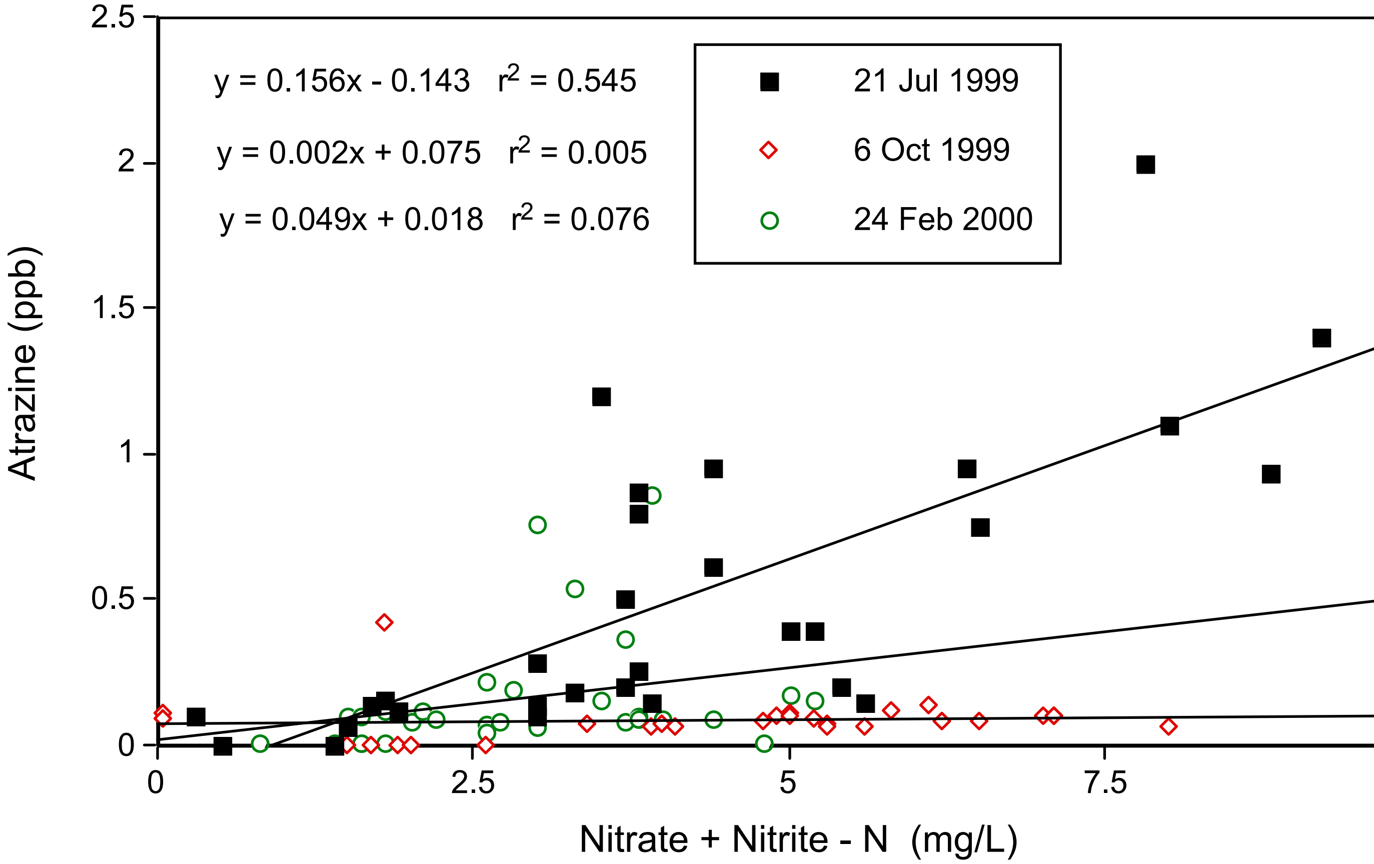

Figure 12. Relationship between nitate and atrazine at 30 stations sampled during the Watershed Assistance Grant (WAG).

Table 6. Comparison of sub-basins with lowest water quality based upon three different methods, ordered from worst (at top) to better; score shown within ( ).

Number of means in the top quartile for a site (Maximum = 6)	Number of times a site had parameters in the top quartile (Maximum = 18)	Rank sum score for sites in top quartile for each parameter (Maximum = 42)
Ten Mile Creek (5)	Ten Mile Creek (10)	Trout Run (24)
Dry Run Creek (4)	Upper Iowa, Decorah (10)	Dry Run Creek (21)
Trout Run (4)	Trout Run (8)	Ten Mile Creek (17)
Little Iowa River (3)	Silver Creek, Cresco (7)	Silver Creek, Cresco (17)
Staff Creek (3)	Coldwater Creek (6)	Unnamed Creek, MN (16)
Unnamed Creek, MN (3)	Trout River (6)	
Bigalk Creek (3)	Coon Creek (6)	
Upper Iowa, Decorah (3)		
Coon Creek (3)		