Red River Valley Tile Drainage Water Quality Assessment: Phase I Final Report

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Introduction

Following many years of increased precipitation in eastern North Dakota, the practice of subsurface drainage of agricultural land (often called tile drainage) has rapidly increased. Farmers install tile to allow timely access to fields, remove wet areas that interrupt field traffic patterns, and reduce salinity; thus increasing crop yield and profit. Subsurface drainage has been used in the US since 1836, but it is relatively new to the Red River Valley of eastern North Dakota and Northwest Minnesota. A significant difference with states farther east is that this area practices rain fed agriculture but has soils prone to increased salinity from rising water tables. This results in high levels of soluble salts in the tile outflow. There are concerns about the possible impact of this water eventually flowing into Lake Winnipeg in Manitoba, Canada via the Red River. This monitoring project was developed to provide a baseline "snapshot" of water quality data including soluble salts, phosphorus, nitrogen and heavy metals from tile outflow. In 2008 the outflow from 18 tile drains were sampled each week for thirty-two continuous weeks. All samples were taken using ND Department of Health (NDDH) and EPA methods. For each sampling site, farmer cooperators provided information on cropping and fertilizer history, tile maps and soil samples when available. The maximum concentration limits (MCL), based on the *Standards of Water Quality for the State of North Dakota,* were exceeded for sulfates (at 13 sites), chloride and boron (at 2 sites), nitrate-nitrogen (at 18 sites) and barium (at 18 sites). The mean concentration for trace metals selenium (at 7 sites) and aluminum (at one site) were found to be above the aquatic threshold as determined by the NDDH for streams in North Dakota. Electrical conductivity (EC) from the two lift station sites were often much higher than the EC of water from the gravity flow outlets. This may be due to the geographical lay of the land and its history of water naturally draining into that area, depositing more minerals than in other subsurface drain locations.

Goals

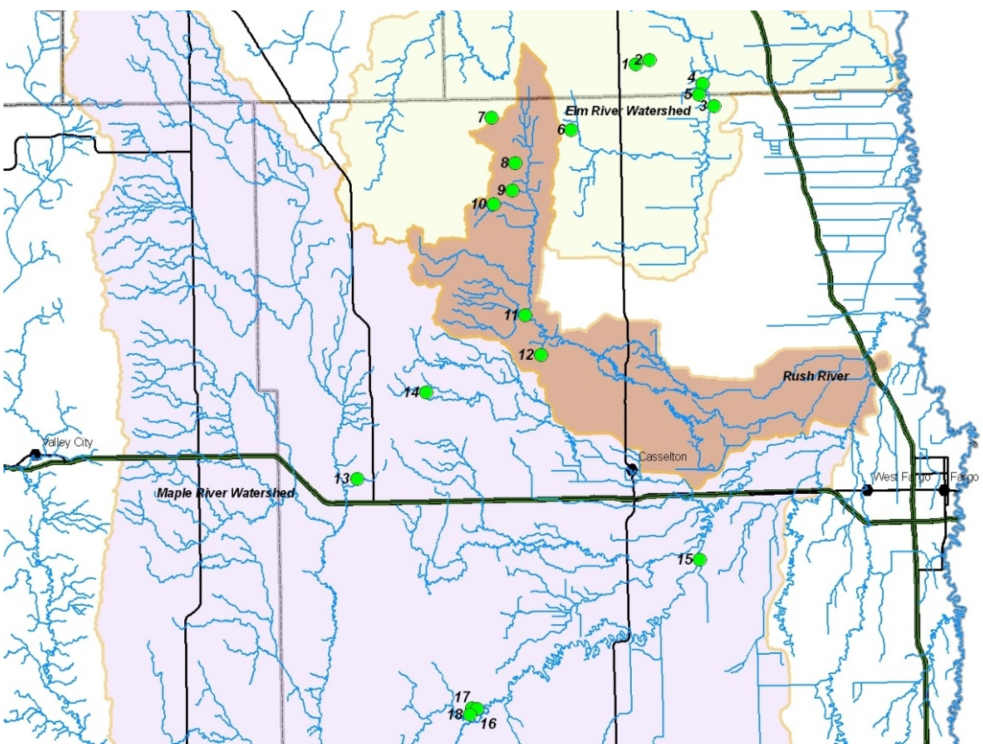
1) Obtain baseline water quality measurements of tile flow to develop a more intensive study to be completed as Phase II.
2) Determine the effect that tile drainage could have on water quality in the Red River Basin.

Objectives and Tasks

Objective 1: Determine the effect tile drainage has on water quality in tributaries of the Red River located in Cass County and southern Traill County.

With the assistance of the Cass County Soil Conservation District watershed coordinator, weekly samples were taken at 18 sites in Cass and southern Traill Counties (Elm, Maple and Rush River watersheds) for a period of 32 weeks in 2008. On site, the water was tested for pH, EC, and temperature using an Oakton Model 35630-62. The meter was owned and calibrated by the Cass County Soil Conservation District. Temperature was helpful in determining if flow, captured in submerged tile outlets, was cooler than the stream water. Initial observations of increased EC measurements at the lift station sites indicated higher mineral loading. Water samples were sent to the North Dakota Department of Health laboratory for general chemistry analysis and pictures were taken of water sample bottles to show turbidity.

Objective 2: NDSU Water Quality Specialists will analyze the results that will be used as baseline data for Phase II monitoring.



The map featured above shows the eighteen sites that were sampled in Phase I. The watersheds included the Elm River, Rush River and the Maple River. GPS locations for each site are shown in the table below.

SITE	STORET	DLAT	DLONG		SITE	STORET	DLAT	DLONG
1	385427	47.2678378	-97.1941469		10	385438	47.1435998	-97.3876838
2	385428	47.271557	-97.1762877		11	385439	47.0426488	-97.3490119
3	385429	47.2278968	-97.0914488		12	385440	47.006681	-97.329125
4	385430	47.248764	-97.106669		*	385441	47.0141758	-97.417248
5	385431	47.2388058	-97.1111861		13	385442	46.8975428	-97.57693
6	385432	47.209878	-97.2823477		14	385443	46.9749188	-97.4825008
7	385433	47.2221418	-97.3881388		15	385444	46.8179458	-97.1246397
*	385434				16	385445	.46.6878188	-97.4300469
8	385436	47.1807888	-97.3581938		17	385446	46.6874728	-97.4232047
9	385437	47.15612	-97.363195		18	385454	46.682143	-97.4328388

*Site dropped

Trace metals of concern for this study include Aluminum (Al), Arsenic (As), Barium (Ba), Boron (B), Copper (Cu), Lead (Pb), Nickel (Ni), Selenium (Se), and Zinc (Zn). Copper, lead, nickel and zinc were calculated using a hardness factor of 400 mg/L $CaC0_3$ to determine if the results were below the aquatic life values required by *North Dakota Standards of Quality for Waters of the State*, Chapter 33-16-02.1. It should be noted that the outlets for four sites (4, 5, 7 and 15) flow directly into a river with the remaining sites depositing into a ditch or wetland near a waterway. There has been extensive research on water quality exiting irrigated tiled fields in California; there has been little research on water quality, specifically metals, coming from tiled fields that are dependent on annual rainfall. However, when the mean concentration of trace metals exceeds a threshold, impairments to the ecosystem may occur. High levels may affect fish populations by altering food availability, may increase fish mortality, reduce fish reproduction, and other ecological damage may occur which may not support aquatic life.

Results

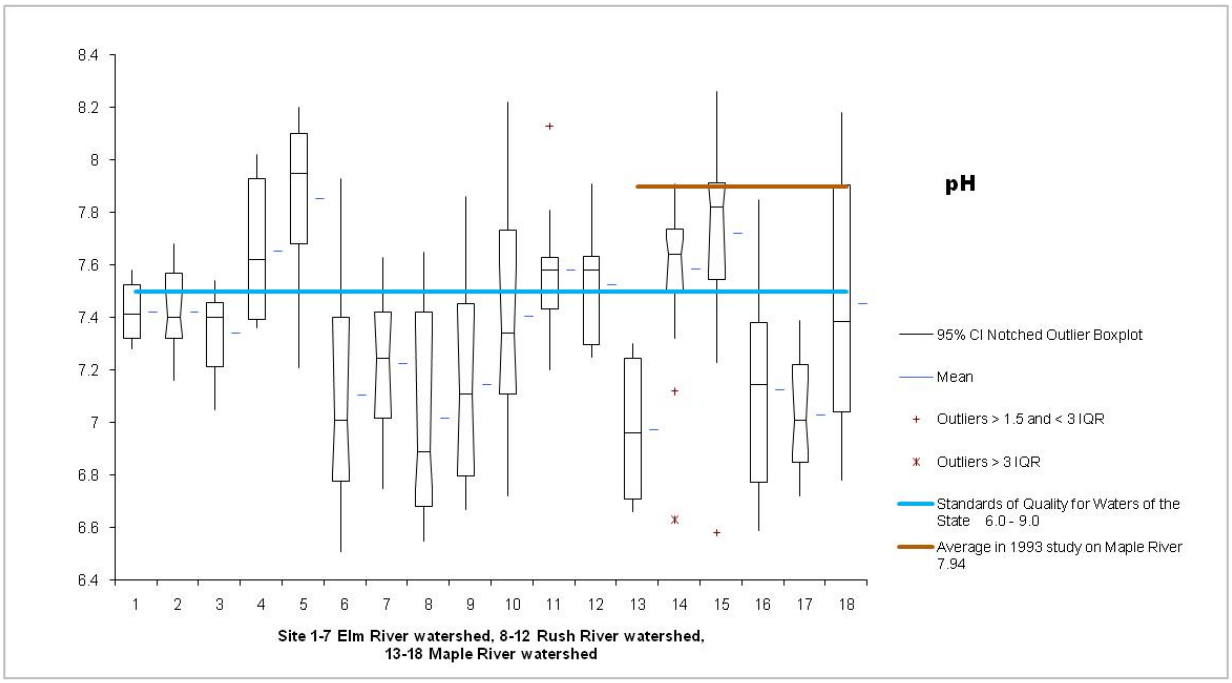
The purpose of this study was to determine baseline water quality from tile drains in Cass County, North Dakota. This project did not include flow measurements and therefore no total loading parameters were calculated. Water quality was compared to previous water quality studies on streams and rivers within the watershed, national drinking water regulations, and North Dakota standards of quality for waters of the state.

The maximum limit allowed based on the *Standards of Water Quality for the State of North Dakota* was exceeded (mean) for sulfates (at 13 sites), chloride and boron (at 2 sites), nitrate (N) (at 18 sites) and barium (at 18 sites). The mean concentration for trace metals, selenium (at 7 sites) and aluminum (at one site), were found to be above the aquatic threshold as determined by the North Dakota Department of Health for streams in North Dakota.

The EPA's Maximum Contaminant Level (MCL) for primary and secondary drinking water standards was exceeded by aluminum at 4 sites, arsenic at 3 sites, selenium at 4 sites, copper at 14 sites, manganese at 1 site, nitrate-nitrogen at 12 sites, and sulfates at 14 sites. The use of MCL's for drinking water is included to provide comparison reference only. The outflow from tile drainage is not used for human consumption.

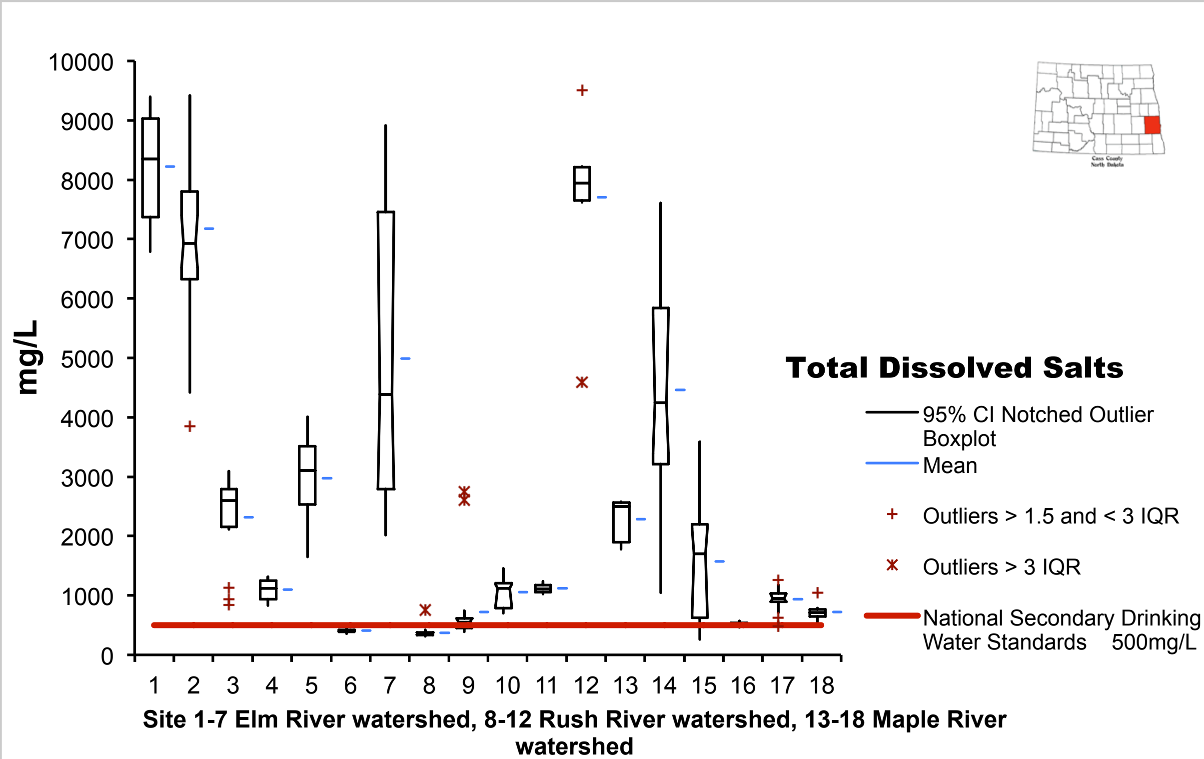
The results from the 18 sampled sites are shown in the following box-plot graphs along with commentary pertinent to each parameter. Box plots show the range of results with the line in the middle indicating the median, the boxes show the range of the 2 and 3 quartile of measurements and the lines, above and below, show the 1st and 4th quartile of measurements.

pH of Water Samples



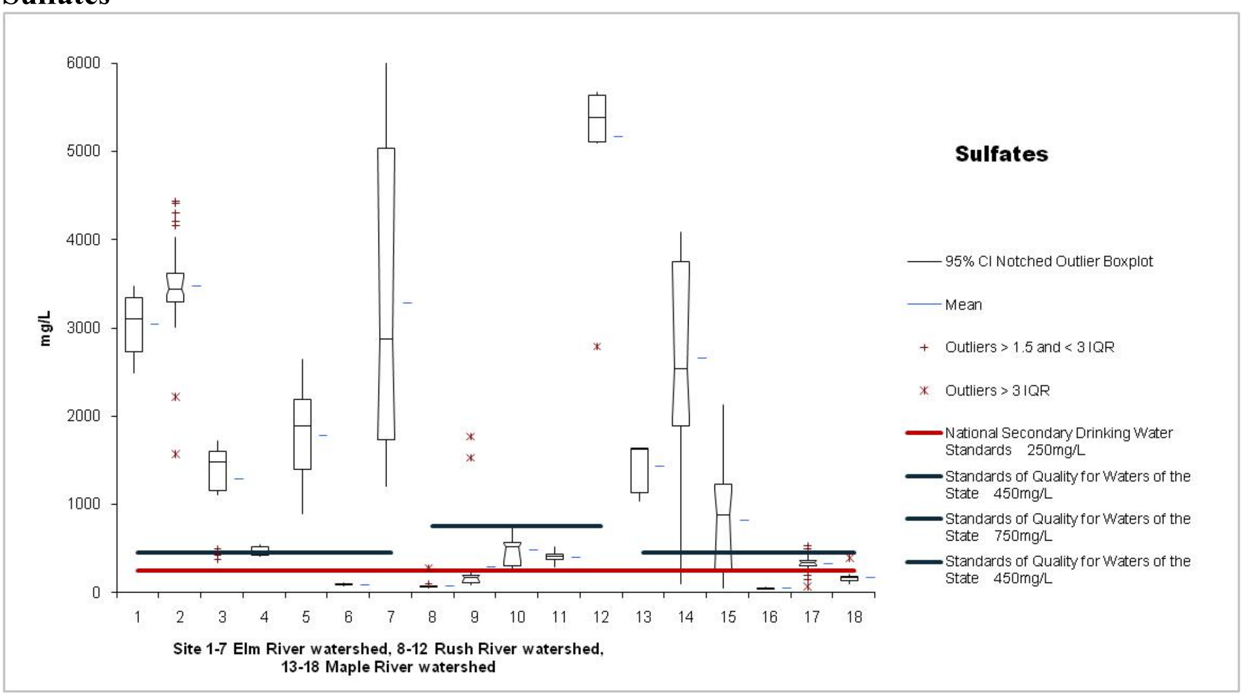
The mean pH values varied from near nuetral water (pH = 7) up to 8. The mean of all samples was 7.5 which is consistent with other water sources in the area.

Total Dissolved Solids (TDS)



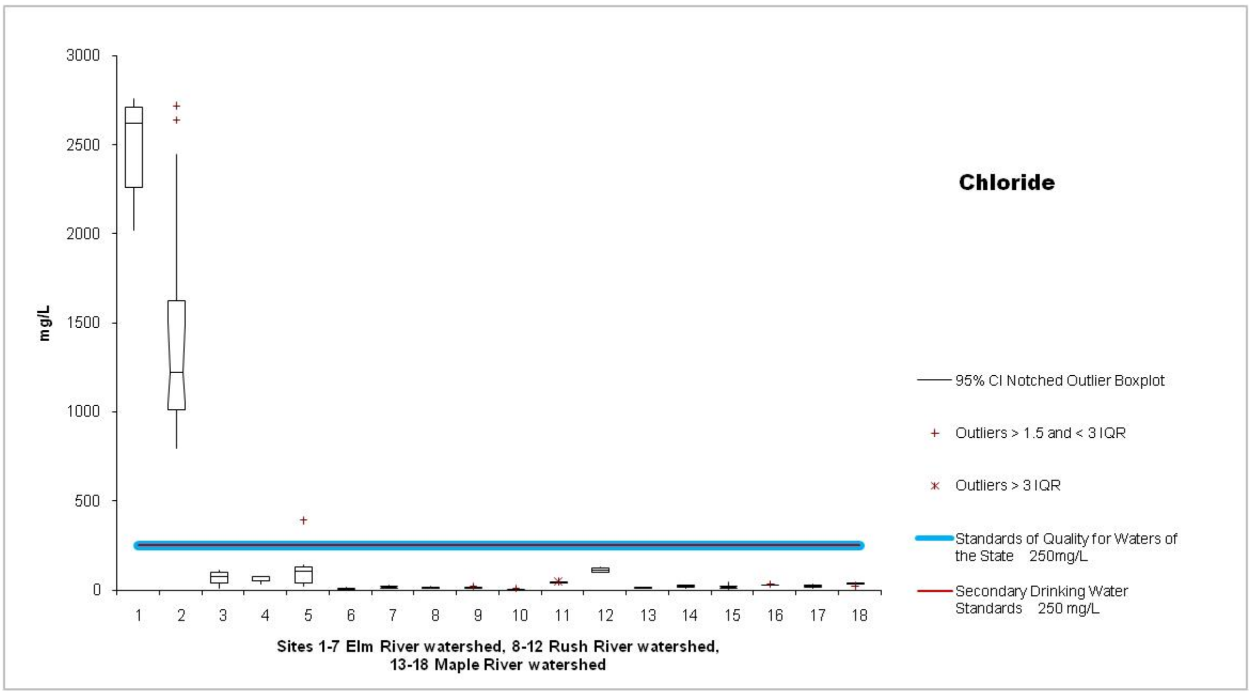
There is a large variation in the mean TDS from the 18 sites. Soil type at each location might impact the amount of TDS but topographical features may be more important. For example, the soil in the fields at sites 1, 2 and 4 are classified as Fargo silty clay. Sites 1 and 2 have high TDS and both have lift stations, yet site 4 has a relatively low TDS but with a gravity outlet.

Sulfates



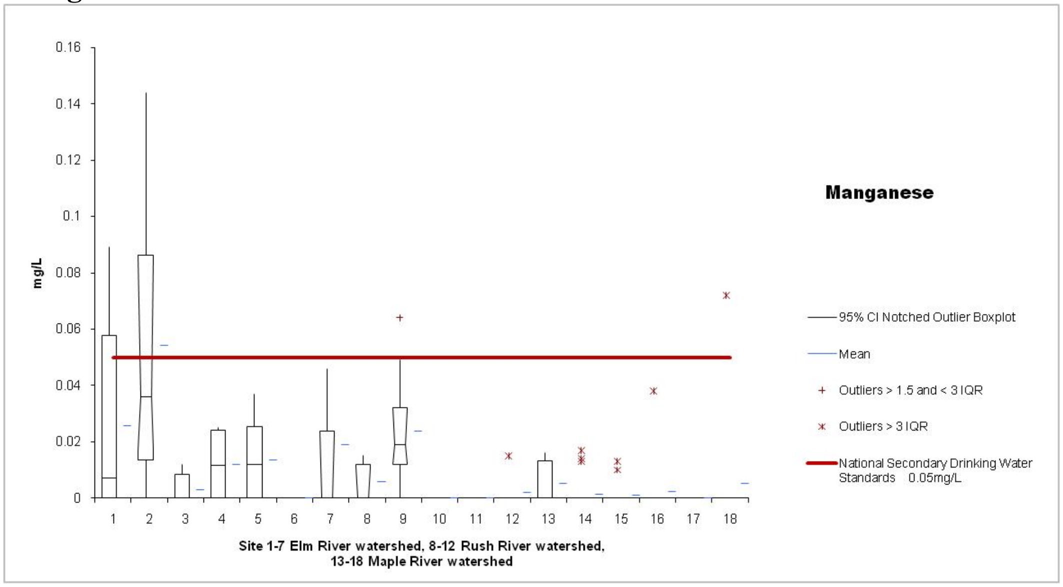
As seen in this graph, sulfate comprises over 60% of the TDS at each site. Sulfate concentrations exceeded the secondary drinking water standard of 250 mg/L at 13 sites. Secondary standards are associated with the aesthetic quality of the water and although may not be pleasant to drink, will not cause health problems. Water high in sulfate usually requires further treatment for public use. Standards of Quality for Waters of the State levels are dependent on the stream classification for sulfates. The Elm River watershed and the Maple River watershed are classified as Class II and have a threshold of 450 mg/L. The Rush River watershed is a Class III and has a threshold of 750 mg/L. All samples on the Elm River watershed exceeded the threshold of 450 mg/L, which may degrade public health and environmental resources. Only site 12 was over the threshold of 750 mg/L in the Rush River watershed and three of the six sites exceeded the standard in the Maple River watershed.

Chloride



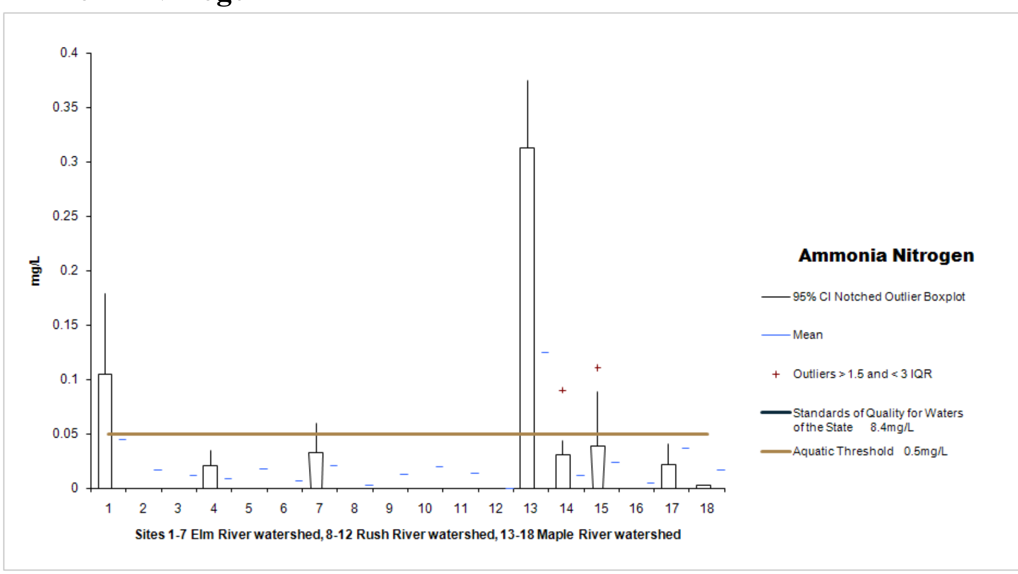
Sites 1 and 2 had concentrations that exceeded the drinking water and surface water thresholds, while the other sites were well below. This may be due to excess salt levels in this area.

Manganese



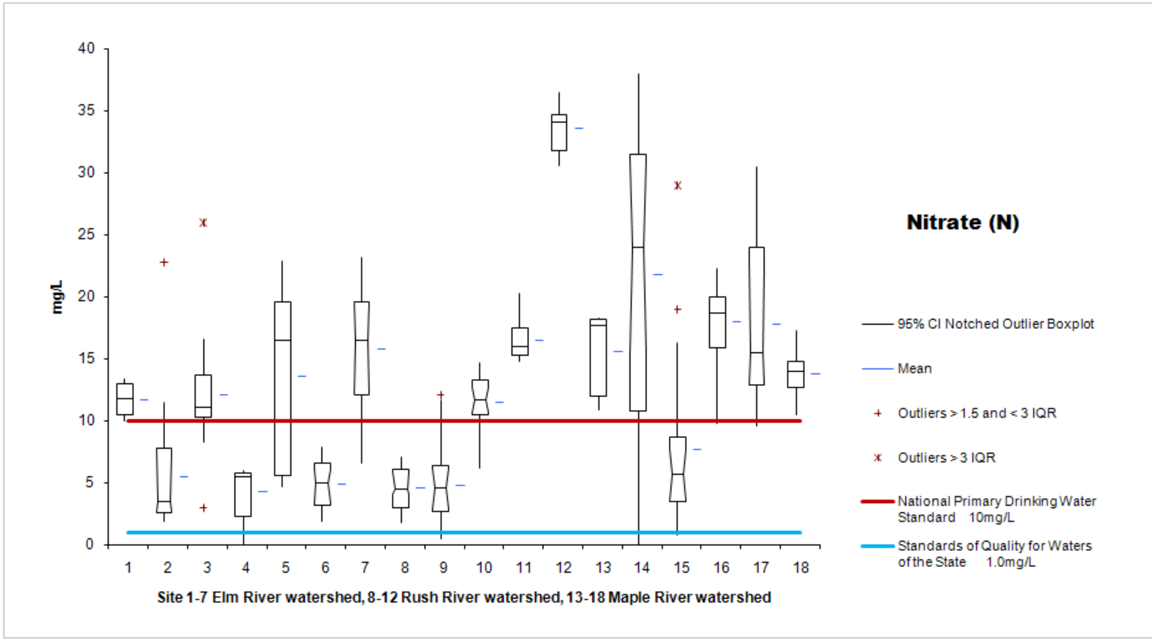
Sites 1 and 2 had manganese concentrations that exceeded the drinking water standards. Recall that sites 1 and 2 also had high levels of chloride common to the in saline soils in this area.

Ammonia Nitrogen



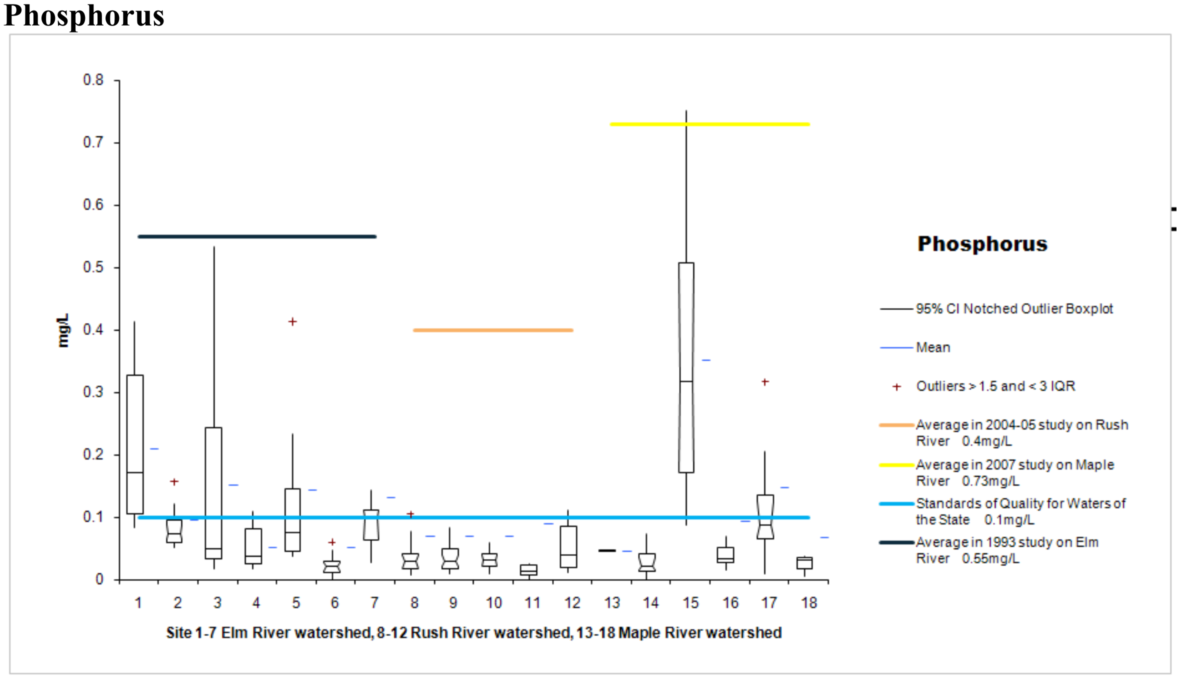
Ammonia nitrogen is believed to harm aquatic life if recommended levels are exceeded. Different species of fish can tolerate different levels of ammonia nitrogen, and plants are more tolerant than animals, and invertebrates are more tolerant than fish. Short periods of high levels of exposure can cause skin, gill and eye damage. Site 13 is the only site that reported high levels of ammonia nitrogen and it was one of three samples. The outlet at this site was constantly submerged and was influenced by ajoining fields.

Nitrate-Nitrogen



It is well known that nitrogen levels are higher in tile drain water than in surface water. Phase I confirmed higher than recommended levels of nitrate nitrogen (NO3-N) were leaving the tile at levels higher than state standards of quality for waters of the state. Best management practices that include split application of fertilizer can be suggested to the producers to reduce the amount of NO3-N leaving the fields. Drinking water standards were exceeded at 12 sites. Although this water is not used for drinking purposes it may be reflected in increased costs to remove it at water treatment facilities although it is not know how much actually gets to a river since 14 of the 18 sites discharge to road ditches or wetlands.

Phosphorus

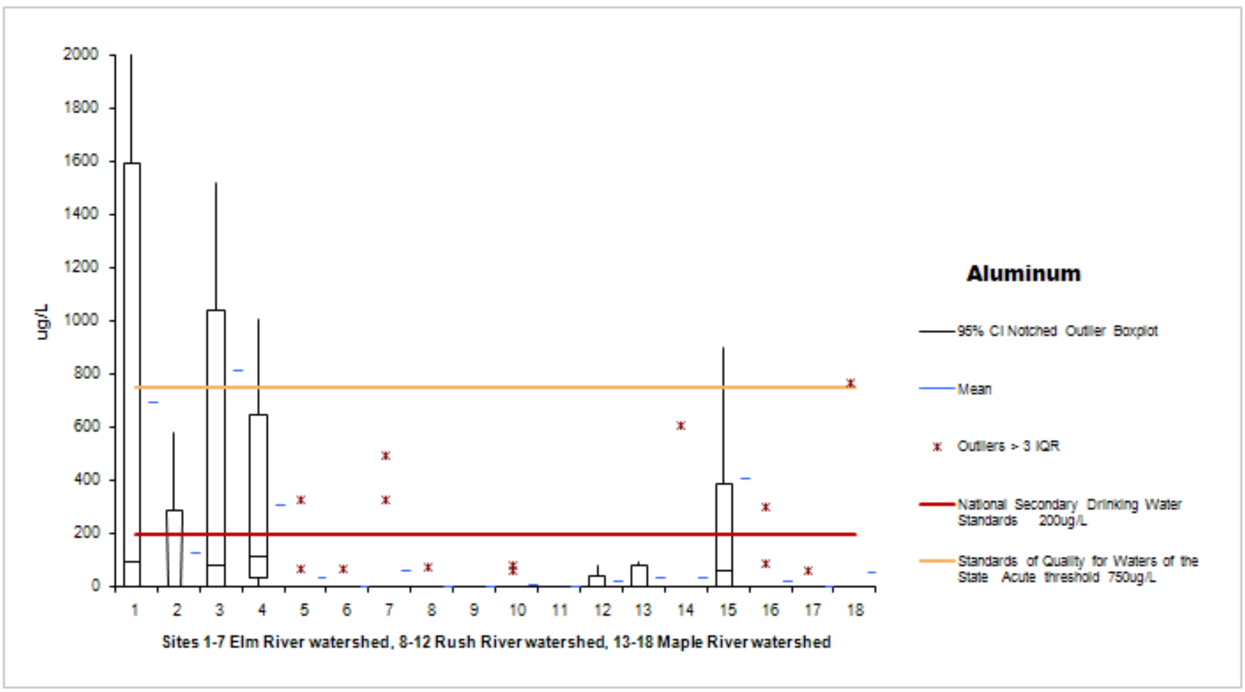


Phosphorus levels in past water quality studies on rivers within their respective watersheds were 0.4 to 0.6 mg/L higher than tile drain effluent levels. Most of the drain water quality was found to be below standards of quality for waters of the state, which is 0.1mg/L (13 of 18). Phosphorus typically adheres to soil particles and with the addition of tile drainage phosphorus does not leave via the drain tile. Rainfall will move through the soil profile and out of the drain rather than moving across the surface and carrying soil particles with it.

The Heavy Metals Dissolved in Water

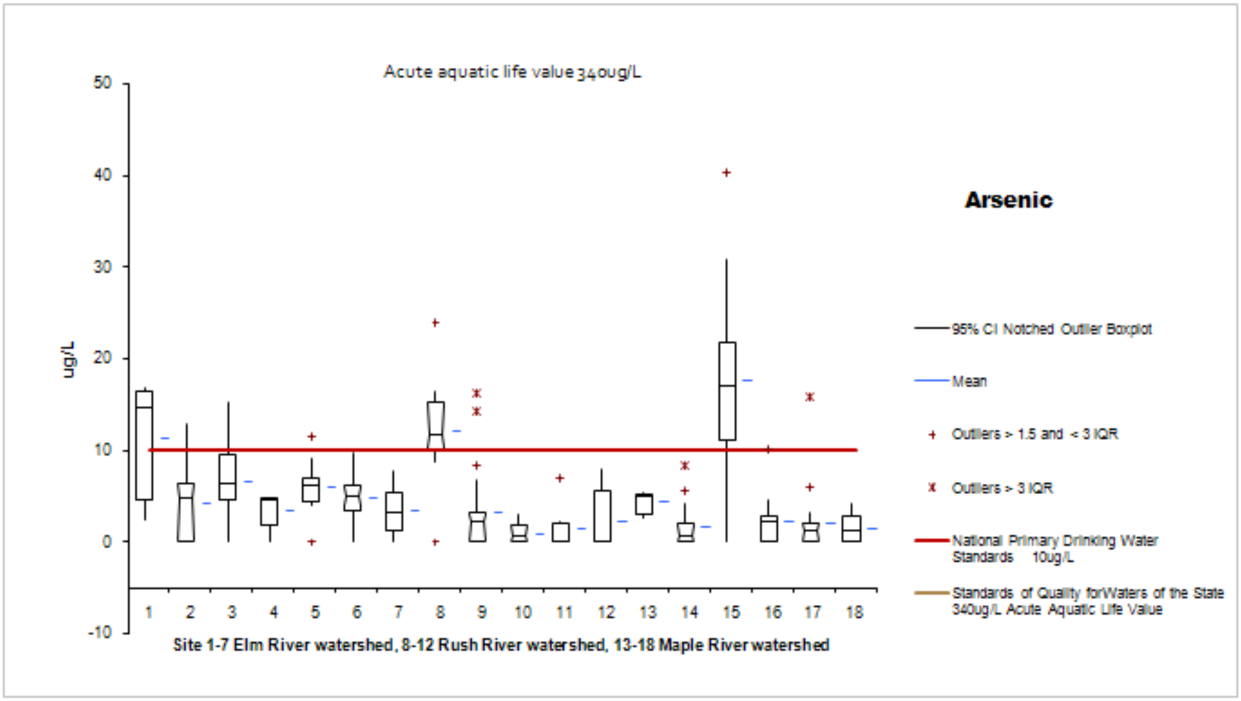
All soil contains traces of various heavy metals and some of these are more soluble than others. Below are the graphs showing the heavy metals that could pose problems for aquatic life. With the exception of barium, the heavy metal concentrations have units of micrograms per liter (ug/L) and 1000 ug/L is equal to 1 milligram per liter (mg/L).

Aluminum



The aluminum concentration exceeded the state aquatic standard and the standards of quality for waters of the state (750ug/L) in 9 of 248 samples (3.6%). Samples concentrations ranged from non-detectible to 4740 micrograms per liter (ug/L) at 5 sites. Two sites flow directly into a river and could result in impairment to aquatic life. Four sites had mean values over the national secondary drinking water standard of 200 ug/L.

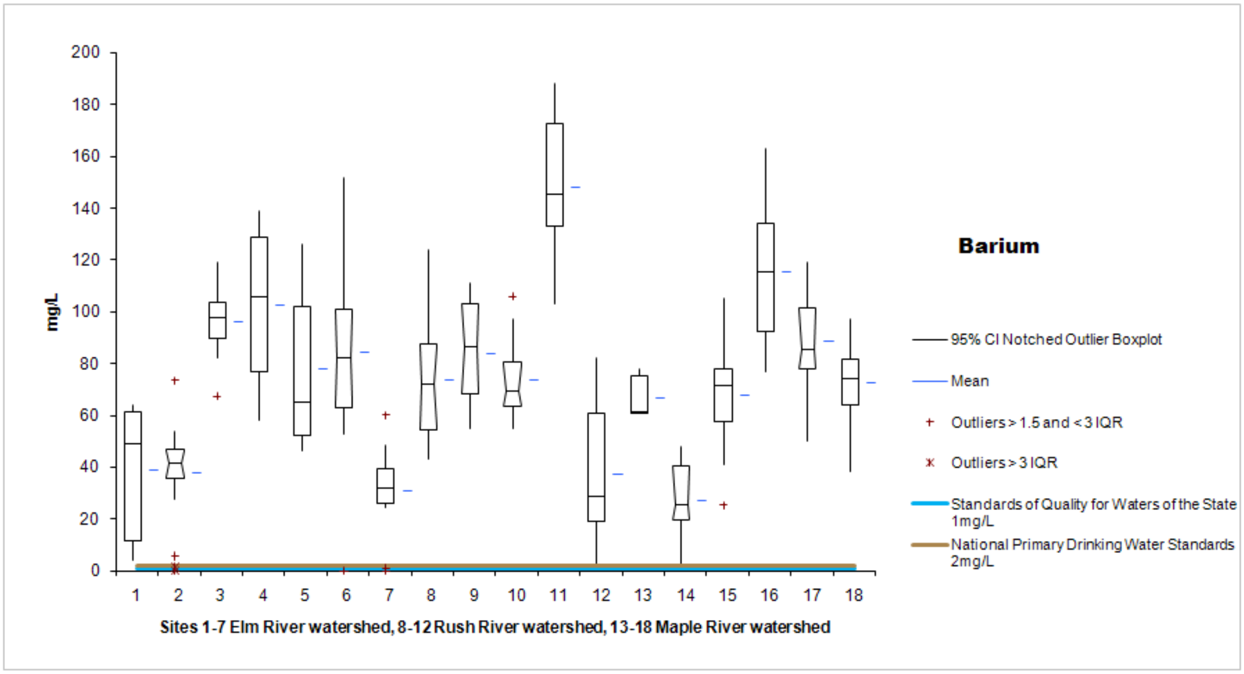
Arsenic



Arsenic concentrations that exceeded the MCL of 10 ug/L were found at 7 sites with twenty-four percent of the 176 samples over the 10 ug/L standard. Site 1 had 3 samples, with 2 over 10 ug/L. Site 2 had 2 samples over the 10 ug/L standard and 7 of 17 samples non-detectible. Site 3 had 8 samples with 2 over the limit and 3 over 8 ug/L. It should be noted that these 3 sites are all in the same area of southern Traill and northern Cass counties. Site 8 had 83% over the limit with 3 over 8.8 ug/L. Site 9 had 2 over the limit or 9.5%. Site 15 was over the limit on 87% of the samples with 2 samples under the limit, one was at 9.2 ug/L. Site 17 had 1 of 17 samples exceeding the limit at 15.8 ug//L.

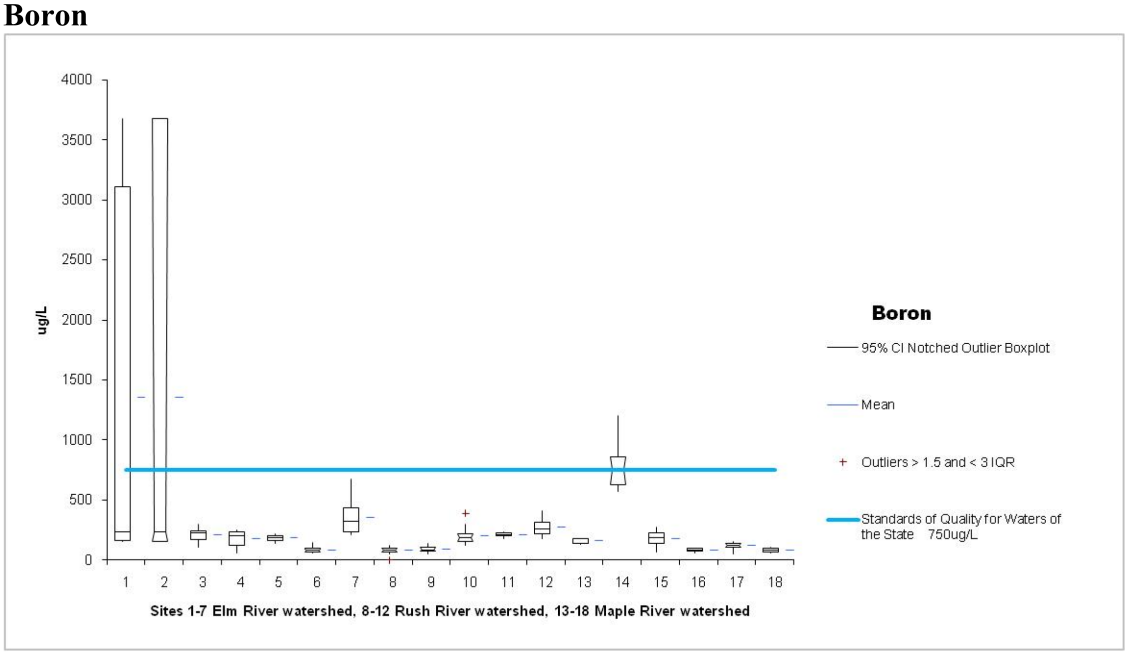
All samples were found to be under the acute aquatic life level of 340 ug/L.

Barium



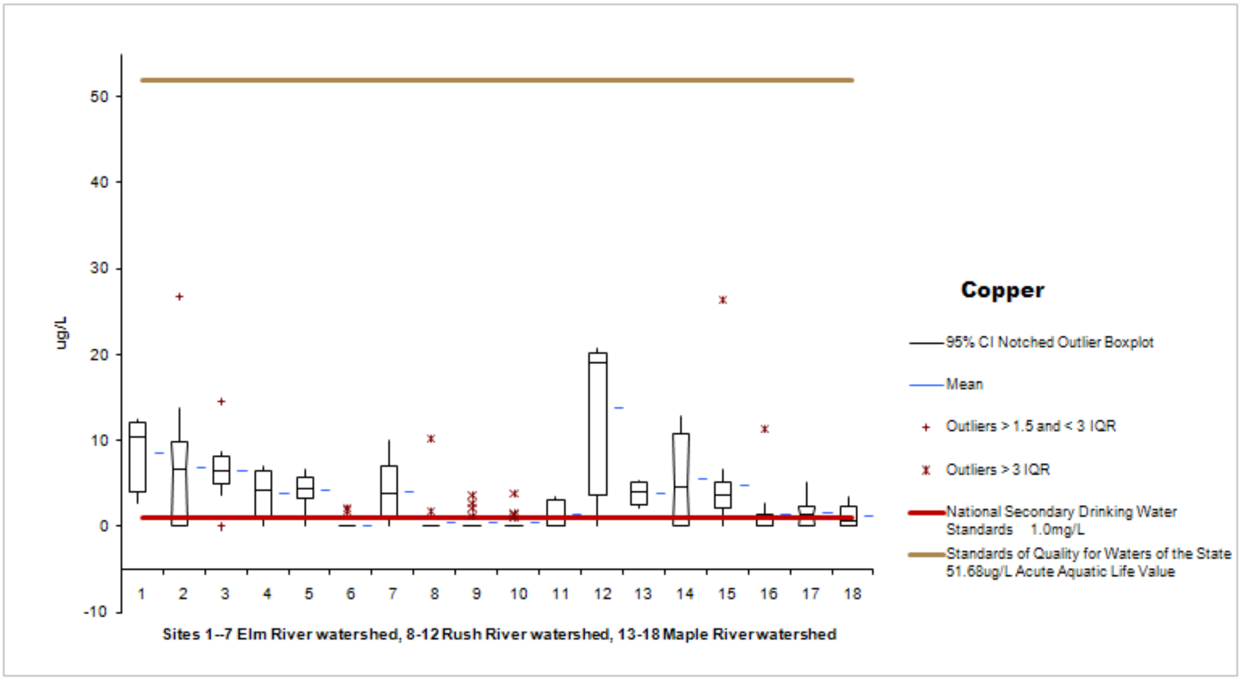
Barium concentrations were found to exceed the threshold for surface water and drinking water standards at all sites. The EPA lists an increase in blood pressure as a side effect of long-term exposure above the MCL for drinking water. There is no aquatic threshold for barium.

Boron



Surface water quality standards for boron is 750 ugL. The mean for sites 1 and 2 exceeded this value. Site 1 was sampled three times and may not be representative of the actual tile drain water. Site 2 is a lift station within one-half mile of Site 1. This area's soils may be naturally high in boron. Both sites drain into the ditch.

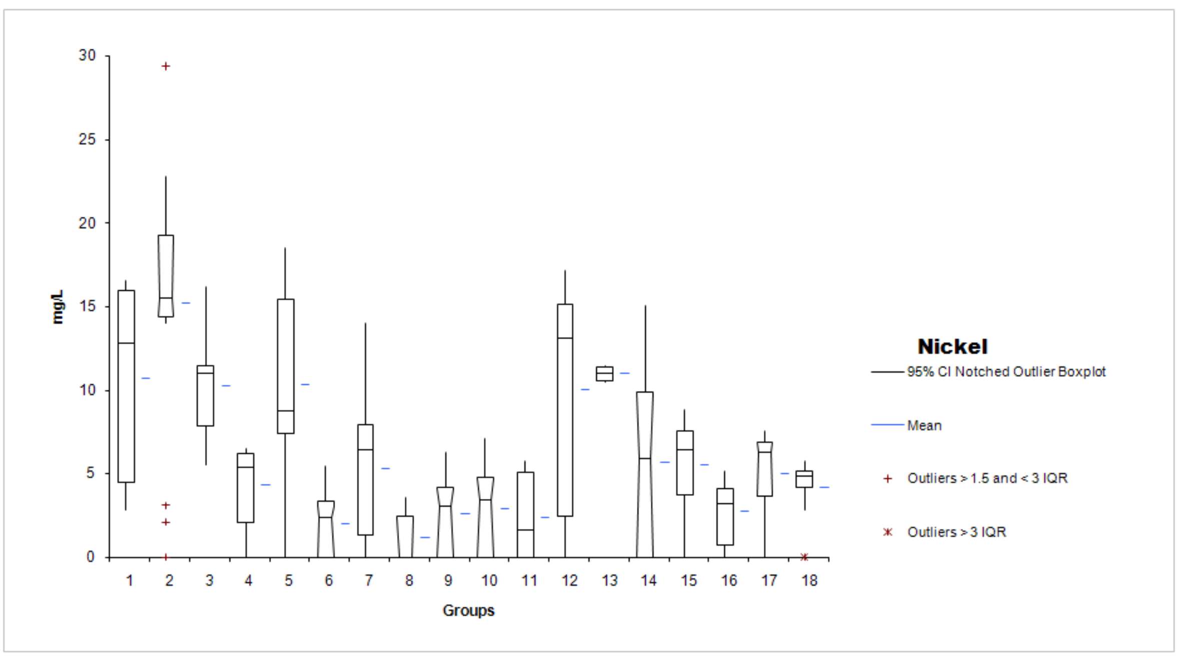
Copper



The calculated aquatic continuous concentration (CMC) or acute exposure value for copper is 51.68 ug/L. No samples exceeded the CMC aquatic threshold. However, secondary drinking water standards were exceeded at 14 of the sites with a maximum value at site 12 of 26.7 ug/L.

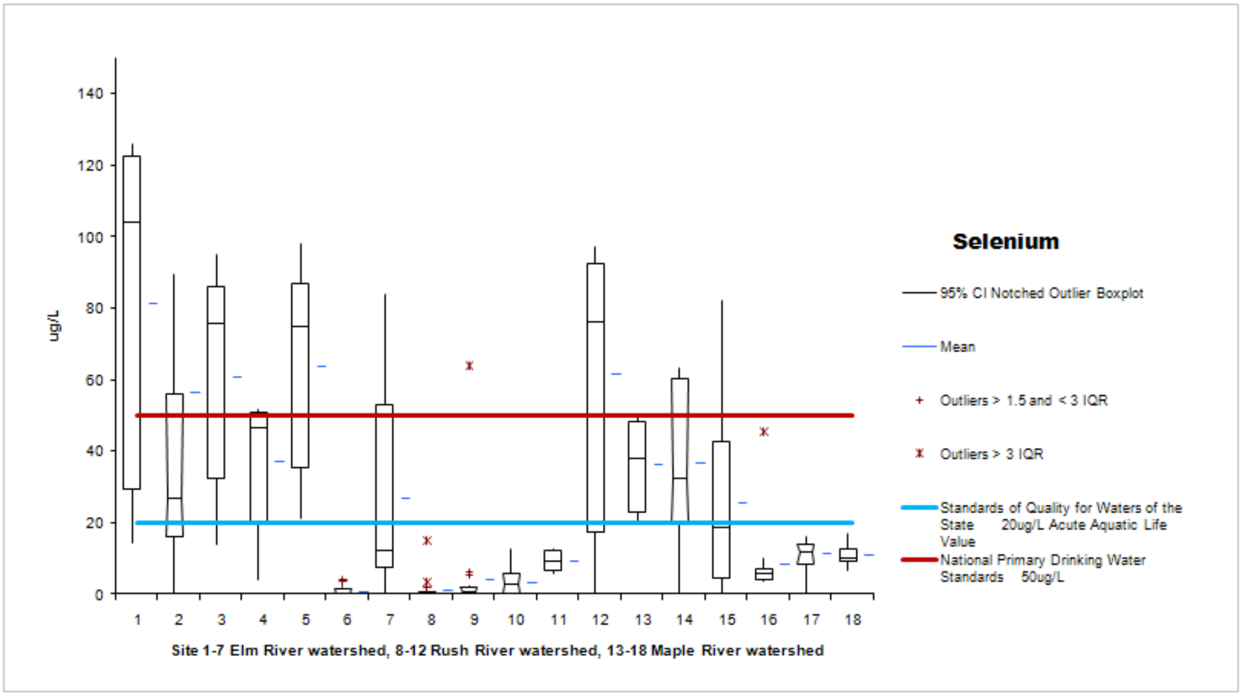
Lead - not detected in any samples.

Nickel



The calculated CMC for nickel is 1515.92 ug/L. All samples fell below this value.

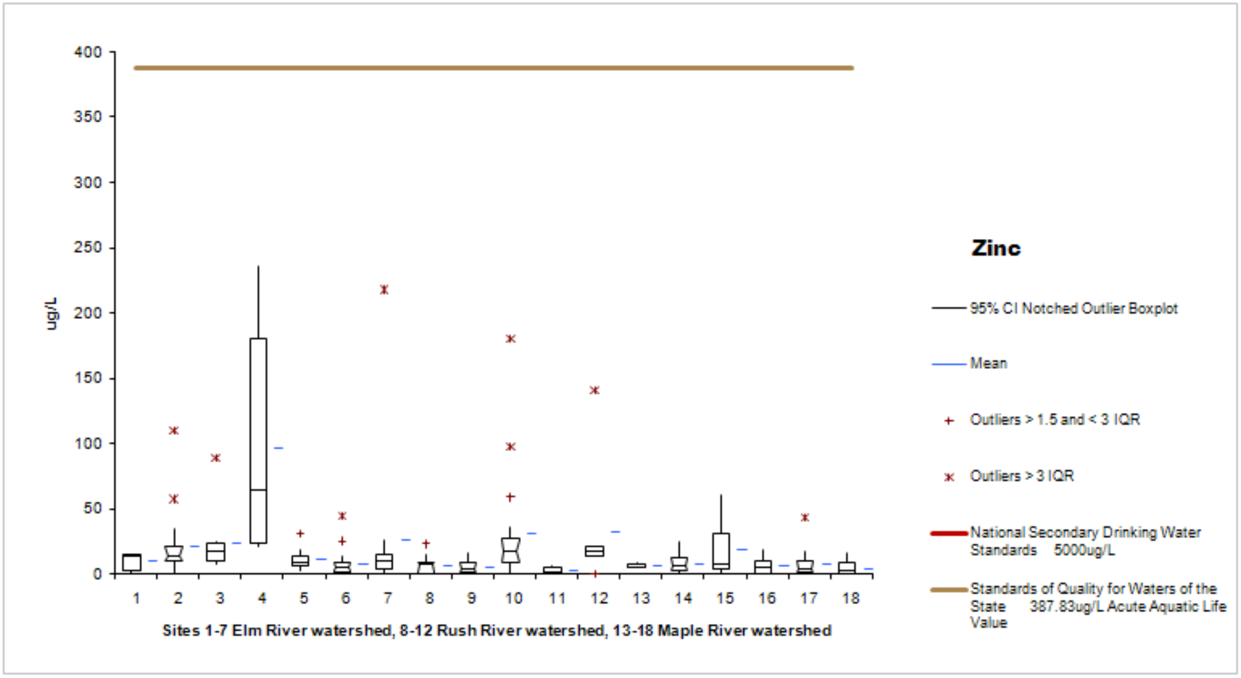
Selenium



While selenium is an essential trace nutrient for animals, higher levels may cause reproductive failures, birth defects or death in livestock, wildlife and fish. It is known to naturally occur in the weathering process of marine shale.

Selenium concentrations exceeded 20 ug/L, the acute standard set by the state (blue line in graph), at 10 of the 18 sites. Seven sites recorded no detection throughout the season. Site 5 exceeded the standard in 100% of the samples (12) with concentrations ranging from 21 to 97.8 ug/L. This site was tiled a year prior to this study in predominately Fargo silty clay. The crop rotation over the previous 3 years was soybean, corn, soybean, with no fertilizer used in 2008. Site 2 had 14 of 18 samples with very high selenium values ranging from one non-detect and increasing to 261 ug/L in November 2008. The level decreased from 89.2 ug/L to 9.69 ug/L between April 30, 2008 and June 23, when it spiked again to 54.7ug/L. Notes do not reflect a rain event at this time. Levels consistently fell from 54.7ug/L to the lower twenties and upper teens until November 13th when it spiked again following a 0.98 inch rain event. This site flows directly into a river. At five sites (red line in graph), the mean concentration exceeded the primary drinking water standard.

Zinc



Zinc is hardness dependent and the calculated acute aquatic life level is 387.83 ug/L. All samples were below this value. All samples were below the secondary drinking water standard.