2014

Calculating nutrient loads from four tributaries of the Cedar River in Iowa

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Recommended Citation

Donaghy, Jacob, "Calculating nutrient loads from four tributaries of the Cedar River in Iowa" (2014). *Dissertations and Theses @ UNI*. 37.
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CALCULATING NUTRIENT LOADS FROM FOUR TRIBUTARIES OF THE CEDAR RIVER IN IOWA

An Abstract of a Thesis

Submitted

In Partial Fulfillment

Of the Requirements of the Degree

Master of Science

Jacob Donaghy

University of Northern Iowa

December 2014

ABSTRACT

A study was done on four tributaries to the Cedar River to determine nutrient concentrations, loads, and the contribution of each watershed per unit area. The Cedar River watershed is primarily agricultural land and extends from southern Minnesota to southeastern Iowa. Past studies have indicated that this watershed is a major contributor of nitrate to the Gulf of Mexico via the Mississippi River. This eutrophication is the cause of the hypoxic Gulf.

From April 13, 2010-September 21, 2010 samples were taken from four tributaries of the Cedar River. Discharge data were taken from USGS gaging stations along with a method developed on ungaged sites. Samples were analyzed for parameters influenced by agriculture such as total dissolved solids, total suspended sediments, nitrate, and chloride.

Average concentrations, total loads, and pounds per acre (lbs/acre) contributions of each parameter were calculated for each subwatershed during the approximately 6 month period of study. The tributary with the highest average nitrate concentration was the West Fork Cedar River with 33.22 ppm. However the Upper Cedar contributed the most nitrate load with 31,994 tons. When all of these factors from each pollutant are taken into consideration it appears that the Upper Cedar River had the most impairment followed by the Shell Rock River, West Fork Cedar River, and finally the Winnebago River.

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This study by: Jacob Donaghy

Entitled:

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has been approved as meeting the thesis requirement for the

Degree of Master of Science in Environmental Science

Date	Dr. Mohammad Iqbal, Chair, Thesis Committee
Date	Dr. Maureen Clayton, Thesis Committee Member
Date	Dr. James Walters, Thesis Committee Member
Date	Dr. April-Chatham Carpenter, Interim Dean, Graduate College

ACKNOWLEDGEMENTS

I would like to thank Dr. Mohammad Iqbal for providing me the opportunity to complete this project and for pushing me to finish it. I would like to thank the National Science Foundation and UNI Environmental Programs which funded this research. I would like to thank Dr. Maureen Clayton and Dr. James Walters for being on my committee and reviewing my work. I would also like to thank Dr. C. Lee Burras who persuaded me into pursuing this degree.

Finally I would like to thank my family for their support and for reminding me that I need to finish what I started.

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CHAPTER 1

INTRODUCTION

Background

Humans have been affecting water quality throughout recorded history. The earliest humans used rivers as sources of drinking water, irrigation of crops, and as lavatories. The consequences of their actions were not understood or even considered because water has historically been viewed as a completely renewable resource by society. However, as humans advanced we have seen the consequences of our actions in the way of water scarcity and poor water quality. Industrial processes, agricultural processes, and waste disposal have all had impacts on our water quality (Pearce, 2006).

The impacts of polluting water can be harmful both spatially and temporally. An example of this would be the zone of hypoxia which forms in the Gulf of Mexico and is an area where dissolved oxygen is very low (< 2ppm). This area, which has been termed a “Dead Zone” by the press, is not a result of the Gulf States polluting the nearby water but rather, the cause for this zone of hypoxia is a domino effect of processes (Fields, 2004). First, nutrient-rich freshwater produced from the Upper Mississippi River Basin flows down the Mississippi to the Gulf. The high concentrations of nutrients in this water, mainly nitrogen and phosphorus, stimulate the growth of algae. Once these algae die, they sink to the bottom and become decomposed by way of benthic respiration. During decomposition by benthic respiration, oxygen is used as the terminal electron acceptor and is thereby depleted in the surrounding water. Decreasing the dissolved oxygen in the water makes it difficult, if not impossible, for organisms to live there thus resulting in the so called Dead Zone.

Locating and quantifying pollution hotspots has become important in recent research. This project was designed to quantify and compare nonpoint source pollution between four tributaries of the Cedar River. It was done to better understand which subwatersheds are contributing more nonpoint source pollution per unit area to the Cedar River. This in turn can be used to rectify these pollution hotspots by implementing best management practices in these areas.

Nitrogen

Nitrogen is abundant in our atmosphere, composing approximately 78% of it. It is in the form of nitrogen gas (N_2) which has a triple bond thereby making it very stable and biologically unusable to many organisms. The nitrogen cycle (Figure 1) shows the sources, sinks, and pathways of nitrogen in a typical Iowa watershed.

Industrial fixation from the atmosphere by the Haber-Bosch process produces inorganic nitrogen fertilizer in the form of ammonium (NH_4^+), which is then spread mainly on agricultural fields, golf courses, and some residential lawns. From this point ammonium can become immobilized by bacteria, which incorporate nitrogen into amino acids and proteins, but when they die this nitrogen is released by decomposition into the soil organic matter. Ammonium can also be nitrified to nitrate by the bacteria *Nitrosomonas* and *Nitrobacter*, uptaken by plants, volatilized as ammonia, or eroded by becoming adsorbed to the soil and moving with overland flow.

Nitrate produced by both nitrification and atmospheric deposition is the main form of nitrogen that is of environmental concern. Nitrate can become immobilized and taken up by plants the same as ammonium but it can also be denitrified back to the atmosphere or leached with moving water. It is the process of leaching that is of main environmental concern to humans. Nitrate can either leach to deeper groundwater or to shallow subsurface water which can make its way back to surface waterbodies with baseflow. Nitrate in groundwater is of special concern to humans and mainly young children because a condition known as methemoglobinemia or "blue baby" syndrome can occur if enough nitrate is ingested (Havlin et al., 2005).

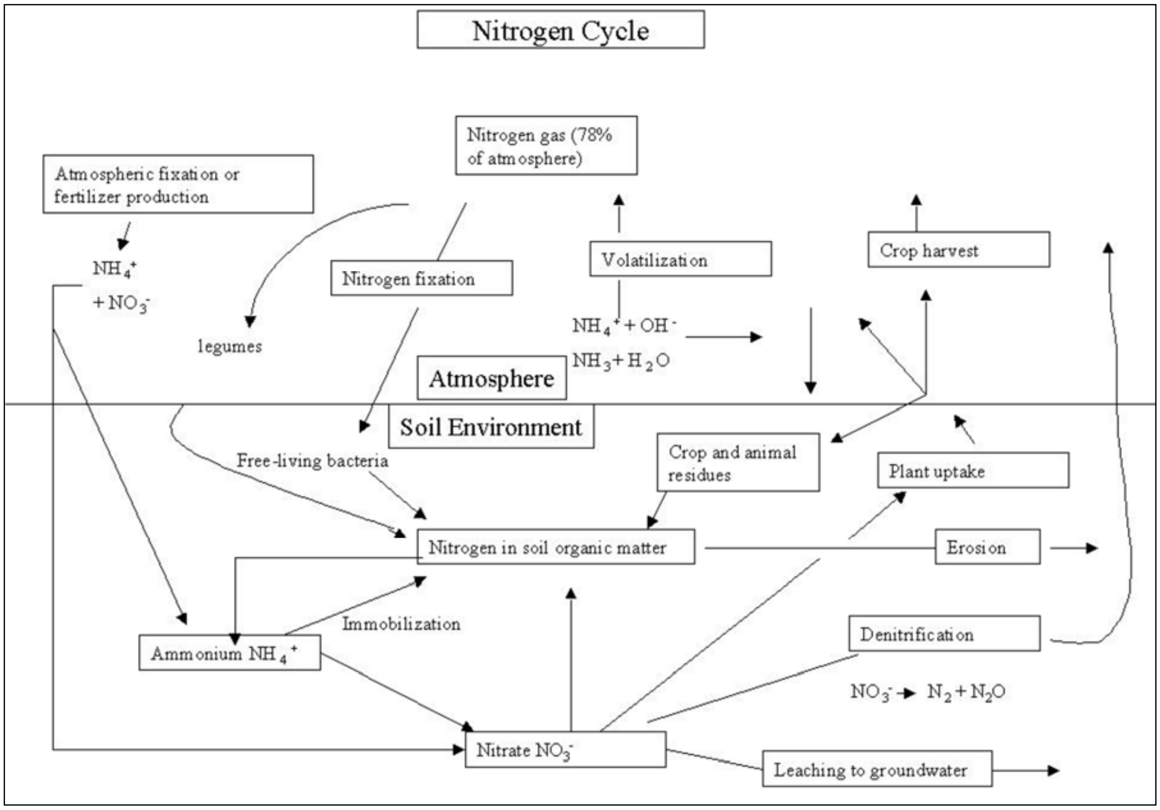

Figure 1. The nitrogen cycle (Dinnes, 2004).

Suspended Sediment

Sediment is a major problem affecting Iowa’s streams and it is also an example of how humans have altered our landscape. The cause of excess concentrations of suspended sediment can be traced to the introduction of farming techniques more than 100 years ago (Knox, 1987). Row crop agriculture forced major channel adjustments in watersheds that drained previously uncultivated land, especially in the Des Moines lobe area. The number of tillable acres was maximized by channelizing streams, removing riparian vegetation, and installing tile lines which increased maximum streamflow and thus streambank erosion.

Sediment delivered to streams and rivers can greatly degrade the aquatic ecosystem by filling in substrates, smothering benthic organisms, depositing in pools, and causing decreased light penetration, which can interfere with growth and reproduction of fish and other aquatic life (Figure 2). All of these processes decrease the quality of the water for recreational use and increase the economic burden for shipping lanes.

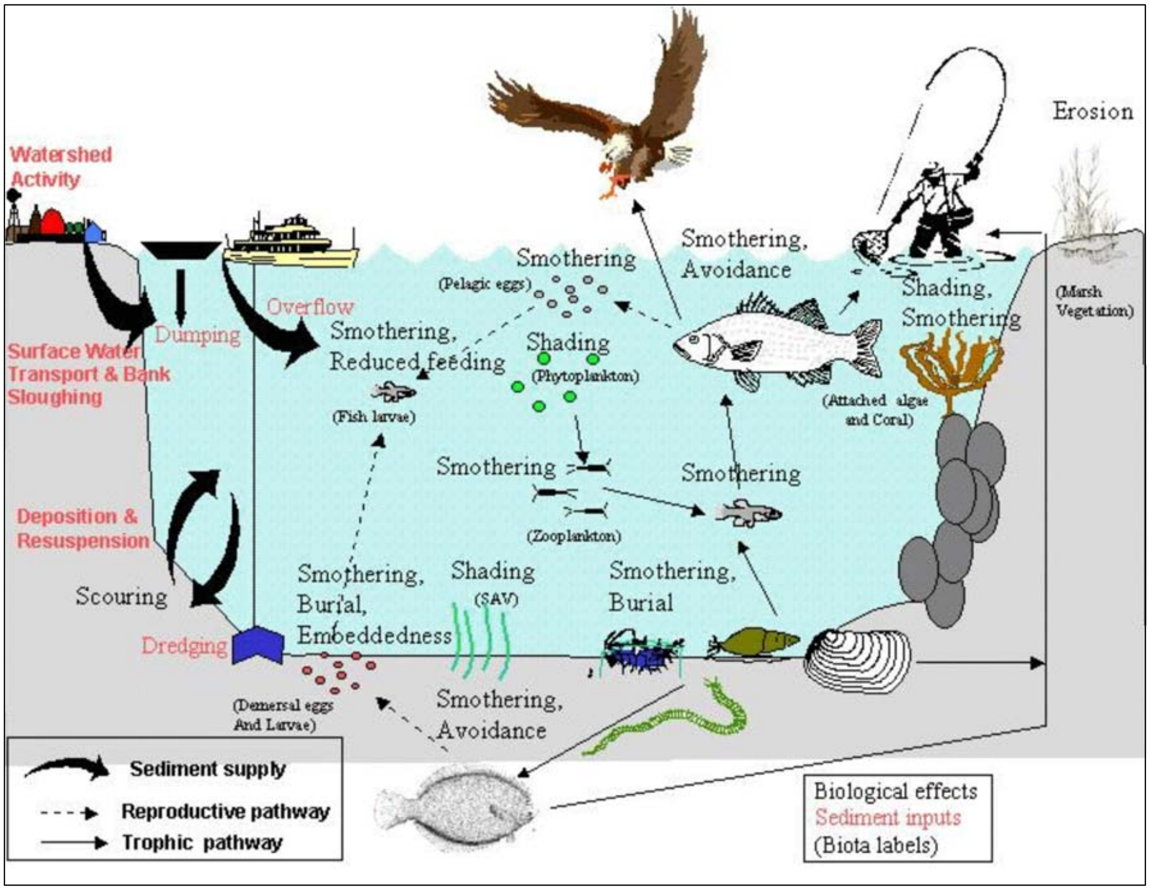

Figure 2. Conceptual model of biological effects of suspended and bedded sediments (Berry et al., 2003).

Sediment in streams can come from different sources including bank erosion, runoff from the surrounding areas, and resuspension from the stream bed. Depending on the region in which the stream is located, the contribution from each of these sources can differ drastically. Once sediment has reached a stream it can be transported by the different processes shown in Figure 3. The different methods of transportation ultimately will affect the way in which the sediment affects the aquatic environment as shown above.

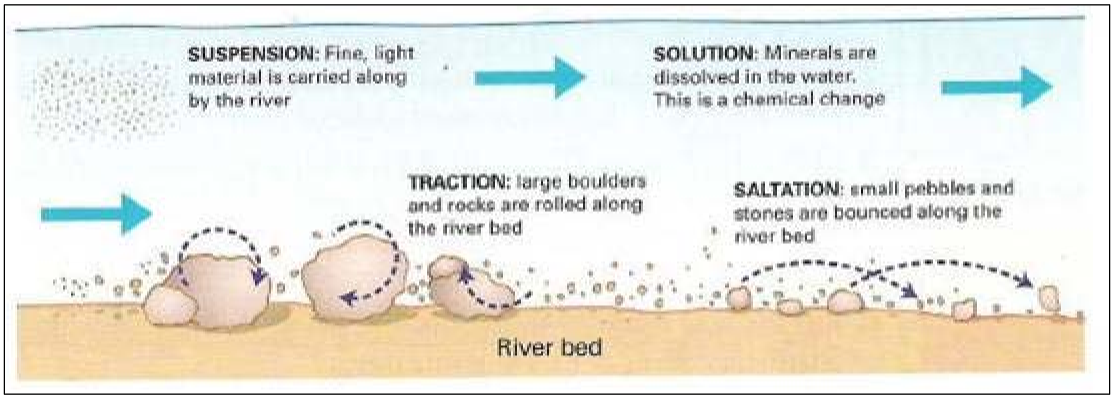

Figure 3. Methods of sediment transportation in streams (River Transport, 2010).

Discharge

Discharge measurements are very important for any hydrologic assessment. The concentration of nutrients, sediments, and chemicals in water changes both temporally and spatially. For example, rain resulting in runoff could dilute stream water which would decrease the overall concentration of a pollutant. This dilution however, doesn’t make the total load leaving the watershed any less and in some instances it can be more because the total amount moving is increased. In order to calculate the total load of a pollutant leaving a watershed both discharge and concentration of the pollutant need to be measured.

Discharge has been greatly affected in Iowa as a result of our agricultural processes. As a result of the tillage and tile lines used in agriculture, our streams and rivers are now more susceptible to higher peak flows and the hydrology has been changed. The pathway of precipitation to the ground and out of a watershed has been altered and the time in which it takes to happen has been reduced greatly. Prior to cultivation precipitation would fall to the ground and infiltrate to the soil, whereas now if it does infiltrate it will be drained through a tile line. This drainage has sped up a natural process that would have taken much more time.

CHAPTER 2

PREVIOUS STUDIES

Nutrient Studies In Iowa

Studying the causes behind the algal blooms and the resultant hypoxia in the Gulf of Mexico increased greatly after the flood of 1993. Preliminary studies of historical discharge and nutrient concentration data indicated that a majority of the nutrient flux was being produced from the Mississippi and Atchafalaya Rivers (Dunn, 1996 and Goolsby et al., 2001). This led to studies being done within the states that make up this watershed which includes Iowa. Finding out where the nutrients are coming from and how to mitigate their effects is an important area of study.

Libra and others (2004) released a study on nutrient budgets for Iowa and Iowa watersheds during water years 2000-2002. The study used different methods to calculate the total inputs, outputs, and transformations of nitrogen for the whole state of Iowa. Figure 4 shows the estimated percentage inputs for the state of Iowa by category. Fertilizer accounted for 25 percent of the inputs with 90 percent of it being applied to agricultural land. Figure 5 shows the outputs by percentage, and of interest to this study was that 5 percent or 198,000 tons left the state via the stream network. This is equivalent to 11 pounds for each acre of the state. The authors point out that this was a relatively dry period in much of the state and that during normal to wet years, stream losses could account for 10 percent or more of the outputs. Nevertheless, this amount indicates that Iowa contributes about 20 percent of the nitrogen that enters the Gulf of Mexico, a percentage that is likely higher during wetter years (Libra et al., 2004).

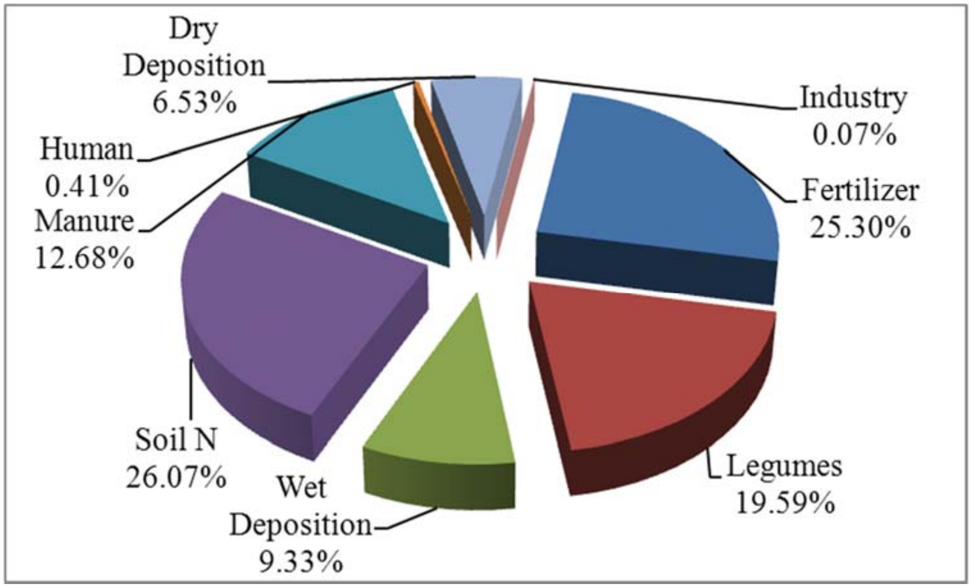

Figure 4. Statewide nitrogen inputs on a percentage basis out of 3,800,000 tons (Libra et al., 2004).

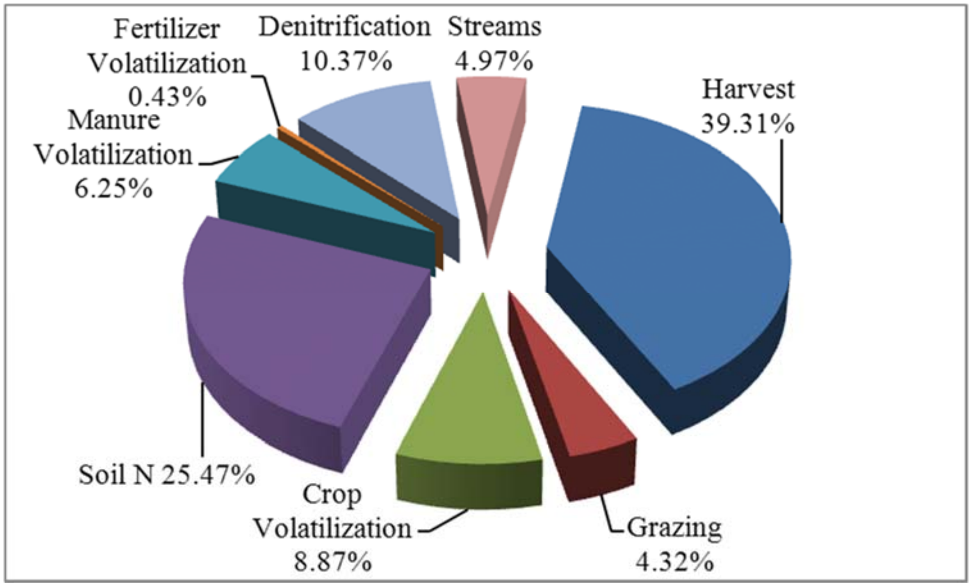

Figure 5. Statewide nitrogen outputs on a percentage basis out of 3,981,000 tons (Libra et al., 2004).

On a watershed basis Table 1 shows the inputs, outputs, stream load per unit area, and average concentration of the four subwatersheds of interest. The study concluded that the West Fork Cedar River had the highest average stream load per unit area and concentration at 19.2 lbs/acre and 9.5 ppm respectively while the Shell Rock River was determined to have the lowest average stream load per unit area and concentration at 14.9 lbs/acre and 7.7 ppm respectively. Their results also suggested that higher nitrogen concentrations occur in watersheds with greater inputs of nitrogen from fertilizer and also ones with greater total N inputs and a high percentage of row crops (Libra et al., 2004).

Table 1. Nitrogen inputs, outputs, stream nitrogen load per unit area, and average nitration concentration for four subwatersheds of the Cedar River (Libra et al., 2004).

Watershed	**Total N Inputs (lbs/acre)**	**Total N Outputs (lbs/acre)**	**Stream N Load Per Unit Area (lbs/acre)**	**Average N Concentration (ppm)**
West Fork Cedar River	257	254	19.2	9.5
Winnebago River	239	237	16.5	7.8
Upper Cedar River	238	242	17.6	8.2
Shell Rock River	241	244	14.9	7.7

Nutrient Studies in the Cedar River

A study completed by the Iowa Department of Natural Resources for Linn County modeled the average discharge, nitrate-nitrogen (Nitrate-N) load, Nitrate-N concentration, and Nitrate-N contribution per unit area for six tributaries of the Cedar

River during 2001-2004 (IDNR, 2006). Figure 6 shows the percent contribution of discharge from each of the tributaries out of 2,960,111 acre-feet/year (ac-ft/yr). This shows that on a discharge basis, the Upper Cedar River contributed the most with 1,184,044 ac-ft/yr, followed by the Shell Rock River with 1,095,241 ac-ft/yr and then the West Fork Cedar River with 414,416 ac-ft/yr. This study did not separate the Winnebago River watershed from the Shell Rock River watershed so the data is the sum of both. Discharge data is important for any hydrologic study to understand nutrient loading versus nutrient concentration and how the two are related.

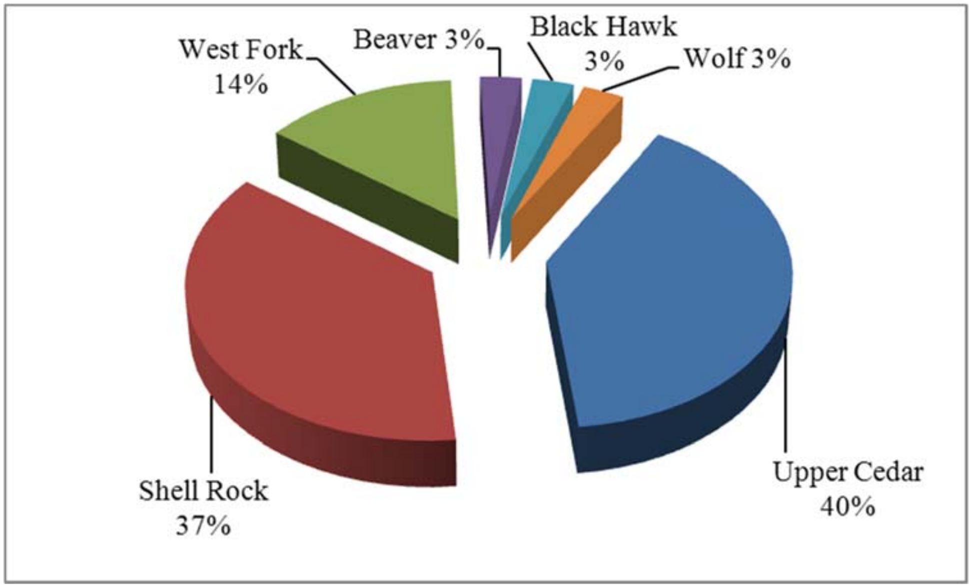

Figure 6. Discharge into the Middle Cedar River on a percentage basis out of 2,960,11 ac-ft/yr (IDNR, 2006).

The modeled nitrate load to the Middle Cedar River was similar in trend to the discharge modeled. Figure 7 shows the percent contribution of the Nitrate-N load to the Middle Cedar River out of 32,570 tons Nitrate-N/yr. Similar to discharge, the Upper Cedar River contributed the most followed by the Shell Rock River and then the West Fork Cedar River. The study showed that both discharge and Nitrate-N loads were connected to watershed size where a large watershed, the Upper Cedar River, contributed the most with 13,679 tons Nitrate-N/yr and the smallest watershed, the West Fork Cedar River, contributed the least with 5,211 tons Nitrate-N/yr (IDNR, 2006).

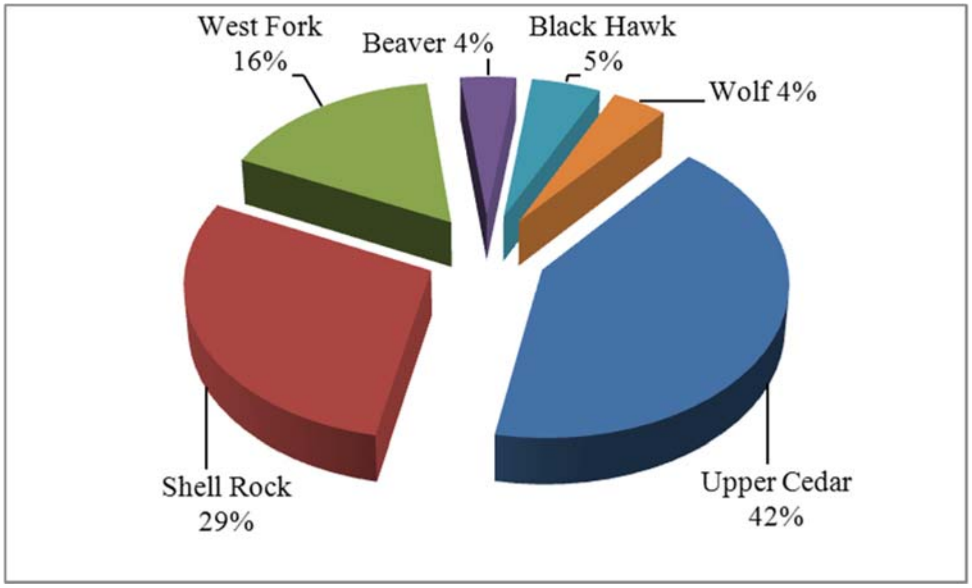

Figure 7. Nitrate-nitrogen loads into the Middle Cedar River on a percentage basis out of 32,570 tons N/yr (IDNR, 2006).

The average Nitrate-N concentrations were determined to be inversely related to watershed size with the largest values measured in the smaller tributaries. This was explained as a result of dilution from a higher percentage of flow coming from deeper baseflow in the larger streams. The Upper Cedar River had an average Nitrate-N concentration of 6.5 ppm followed by the West Fork Cedar River with 6.3 ppm and then the Shell Rock River with 4.9 ppm. The Shell Rock River does not follow the trend as noted by having a much smaller average Nitrate-N concentration than would have been expected. The study explains this by pointing out a dam that is located upstream of the gaging station used for their data. A dam would slow the flow of the river and increase the biological activity, which would in turn take up more nitrate and lower the concentration. Comparing the results of the Libra et al. (2004) study with this shows that the results are similar but it should be noted that the IDNR study did not separate the Shell Rock River from the Winnebago River so the results are slightly different.

The Nitrate-N contribution per unit area followed the same trend as both discharge and Nitrate-N load. The Upper Cedar River contributed 25.5 lbs/ac followed by the West Fork Cedar River with 19 lbs/ac and then the Shell Rock River with 16.5 lbs/ac. These results differ with Libra’s 2004 study but the values are within a reasonable range and highlight temporal differences in nutrient values.

A study completed by Chad Fields from April 28, 2002 to September 28, 2002 measured discharge, Nitrate-N concentrations, and Nitrate-N loads for the Shell Rock River, Upper Cedar River, and West Fork Cedar River (Fields, 2004). This study used the USGS stream gaging network for discharge data and directly measured the nitrate concentration on a weekly basis. Suspended sediment was also measured and will be discussed later.

Discharge during the study period was slightly different than the previous studies with the Shell Rock River being higher than the Upper Cedar River. It was observed that the Shell Rock River had the highest flow with 269,967 ac-ft, followed by the Upper Cedar River with 235,106 ac-ft, and then the West Fork Cedar River with 162,953 ac-ft (Fields, 2004).

Average Nitrate-N concentrations followed the same trend as with the Iowa DNR study in that the smaller watersheds had a higher concentration. The West Fork Cedar River had an average concentration of 7.2 ppm, followed by the Upper Cedar River with 2.8 ppm, and finally the Shell Rock River with 4.1 ppm. The total Nitrate-N load for the watersheds followed the same trend as discharge with the Shell Rock River contributing the most with 1,896 tons followed by the Upper Cedar River with 1,764 tons, and the West Fork Cedar River with 1,742 tons. This study also observed that Nitrate-N concentrations were highest in the spring and summer months, which coincides with the period of peak agricultural fertilization. Also observed was that nitrate peaks tended to follow discharge peaks suggesting a lag in the nitrogen flux. This relationship could be due to a high percentage of the discharge initially coming from overland flow causing a dilution in concentration and then returning to baseflow which may have a higher nitrate concentration (Fields, 2004).

Suspended Sediment Studies in Iowa

Soil erosion is one of the world's greatest resource management problems. Soil particles are transported from one location where they are utilized beneficially to another where they usually cause a problem. Sediment is frequently cited as the agricultural pollutant having the greatest water quality impacts, however, few studies have been done to physically measure its flux (IDNR, 2000). The lack of physical measurements is due to the short periods of intense loading followed by longer periods where sediment transport is low. In temperate climates dominated by agriculture most of the sediment flux occurs in the early spring months of little vegetation and high precipitation. During high precipitation sediment loads can increase an order of magnitude from their average values which shows how variable they are.

A study was completed by Odgaard (1984) that used historical records, field measurements, and laboratory soil tests to develop a formula to calculate the suspended sediment load leaving the state of Iowa through its rivers per year. Historical plots of suspended sediment and discharge were used to perform linear regression analysis on the major rivers in Iowa. It was calculated that the average annual rates of suspended sediment transport was 31,340,000 tons for the state of Iowa (Odgaard, 1984). This is a very large amount of sediment that is no longer useable for agriculture.

Chad Fields also looked at suspended sediment within the tributaries of the Cedar River in his 2002 study. Measurements were taken from July 11, 2002 to August 28, 2002, and the data observed indicated a high variability in suspended sediment with no observable pattern. The West Fork Cedar River had the highest average concentration at

397.1 mg/L followed by the Shell Rock River with 353.7 mg/L and the Little Cedar River with 321.2 mg/L (Fields, 2004).

CHAPTER 3

STUDY AREA

This research focused on a study area consisting of four major tributaries of the Cedar River. The tributaries were: Shell Rock River, West Fork Cedar River, Upper Cedar River, and Winnebago River. Ten sampling sites were chosen to quantify the quality of water leaving each subwatershed. These sampling sites were: Winnebago River near Rockford, Shell Rock River in Rockford and Shell Rock, West Fork Cedar River in Finchford, and the Upper Cedar River in Charles City, Chickasaw, Plainfield, and Janesville. Also, a final sampling site was located in Cedar Falls. The Cedar River flows from its headwaters in southern Minnesota to its point of confluence with the Iowa River in Conesville, Iowa and ultimately to the Mississippi River. The river drains an area of 20,242 km^2, a majority of which is located in Iowa.

Landform Regions

The main landform regions occupied by the four subwatersheds of the Cedar River studied are the Des Moines Lobe and the Iowan Surface shown in Figure 8. The Des Moines Lobe is the youngest landform region in Iowa, formed 12,000-14,000 years ago during the last glacial episode (Prior, 1991.) It is characterized by low relief with some distinct ridges near the eastern boundary and occasional depressions that form lakes, ponds, and swamps. Glacial till is the dominant surficial material, and alluvium is present along the streams. Poorly drained soils developed on this till, which was initially poorly suited for row-crop agriculture due to a high water table. Drainage by way of extensive channelized ditching and tiling of fields during 1900-1920 augmented the natural surface drainage in this area. Many small low gradient streams form here that drain into a few larger rivers (Becher et al., 2000).

The Iowan Surface has gently rolling topography with long slopes, low relief, and a mature dendritic drainage pattern. This landform was initially part of the Southern Iowa Drift Plain but underwent extensive erosion from 16,500 to 21,000 years ago. Tundra conditions prevailed during this time characterized by a regular freeze-thaw pattern and turbulent winds which eroded the landscape drastically (Brown and Jackson, 1999). The surficial material is primarily glacial drift with thin layers of windblown loess on the ridges and alluvium near the streams. Drainage is well developed, although streams generally have slight gradients. The major streams are characterized by broad valleys and flanked by low, rolling hills that merge with moderately dissected stream divide (Becher et al., 2000).

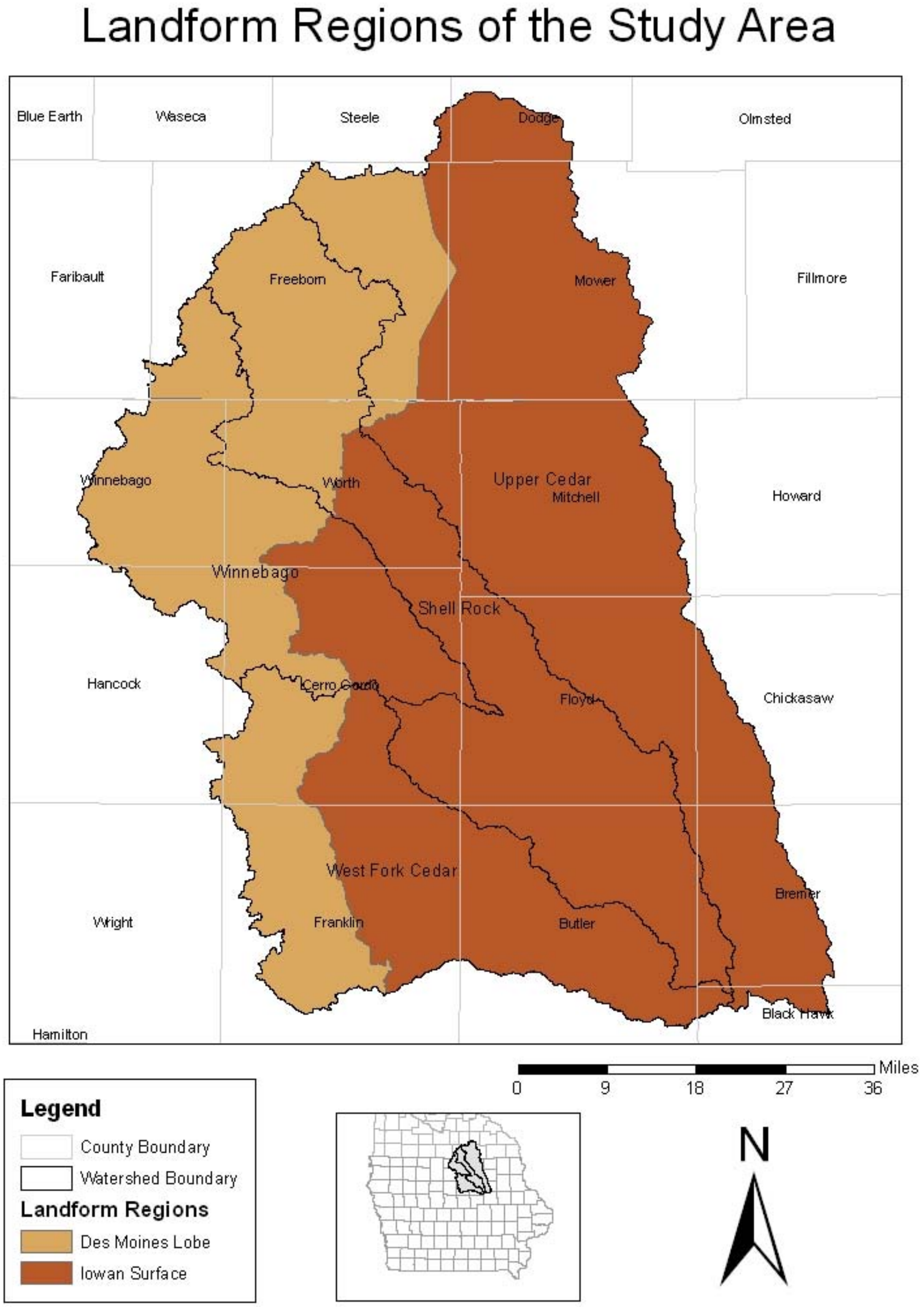

Figure 8. Landform regions of the study area.

Common Resource Areas

The National Resources Conservation Service (NRCS) has classified the geology of the United States into areas known as Common Resource Areas or CRAs. They describe it as "a geographical area where resource concerns, problems, or treatment needs are similar" (NRCS, 2007). Four common resource areas are found in the study area and they include: Iowa and Minnesota Till Prairies, Iowa and Minnesota Rolling Prairie/Forest Moraines, Silty and Loamy Mantled Firm Till Plain, and Eastern Iowa Eroded Till Plain (Figure 9). Each of these common resource areas has their own unique attributes and common resource issues.

The Iowa and Minnesota till prairies are primarily loamy glacial till soils with scattered lacustrine areas, potholes, outwash, and floodplains. They are nearly level to gently undulating with relatively short slopes and the resource concerns are water and wind erosion, nutrient management, and water quality. The Iowa and Minnesota rolling prairie/forest moraines are primarily loamy glacial till soils with some potholes, outwash, and floodplains. They are gently undulating to rolling with relatively short complex slopes and the resource concerns include water and wind erosion, nutrient management, and water quality and wildlife habitat management. The silty and loamy mantled firm till plain is primarily a thin silty material over loamy till underlain by sedimentary bedrock. They are gently sloping to very steep dissected till plain and the primary resource concerns are cropland erosion, surface water quality, grazing land and woodland productivity, and soil erosion during timber harvest. The eastern Iowa eroded till plain is primarily poorly drained soils that consist of silty, loamy materials over glacial till. The area is nearly level to moderately sloping and the resource concerns are soil erosion, water quality, and nutrient management (NRCS, 2007). All of the regions in the study area have problems with wind and water erosion, water quality, and nutrient management. More specifically the concerns include sheet, rill, gully, and wind erosion along with the over application of nutrients and their effects on water quality.

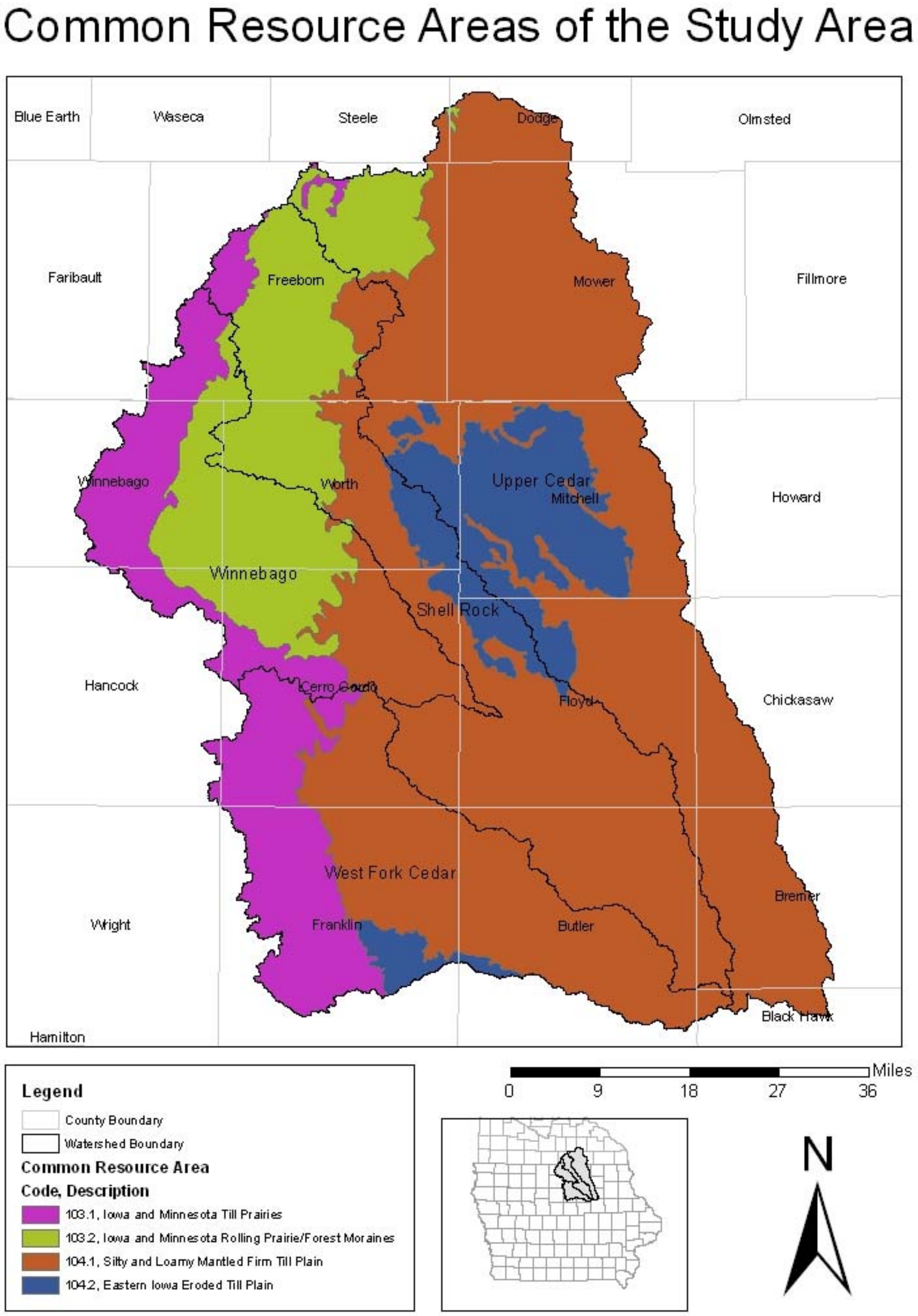

Figure 9. Common resource areas of the study area.

Land Use

The land use within the Cedar River watershed is primarily (>75%) row crop agriculture (Table 2). The conversion from natural prairie to row crop agriculture has greatly altered the landscape and hydrology. The primary crops grown in the Cedar River watershed include corn, soybeans, oats, hay and pasture. Chemical fertilizers are applied to increase crop production with application rates for nitrogen averaging 130 lbs/acre/year (Heffernan et al., 2010). This nitrogen has the potential to enter our waterways through tile drainage and interflow. Along with entering surface water, nitrogen can infiltrate down to deeper groundwater and affect our drinking water. Under natural conditions the nitrogen levels in the soil would be lower and the cycle slower. Due to our transformation of the land by tiling, digging drainage ditches, removing vegetation, applying fertilizers, and increasing the amount of impervious surfaces this process has sped up and the amount of nitrogen present has increased along with the hydrologic cycle being altered (Heffernan et al., 2010).

Table 2. Land use in the Cedar River watershed.

Sub-Basin	Area (Ac)	Water	Developed or Urban	Barren	Forest	Hay and Pastureland	Row Crop	Wetland
Upper Cedar	1,078,111	0.57%	8.25%	0.03%	2.70%	9.28%	77.26%	1.89%
Shell Rock	691,355	1.22%	8.36%	0.05%	2.17%	7.49%	78.57%	2.13%
Winnebago	440,588	1.87%	9.83%	0.19%	1.60%	8.34%	75.91%	2.25%
West Fork Cedar	551,106	0.30%	7.06%	0.04%	1.06%	7.16%	82.07%	2.32%
Total	2,761,159	0.89%	8.29%	0.06%	2.07%	8.26%	78.33%	2.10%

Hydrology

The natural hydrology of the Cedar River has been greatly altered by human influence. Tiling, tillage, stream channelization, and urban development have all changed the local water cycle. Tiling has enhanced the subsurface drainage component of flow to streams while tillage has decreased the infiltration capacity of the soil and simultaneously increased the amount of overland flow. Channelization has decreased the travel time and taken away the natural meander of streams. This has led to the streams being flashier in response to precipitation events. Urban development has increased the percentage of impermeable surfaces which decreases infiltration and increases overland flow (Becher et al., 2000).

The Cedar River receives most of its flow in the form of overland flow and baseflow. On an annual basis it is estimated that between 70-77% of the flow is baseflow while the rest is overland flow (Squillace and Engberg, 1988). In the spring the rapid melting of the snowpack combined with rainfall or thunderstorm activity can cause flooding. On the other hand, droughts can result from a shift in the normal seasonal atmospheric storm track by high-pressure conditions, lack of thunderstorm development, or a block or decrease in moist airflows.

Climate

The climate in the study area is considered continental, with large seasonal temperature changes ranging from as high as 38.8°C in the summer to as low as -27.8°C in the winter. Primary climatic forces in the study area are warm, moist air from the Gulf of Mexico and surges of cold, dry air from Canada, which predominate in the summer and winter respectively. Average precipitation (Figure 10) ranges from 31 inches in the upper northwest of the study area to 35 inches in the south east of the study area, with considerable annual variability. Most of this precipitation (about 71 percent) falls as rain from April through September. Peak precipitation occurs in June and drops sharply during the autumn. During the late spring and summer months of the year precipitation generally is of short duration and high intensity, whereas during the cooler months it tends to be of longer durations and lower intensity (Wendland et al., 1992). These differences in precipitation coupled with the channelization of the streams can lead to flash flooding of the area.

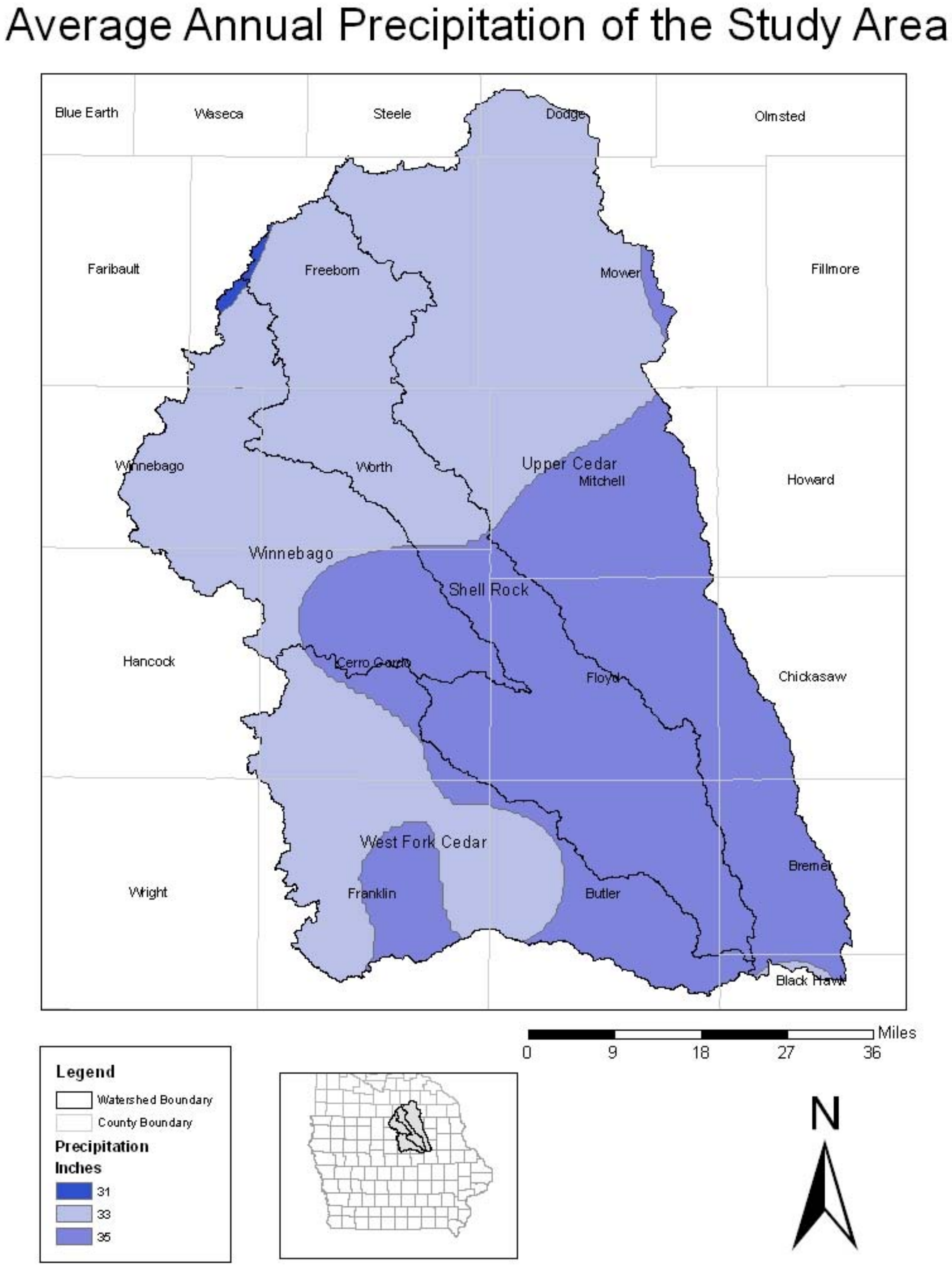

Figure 10. Average annual precipitation of the study area.

CHAPTER 4

MATERIALS AND METHODS

Sampling Sites

Ten sampling sites were chosen from four major tributaries of the Cedar River and weekly samples were taken from April 13, 2010 to September 21, 2010. The sites were chosen by their proximity within each subwatershed to determine the quality of water leaving them. The major tributaries that were sampled include the West Fork Cedar River, Winnebago River, Shell Rock River, and the Upper Cedar River. These tributaries contribute the majority of the water to the Cedar River and other streams are of little significance.

At all sites the water was tested in the field for total dissolved solids (TDS), conductivity, pH, temperature, dissolved oxygen (DO), and turbidity. Samples were taken to be analyzed in the laboratory for total suspended solids (TSS), nitrate (NO_3^-), chloride, and sulfate (SO_4^{2-}). Five of the sites were chosen by their proximity to United States Geological Survey (USGS) discharge monitoring stations so discharge data was readily available. The other five sites required the development of a method to calculate discharge. The sampling sites can be seen in Figure 11. The goals for this study were to look at the nutrient and sediment flux from each tributary along with identifying pollution hotspots within each watershed.

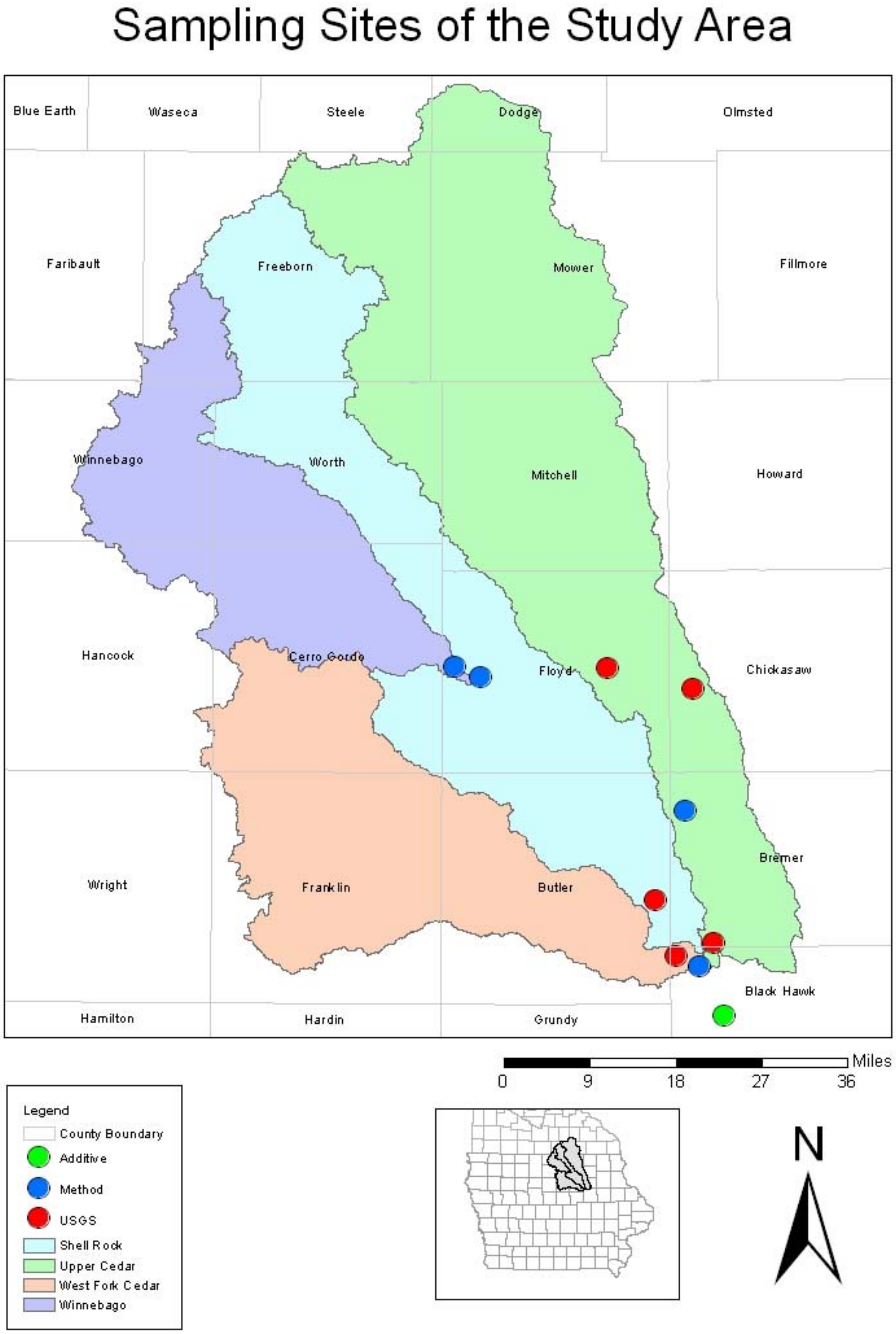

Figure 11. Sampling sites of the study area.

Discharge

A method was developed to calculate discharge at the sampling sites that were not near any USGS stations. This method was used to estimate the discharge at four of the sampling sites (Figure 11). As with most methods this one was based on some assumptions. First, it was assumed that the stream profile would not change during the sampling period. Due to physical limitations with calculating the cross sectional area this had to be assumed. Second, it was assumed that any rise in water level in the stream was in a strictly vertical manner and any horizontal overbank spread was negligible. This was assumed because along with the first assumption cross sectional area could not be measured by the usual method every week. Third, velocity was only taken once during the sampling period when flow was at its lowest. This was once again due to physical limitations based on stream depth and available equipment. Instead of assuming a constant velocity for all the sampling weeks a method was developed to extrapolate the velocity based on the change in velocity with a change in depth.

The discharge was measured once at each of the four sites during a low flow period as it was the only time this could be physically accomplished. At each site the same procedure was followed. The distance across the stream was measured and divided into equal segments. The depth was taken in the middle of each segment along with velocity which was taken at 60% of the depth using an FP101 velocity meter. The discharge of each section was calculated by multiplying the section width, depth, and velocity. Then all sections were added up to calculate the total discharge. Figure 12 demonstrates the way in which the stream cross section was divided and where velocity measurements were taken.

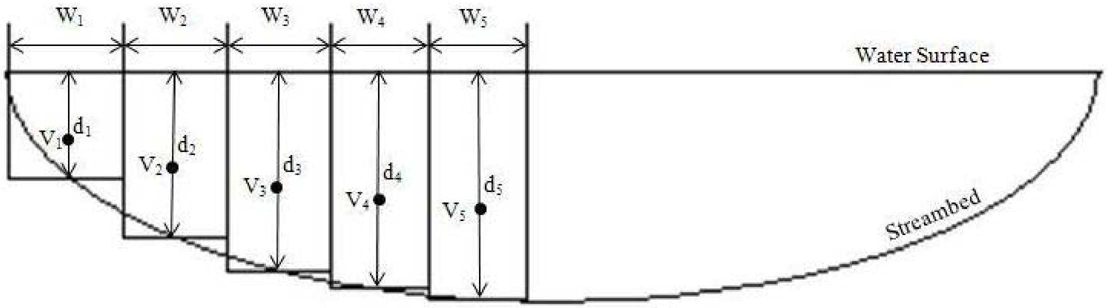

Figure 12. Cross section of a stream with measurements indicated.

At the same time, the water level was measured above from a fixed point using a water level meter. Each week the vertical distance from that fixed point to the water surface was measured using the same water level meter (Figure 13). This was to observe the up or down fluctuation in the water level. From this change in water level a new cross sectional area was calculated for each section and this was used in the discharge calculation each week.

Figure 13. Method used to measure any change in water level.

The average stream velocity has been found to be located at 60% of the depth of the stream (Hulsing et al., 1966). Above and below that point the velocity becomes faster and slower respectively. The depth of each section was known each week based on the change in water level observed. From this, the calculations in Figure 14 were made to determine the velocity of each section each week. The depth was multiplied by 40% to find the depth from the bottom that would equal 60% of the total depth. This value was then divided by the total depth at the time the discharge was calculated in the field. This gave a percentage of depth which was then plugged into the formula in Figure 14 to calculate the percentage of the average velocity. This percentage was then multiplied by the velocity measured at the time the discharge was measured in the field. Once these calculations were made the discharge was calculated for each section and then added up to determine the total discharge.

D_m= Depth of section when discharge was measured

D_w= Depth of section measured weekly

D_v= Depth above river bottom that velocity would be measured in the field

V_m=Velocity of section when discharge was measured

V_w= Velocity of section based on calculation

$$D_w * 0.4 = D_v \qquad (D_m - D_v) / D_m = \%D_m$$

$$V_w = (-5.6609 * \%D_m^6 + 14.161 * \%D_m^5 - 13.723 * \%D_m^4 + 6.1173 * \%D_m^3 - 1.6505 * \%D_m^2 + 0.1218 * \%D_m + 1.1585) * V_m$$

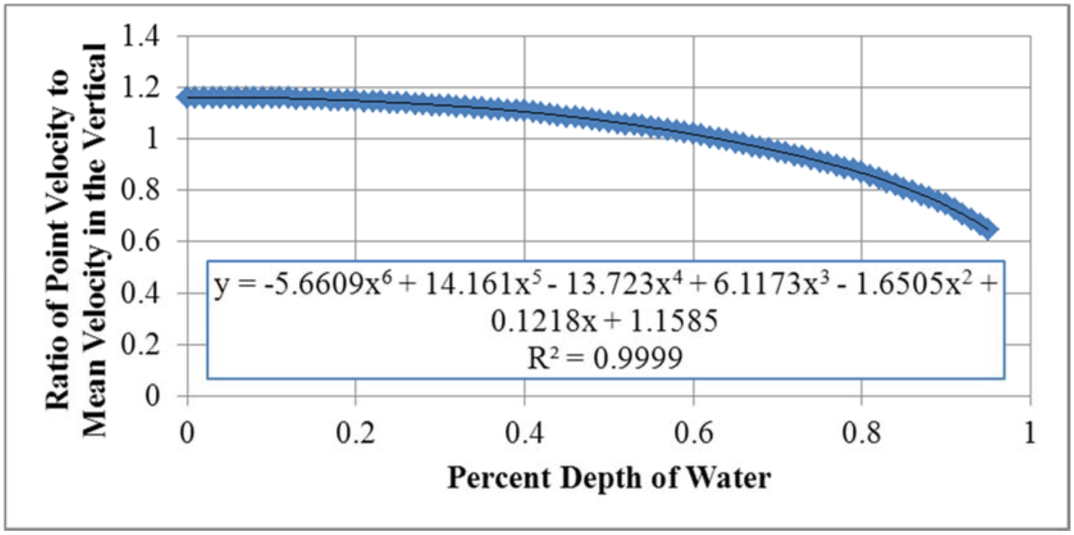

Figure 14. Equations used to calculate the velocity of each subsection.

Load Calculation

A stream load can be defined as the mass per unit volume of a certain substance passing a given geographical point over a set amount of time. For the USGS stations, discharge data was available every day throughout the study period. For the ungauged stations, a linear regression was performed between each week's discharge measurements and discharge measurements were calculated for the days in between sampling times. For nutrient data, the average between each consecutive week was used for load measurements. Once these values were calculated, the nutrient concentrations were multiplied by the discharge to give a mass per unit volume. These values were then added up to calculate the entire load for the sampling period.

Sampling Procedure

At each sampling site the same sampling protocol was followed each week. Samples were collected in 125 mL and 1000 mL high density polyethylene plastic bottles (HDPE). Each bottle was rinsed four times with the upstream river water and then filled and capped beneath the water as to eliminate any air bubbles on the top. Along with the bottles of water, a small vial and an open container were used to collect water for field analysis.

Field Analysis

Immediately after the samples were collected, pH, turbidity, dissolved oxygen, total dissolved solids and conductivity were measured. Table 3 shows the parameters and the respective equipment used to measure them. Figure 15 shows the equipment with which these parameters were measured in the field.

Table 3. Field parameters and the respective equipment used to measure each parameter.

Parameters	**Equipment**
pH	Extech S/N 33214 ExStik II
TDS, Conductivity, Temperature	Hanna HI98311 Probe
DO	Hach LDO Probe
Turbidity	2020i LaMotte Turbidity Meter

Figure 15. Measuring of the field parameters using their respective equipment.

Laboratory Analysis

Laboratory analysis of the water samples consisted of analyzing for dissolved ions and suspended sediment. Suspended sediment was analyzed by first weighing a dry 0.7

micrometer millipore filter, filtering 600 mL of sampled water using a vacuum pump apparatus (Figure 16), drying the filter at 105°C for 24 hours, then reweighing the filter. Suspended sediment is usually reported in mg/L so the following calculations were completed:

$$\frac{\left(End\ weight\ (mg) - Beginning\ weight\ (mg)\right)}{0.6L}$$

Figure 16. Vacuum pump apparatus used to filter the sample water to calculate suspended sediment.

The concentrations of dissolved chloride, nitrate, and sulfate in water were determined with a Dionex® (Model DX-120) ion chromatograph under suppressed conductivity. Ion elution was accomplished using a CO_3-HCO_3 solution. Before analyzing the samples, de-ionized water was injected to verify the stability of the machine. Flow rate was set at 1.95 mL/min. Known standards of the target ions (5, 25, 50 ppm) were used for machine calibration, and a separate 25 ppm standard solution was used to check the validity of calibration. Samples were stored for one month at a temperature of ~4°C before analysis. The unknown samples were poured into 5 mL plastic vials fitted with 20 micron filter caps and then loaded into an AS40 automated sampler for injection into the system. The samples flowed from the injection loop first to the guard column (AG14) and then to the anion exchange column (AS14), and finally to the ASRS 300 (4 mm) suppressor to complete the cycle. The peak retention times were 1.9 minutes for chloride, 3.0 minutes for nitrate, and 4.4 minutes for sulfate. Sample scan, data acquisition, and statistical analysis were done by a Chromatography Management System (CMS) software called “Chromeleon” (released from Dionex) remotely from a computer work station. The analytical margin of error was ± 0.5 ppm .

CHAPTER 5

RESULTS AND DISCUSSION

Discharge

Discharge measurements from the USGS monitoring stations indicated great variability in the streamflow from the tributaries. Each of the tributaries followed a pattern of having a peak in May, the highest peak in June, and another peak in July followed by low flow. The Upper Cedar River had the most total flow with $2.73*10^{10}$ ft^3 followed by the Shell Rock River $2.65*10^{10}$ ft^3, West Fork Cedar River $2.29*10^{10}$ ft^3, and the Winnebago River $4.05*10^9$ ft^3. The inches per acre (in/acre) contribution differed from the total flow. Highest was the West Fork Cedar River with 11.4 in/acre, followed by the Shell Rock River with 10.5 in/acre, then the Upper Cedar River with 7 in/acre and finally the Winnebago River with 2.5 in/acre. The difference in total discharge and contribution per acre could indicate differences in precipitation but also a difference in the path of water through the watershed. There is an order of magnitude difference between the Winnebago River and the rest of the tributaries that can be attributed to both its smaller size and an underestimation of the weekly discharge by using the discharge measurement method developed for this study. An upstream USGS stream gauge on the Winnebago River recorded $6.99*10^9$ ft^3 of flow during the study period. When the discharges are compared to each other it is noticeable that the Winnebago River fluctuations are much smaller in comparison to the other watersheds. With this relationship, the load calculations would also be underestimated.

Total Dissolved Solids

Total dissolved solids (TDS) for the sampling sites didn’t seem to fluctuate very much. Most of the sites followed a pattern of maintaining a relatively stable TDS concentration, but it appears that the concentration was diluted during high flow events. This dilution could be attributed to flow coming more directly from precipitation during these high flows. Figure 17 shows the ten sampling sites’ TDS concentrations with relationship to discharge.

Figure 18 shows the average, minimum and maximum TDS concentrations of the 10 sites throughout the sampling period. The average TDS ranged from 230 ppm at Chickasaw – Little Cedar River to 301ppm at Rockford-Winnebago River. The maximum observed was 525 ppm at Shell Rock-Shell Rock River while the minimum observed was 160 ppm at Chickasaw-Little Cedar River. There wasn’t much fluctuation between the minimum and maximums which could indicate a strong baseflow component of the streamflow. If streamflow was more dependent on overland flow the TDS would be expected to fluctuate more.

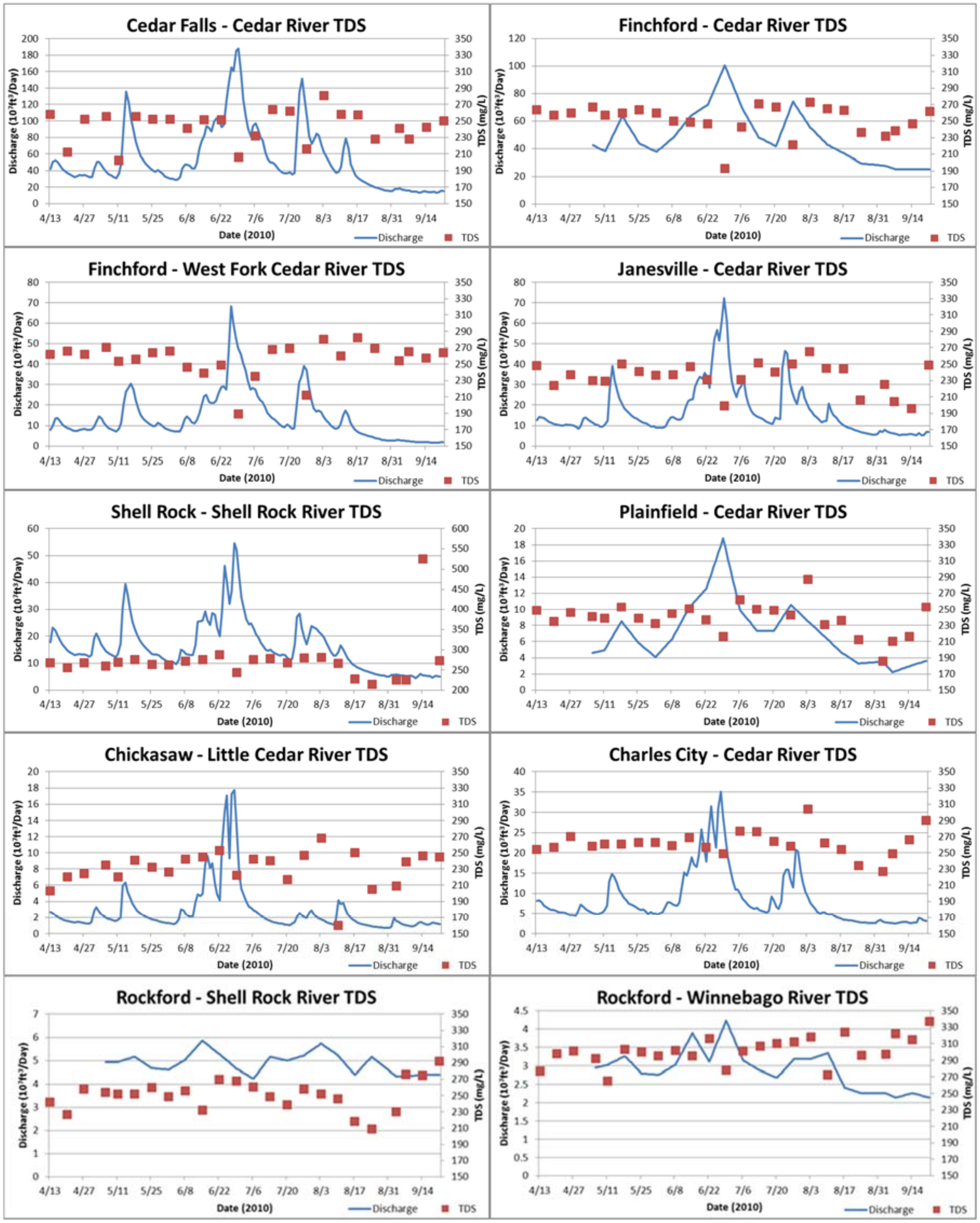

Figure 17. Hydrograph and TDS concentrations for the 10 sampling sites.

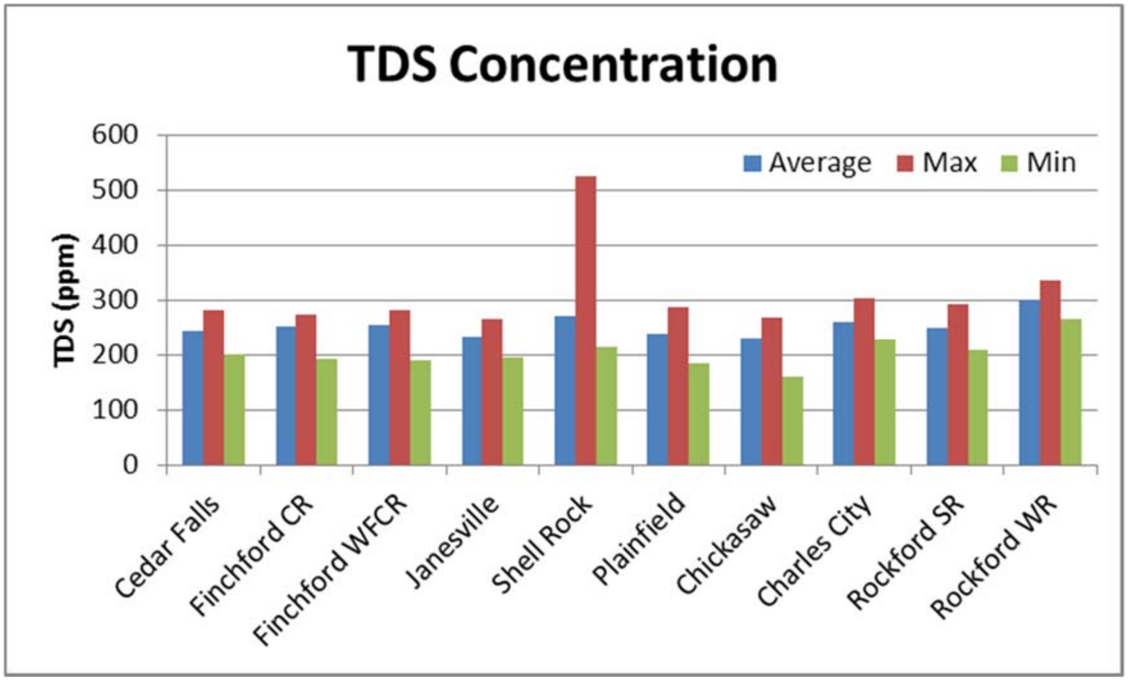

Figure 18. Average, maximum, and minimum TDS concentrations for the 10 sites.

<u>TDS by Subwatershed</u>

Figures 19-22 show the TDS concentrations and discharge of the 4 subwatersheds. The dilution effect discussed earlier can be seen by the decreased TDS concentration at high discharges. The average TDS concentrations of the subwatersheds were as follows: the highest was the Winnebago River with 301 ppm, followed by the Shell Rock River with 272 ppm, the West Fork Cedar River with 256 ppm, and then the Upper Cedar River with 234 ppm.

The TDS load from each subwatershed was calculated and they differed greatly. Also, a calculation was made to determine the pounds per acre contribution of each subwatershed. This calculation entailed dividing the pounds of TDS by the area of the subwatershed. Figure 23 shows the TDS loads along with the pounds per acre contribution of each subwatershed. The Shell Rock River contributed the most during the study period with 221,988 tons followed by the Upper Cedar River with 199,415 tons, the West Fork Cedar with 174,883, and then the Winnebago with 38,127. When watershed size is taken into consideration, the Shell Rock is still the largest contributor with 642 lbs/ac followed by the West Fork Cedar with 634 lbs/ac, the Upper Cedar with 370 lbs/ac and then the Winnebago with 173 lbs/ac. This calculation assumes a uniform contribution per acre and did not differentiate by land type. A pounds per acre calculation is useful to identify pollution hotspots. From a management standpoint once a watershed is identified as a pollution hotspot, work can be done within the watershed to identify the pollution sources and establish best management practices to remediate the problem.

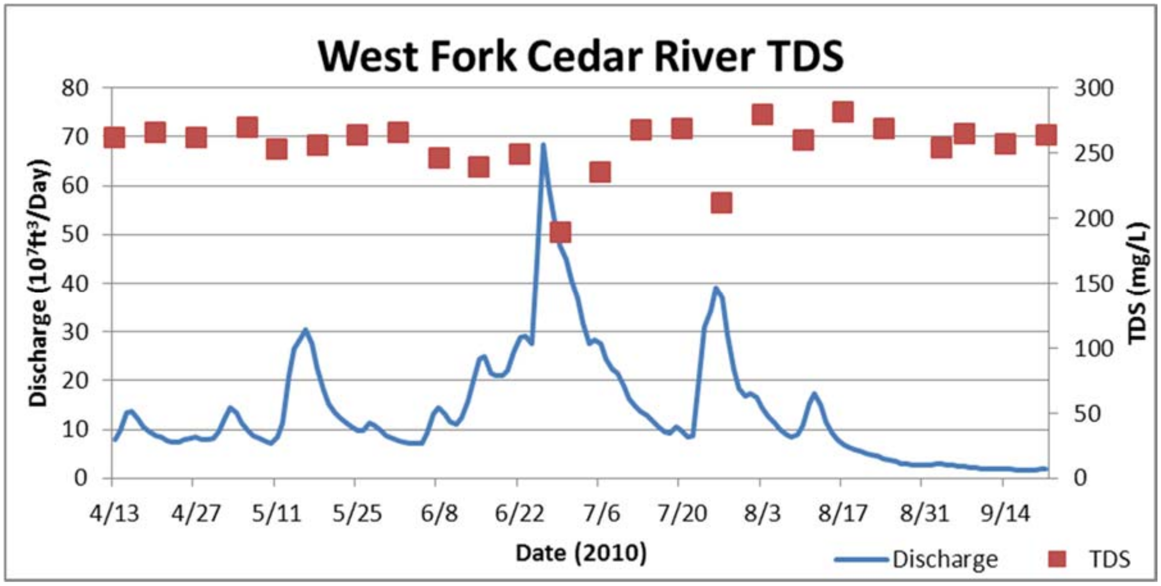

Figure 19. Hydrograph and TDS of the West Fork Cedar River.

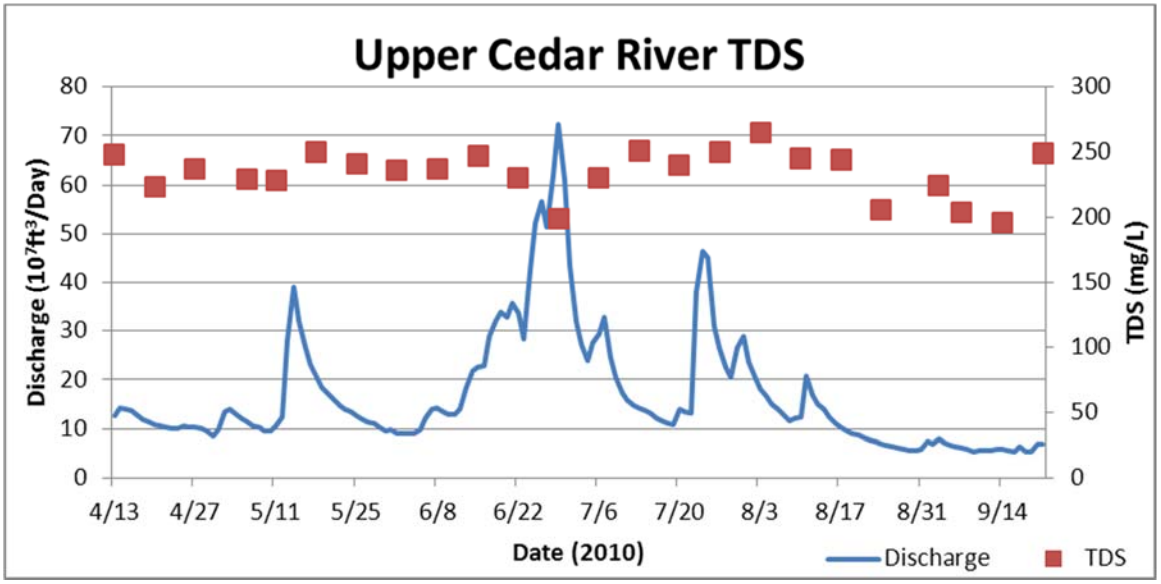

Figure 20. Hydrograph and TDS of the Upper Cedar River.

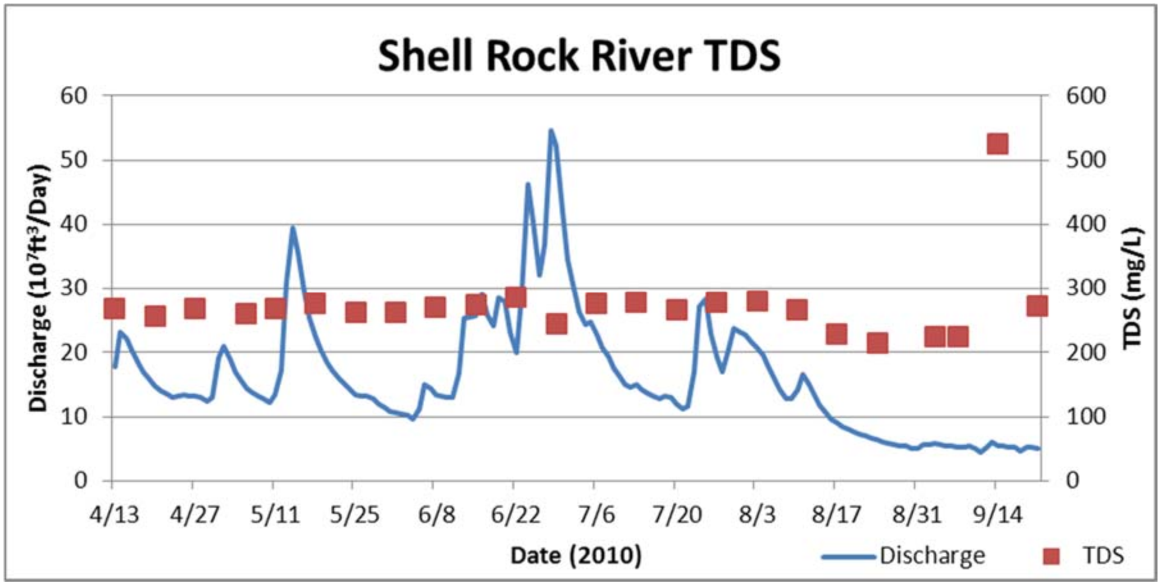

Figure 21. Hydrograph and TDS of the Shell Rock River.

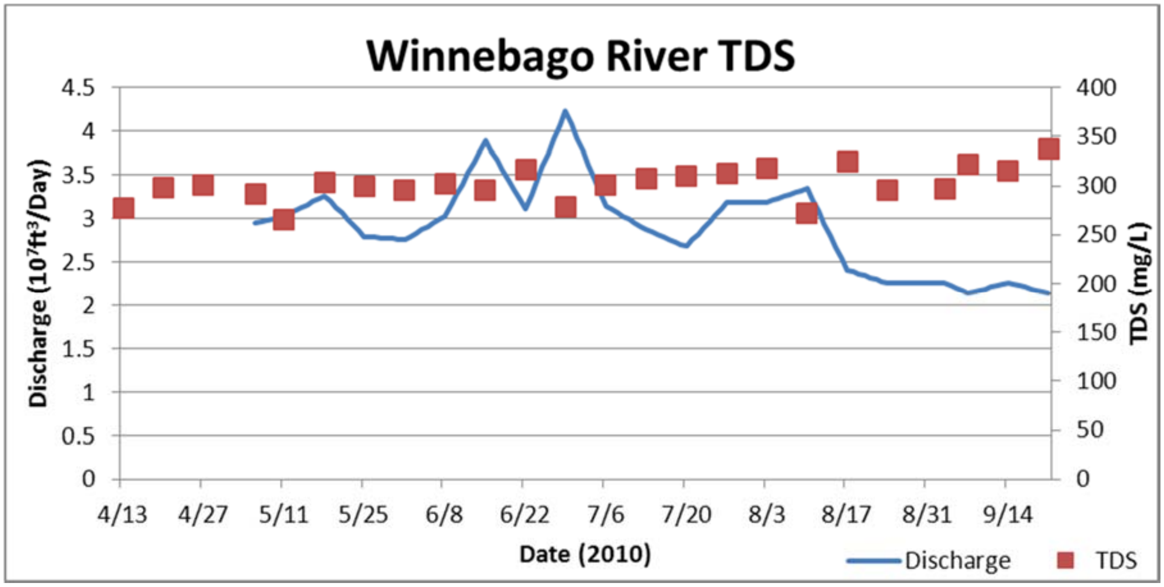

Figure 22. Hydrograph and TDS of the Winnebago River.

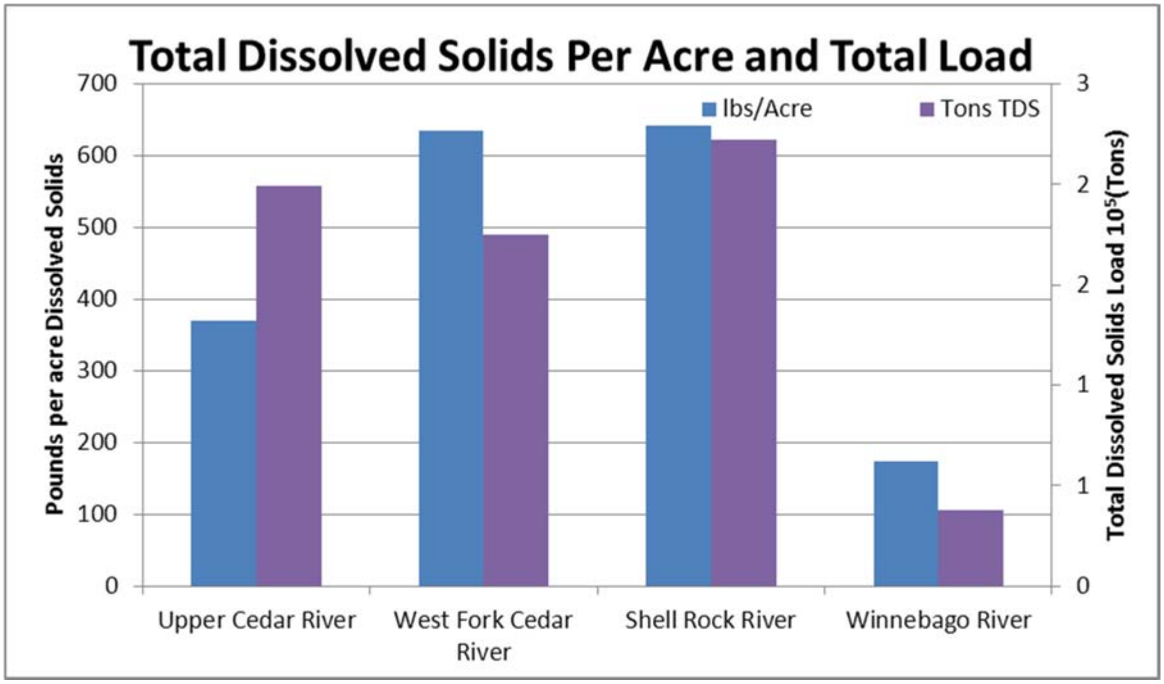

Figure 23. Pounds per acre contribution and total load of TDS for the 4 subwatersheds.

Total Suspended Sediment

Total Suspended Sediments (TSS) differed throughout the study period both temporally and spatially. Figure 24 shows the TSS concentration in relationship to discharge at the 10 sampling sites. Some of the sample sites trended with discharge while others were somewhat erratic with relation to discharge. It should be noted that the collection method for suspended sediments was not a composite sample but a grab sample so that might tie into some of the erratic measurements. Also, suspended sediments appeared to be highly variable and in order to get a more accurate estimation of load, sampling frequency should be higher.

Figure 25 shows the average, minimum and maximum TSS concentrations of the 10 sites throughout the sampling period. The averages ranged from 20 mg/L at both Charles City – Cedar River and Rockford – Shell Rock River to 42 mg/L at Janesville – Upper Cedar River. Both the maximum of 176 mg/L and the minimum of 4 mg/L were observed at Chickasaw – Little Cedar River. The Chickasaw site was very flashy in relation to the other sampling sites and this could be related to why both the minimum and maximum concentrations were observed there.

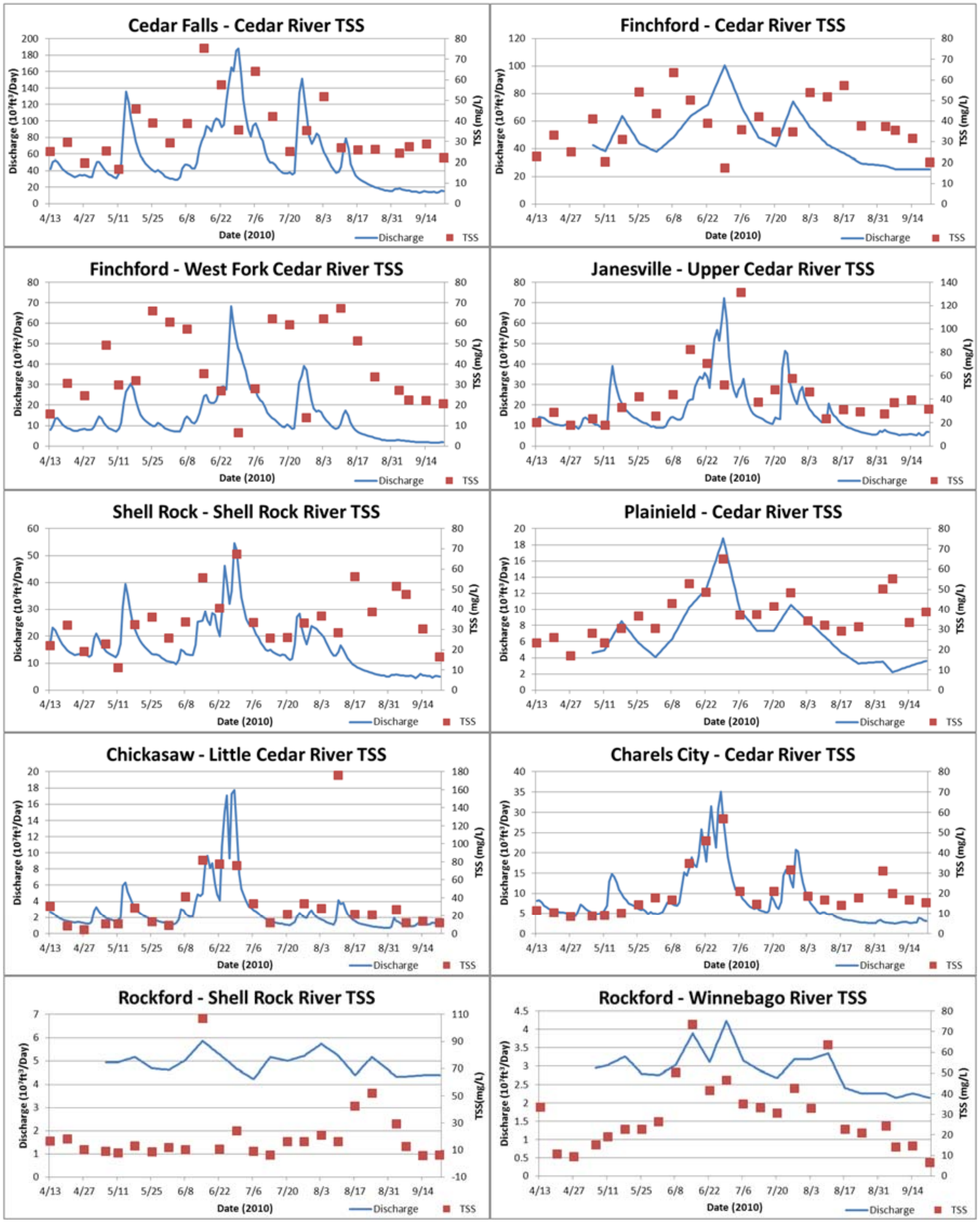

Figure 24. Hydrograph and TSS concentrations for the 10 sampling sites.

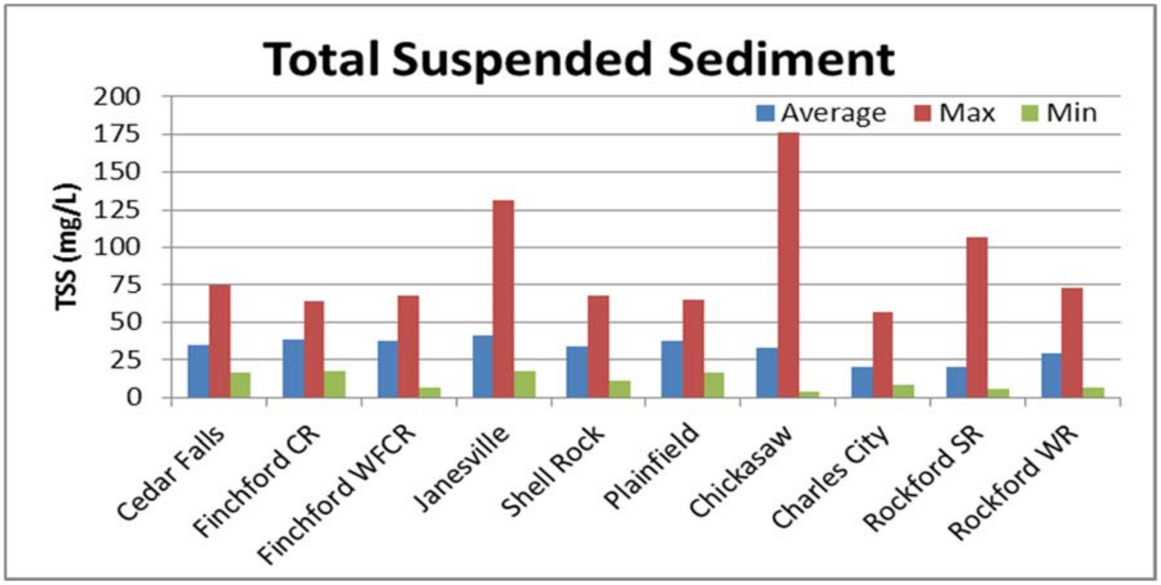

Figure 25. Average, maximum and minimum TSS for the 10 sampling sites.

Suspended Sediment by Subwatershed

Figures 26-29 show the trends of TSS with discharge for the 4 subwatersheds. It appears that for the Winnebago River and the Upper Cedar River the TSS concentration followed the discharge. The West Fork Cedar River TSS concentration appeared to have an inverse relationship with discharge and the Shell Rock River seemed erratic.

The average suspended sediment concentrations of the subwatersheds were as follows: the highest was the Upper Cedar River with 41.54 mg/L, followed by the West Fork Cedar River 37.65 mg/L, the Shell Rock River 34.25 mg/L, and then the Winnebago River at 29.67 mg/L. Figure 28 shows the contribution per acre and the total suspended sediment load. The Upper Cedar contributed the most with 43,316 tons, followed by the Shell Rock with 29,880 tons, the West Fork Cedar with 25,030 tons, and the Winnebago with 4,343 tons. When watershed size is taken into consideration the pounds per acre contributions differed greatly. The West Fork Cedar contributed the most with 91 lbs/ac, second was the Shell Rock with 86 lbs/ac, third was the Upper Cedar with 80 lbs/ac and last was the Winnebago with 20 lbs/ac. Once again the contribution by the Winnebago River is underestimated due to the method used to calculate discharge.

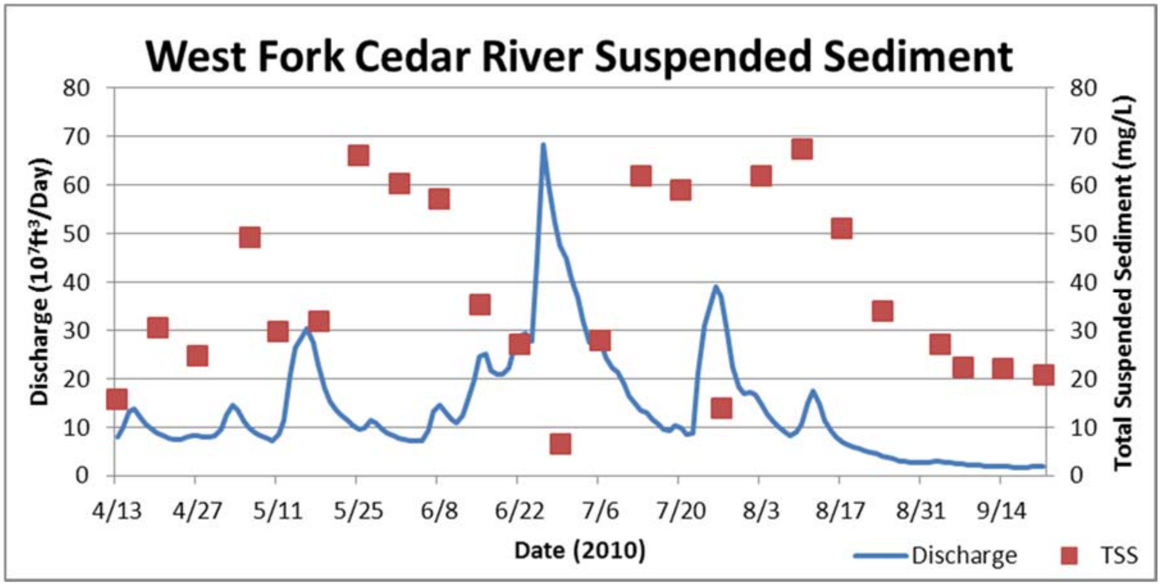

Figure 26. Hydrograph and suspended sediment concentration of West Fork Cedar River.

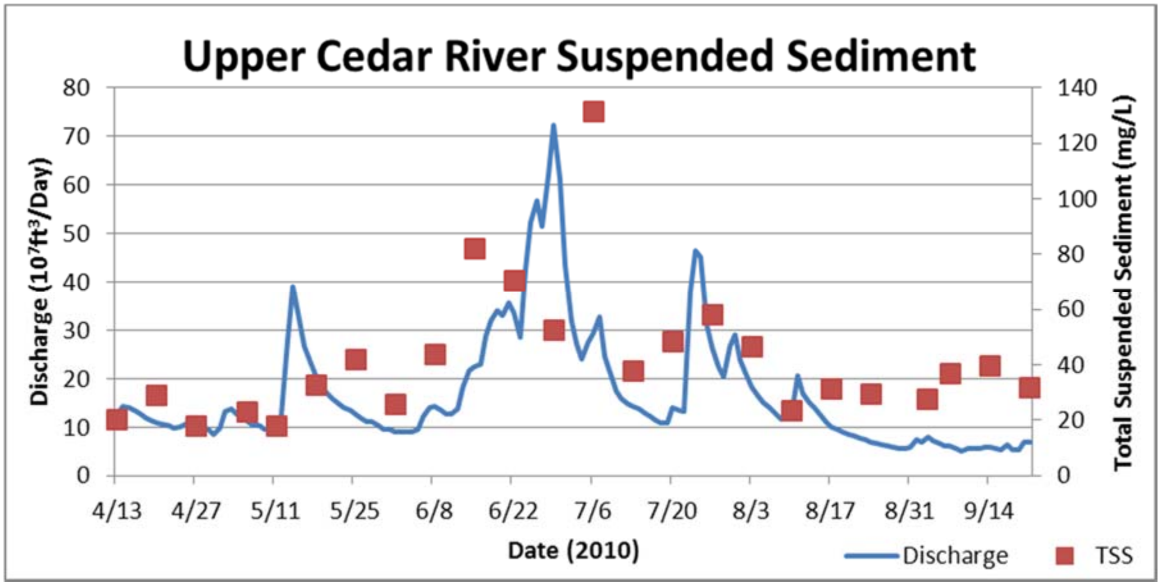

Figure 27. Hydrograph and suspended sediment of Upper Cedar River.

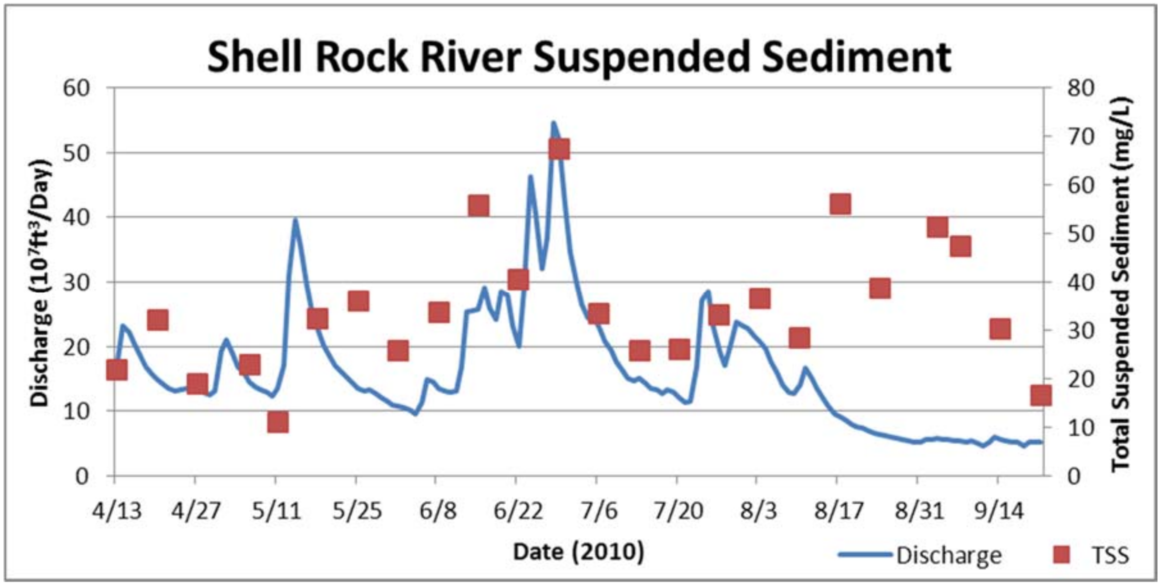

Figure 28. Hydrograph and suspended sediment of Shell Rock River.

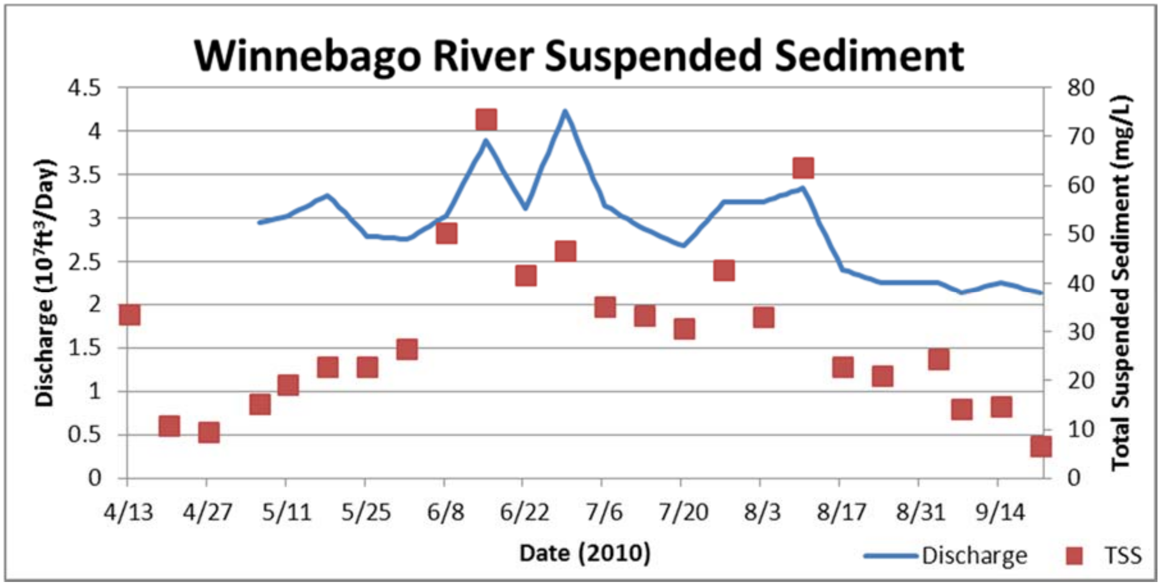

Figure 29. Hydrograph and suspended sediment of Winnebago River.

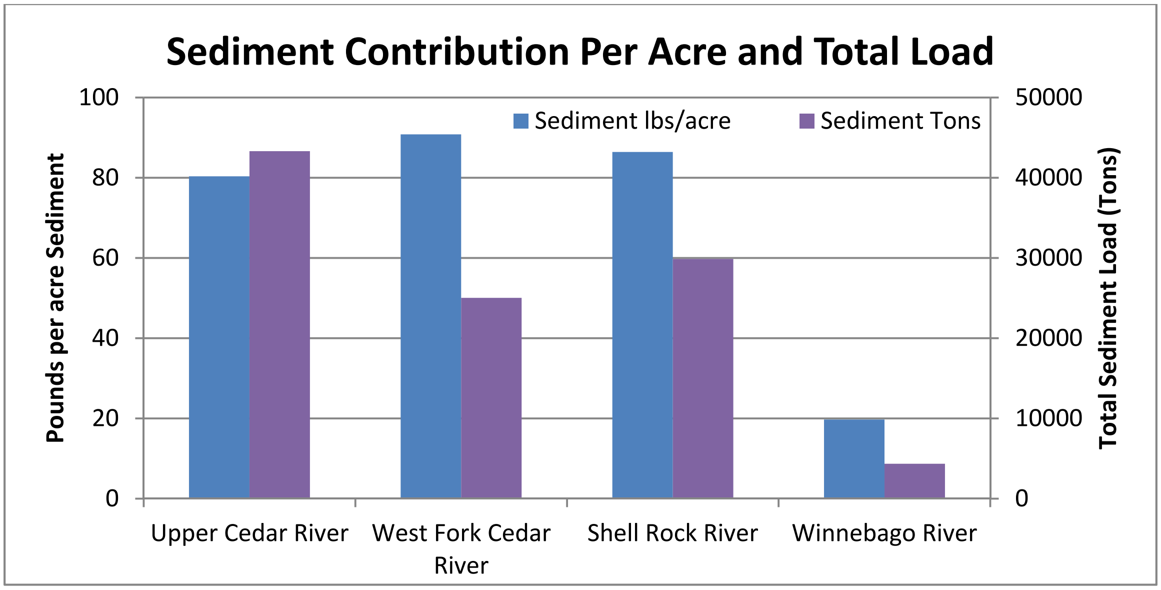

Figure 30. Sediment load and contribution per acre during study period.

Suspended Sediment and Turbidity

Turbidity and suspended sediment are two physical characteristics of water that measure similar attributes and are thus related. Turbidity is a measure of water clarity by how much the material suspended in water decreases the passage of light. Suspended sediment is just the physical quantity of sediment that is suspended per unit volume of water. There was a positive correlation between turbidity and suspended sediment (Figure 31). Different organizations use different measurements when dealing with stream quality, so being able to estimate one parameter from the other is useful. Also, since turbidity is easily measured in the field, TSS estimation can be made and a load calculation can be made much quicker.

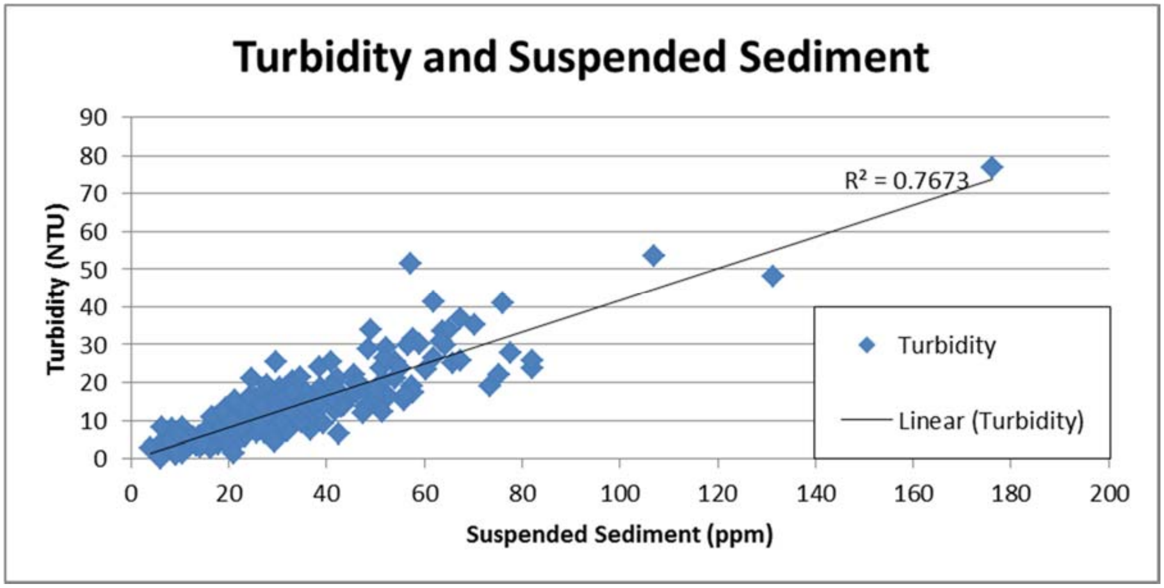

Figure 31. Relationship between turbidity and suspended sediment.

Nitrate

Throughout the study period, nitrate concentrations within each watershed varied both spatially and temporally. In general, the nitrate concentration and discharge seemed to rise and fall together (Figure 32). The highest measured nitrate concentrations occurred during early spring and summer (May-June). A steady decline in concentration followed these peaks leading into the fall. The peaks occurring in early spring and summer can be attributed to the fertilization of row crops and the fact that the plants are still very small. Most row crops undergo nitrogen fertilization at this time so there is more nitrogen in the soil. Along with this, rainfall is also fairly high during this period which would cause more nitrogen to leave the soil. During the high flows it appears that the concentration was diluted by precipitation, just as with TDS.

The average nitrate concentrations (Figure 33) of the ten sampling sites ranged from 13 ppm at Rockford – Shell Rock River to 45 ppm at Chickasaw – Little Cedar River. The minimum concentration was observed at Rockford – Shell Rock River where the concentration was below the detection limit of the ion chromatograph and the maximum of 84 ppm was observed at Chickasaw – Little Cedar River.

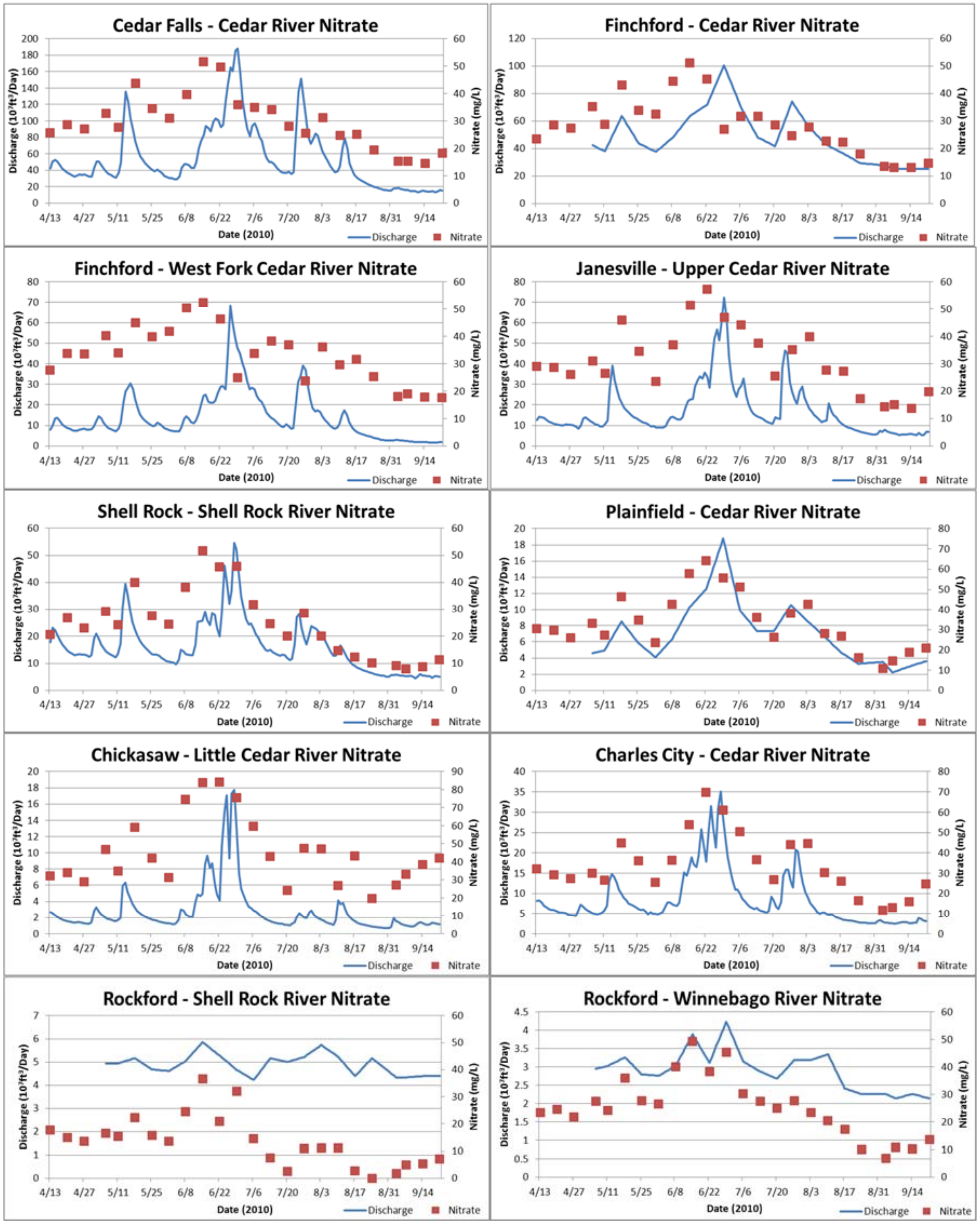

Figure 32. Hydrograph and nitrate concentrations of the 10 sampling sites.

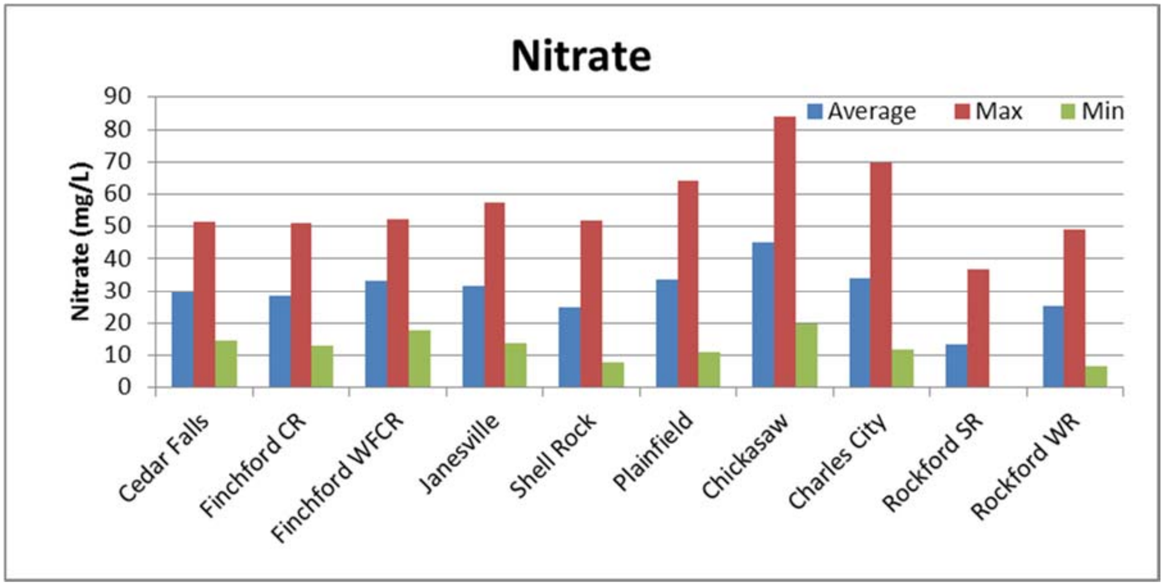

Figure 33. Average maximum and minimum nitrate concentrations of the 10 sites.

Nitrate by Subwatershed

The trend of the nitrate concentrations being higher in the spring and low in the fall is clear in Figures 34-37. The average nitrate concentrations of the subwatersheds were as follows: the highest was the West Fork Cedar River with 33.22 ppm, followed by the Upper Cedar River with 31.44 ppm, the Shell Rock River with 24.90 ppm, and then the Winnebago River at 24.27 ppm. The nitrate load from each watershed differed greatly (Figure 38). During the study period the Upper Cedar contributed the most with 31,994 tons, followed by the West Fork Cedar with 25,557 tons, the Shell Rock with 21,504 tons, and the Winnebago with 3,473 tons. When watershed size was taken into account, the West Fork Cedar contributed the most with 93 lbs/ac, second was the Shell Rock with 62 lbs/ac, third was the Upper Cedar with 59 lbs/ac and last was the

Winnebago with 16 lbs/ac. The difference in the total load and the contribution per acre shows the importance of discharge.

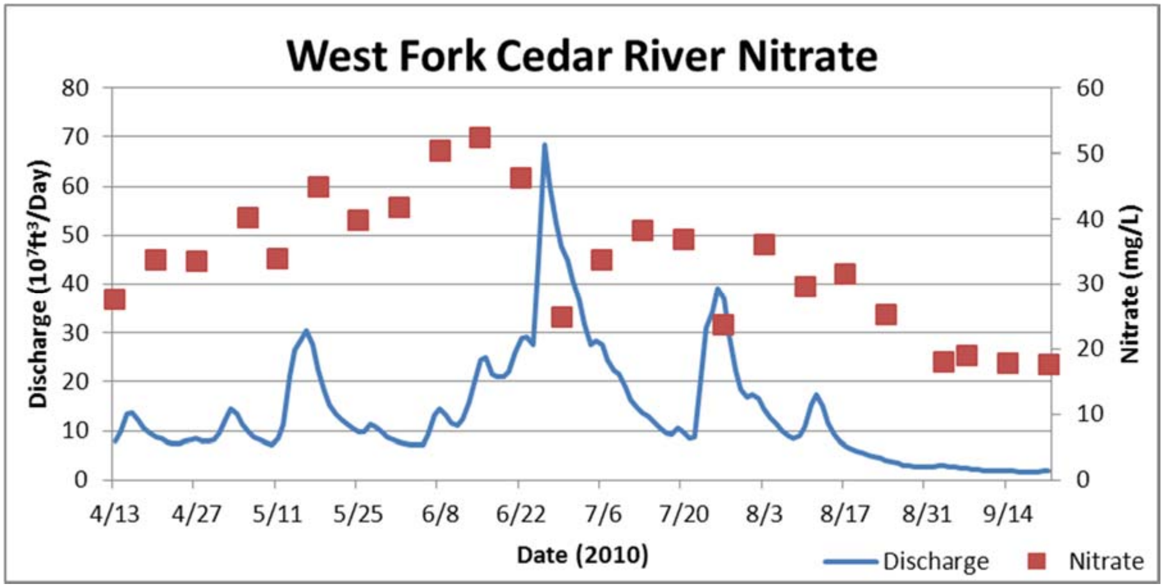

Figure 34. Hydrograph and nitrate concentrations of West Fork Cedar River.

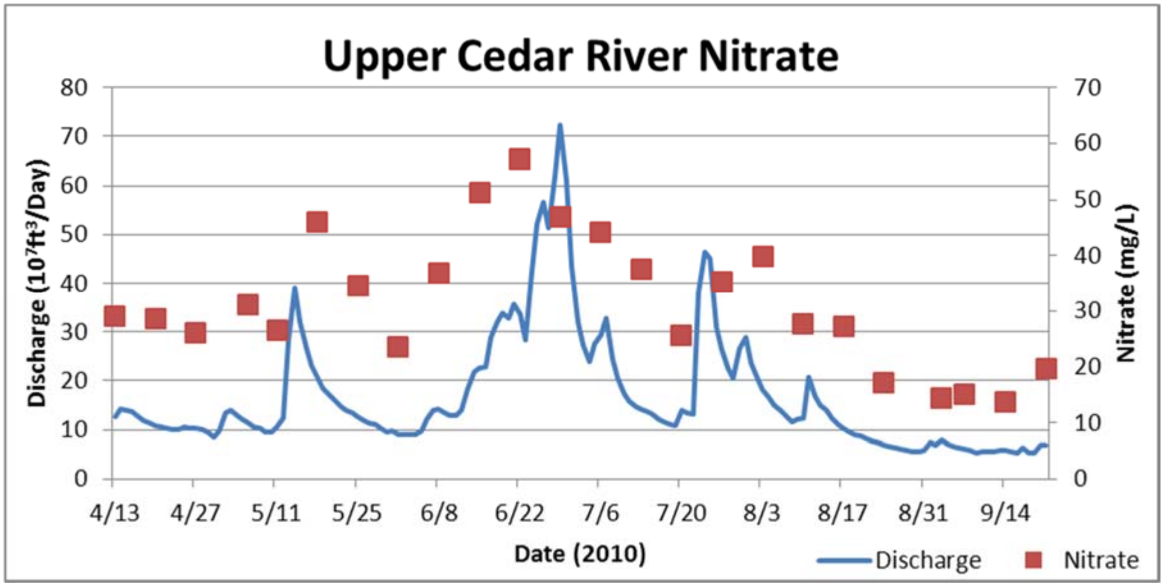

Figure 35. Hydrograph and nitrate concentrations of Upper Cedar River.

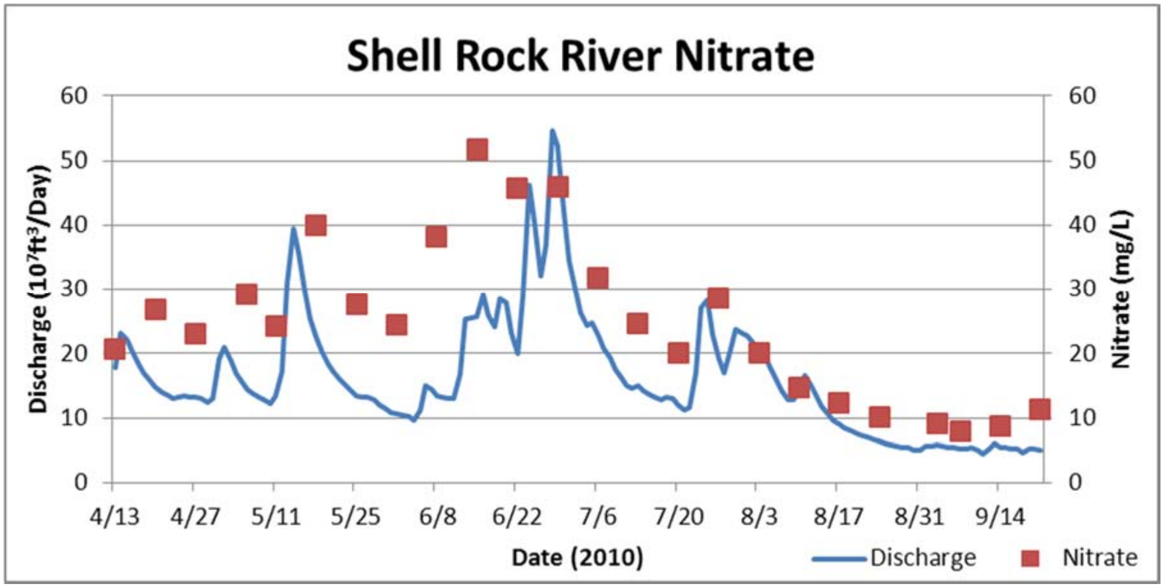

Figure 36. Hydrograph and nitrate concentrations of Shell Rock River.

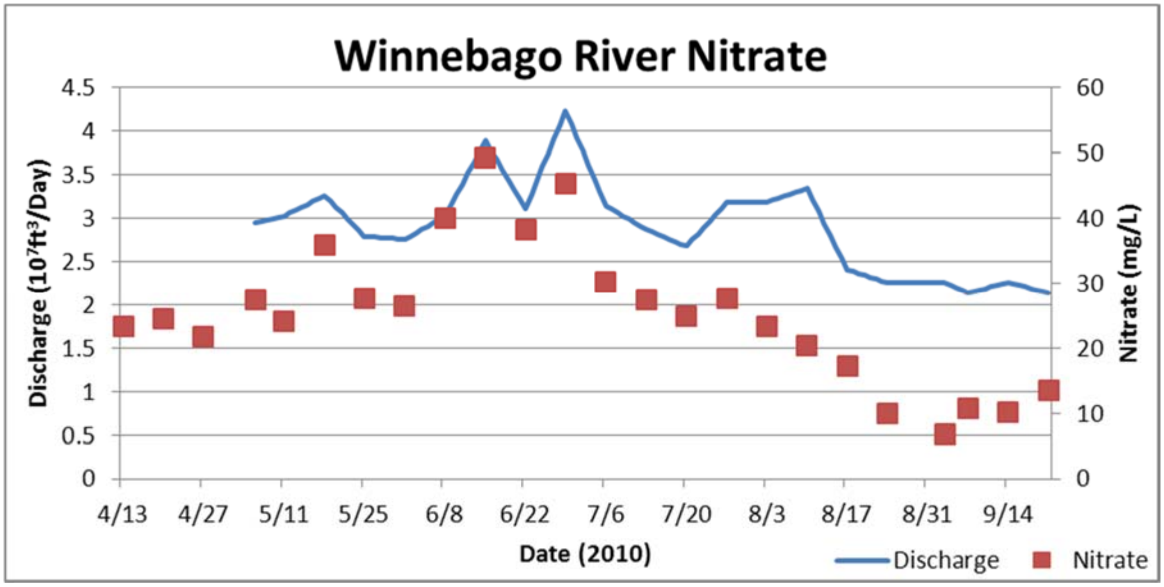

Figure 37. Hydrograph and nitrate concentrations of Winnebago River.

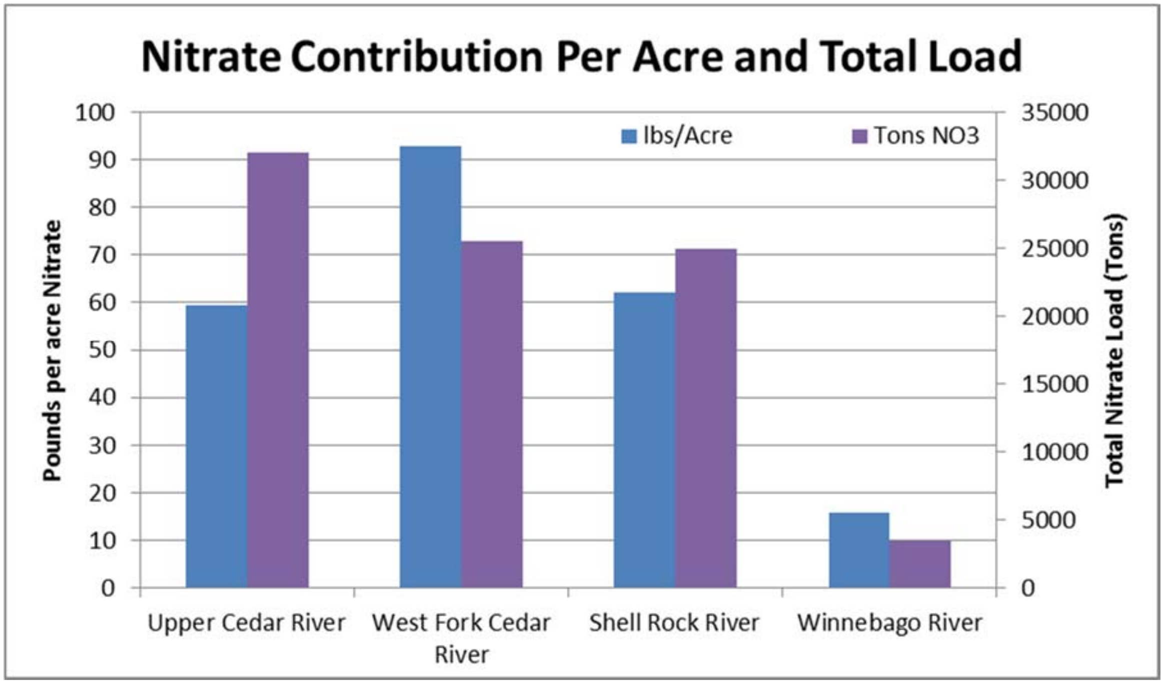

Figure 38. Nitrate load and contribution per acre during study period

Nitrate Concentrations and Discharge

Nitrate concentrations generally trended with discharge in that when discharge went up or down nitrate concentrations did the same. Along with this, nitrate loads showed to be more dependent on discharge as opposed to nitrate concentration. When comparing the nitrate concentrations to the nitrate load and the discharge to the nitrate load, this relationship is apparent by looking at the R^2 of each variable (Figure 39). The range of discharge measurements was much greater than the range in nitrate concentration measurements. This along with the way in which load is calculated, could explain why the nitrate load is more dependent on discharge.

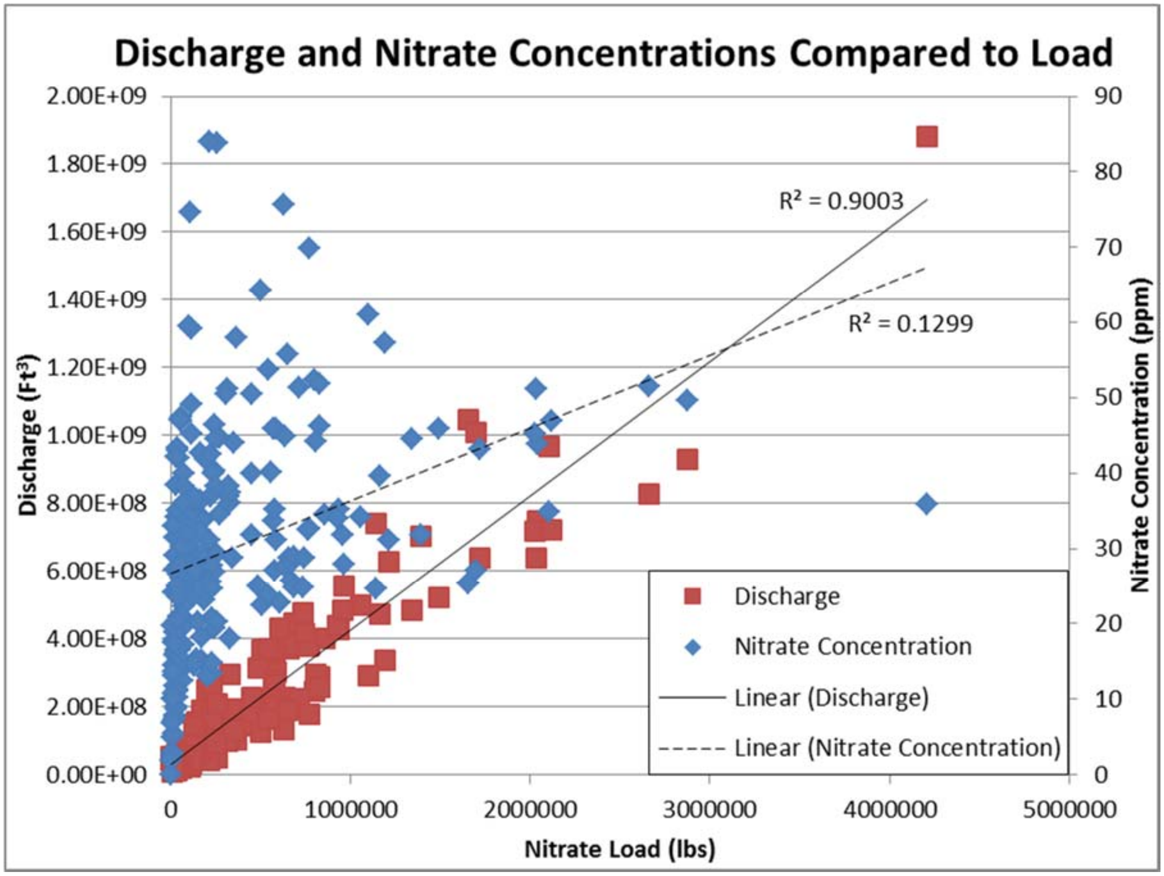

Figure 39. Discharge and nitrate concentrations compared to nitrate load.

Chloride

Chloride concentrations were fairly steady with a noticeable dilution during high flows (Figure 40). Figure 41 shows the average, minimum and maximum chloride concentrations of the 10 sampling sites throughout the sampling period. The average chloride concentrations ranged from 15 ppm at Finchford – West Fork Cedar River to 30 ppm at both Charles City – Cedar River and Rockford – Shell Rock River. The maximum observed was 45 ppm at Charles City – Cedar River and the minimum was 9 ppm at both Finchford – Cedar River and Finchford – West Fork Cedar River.

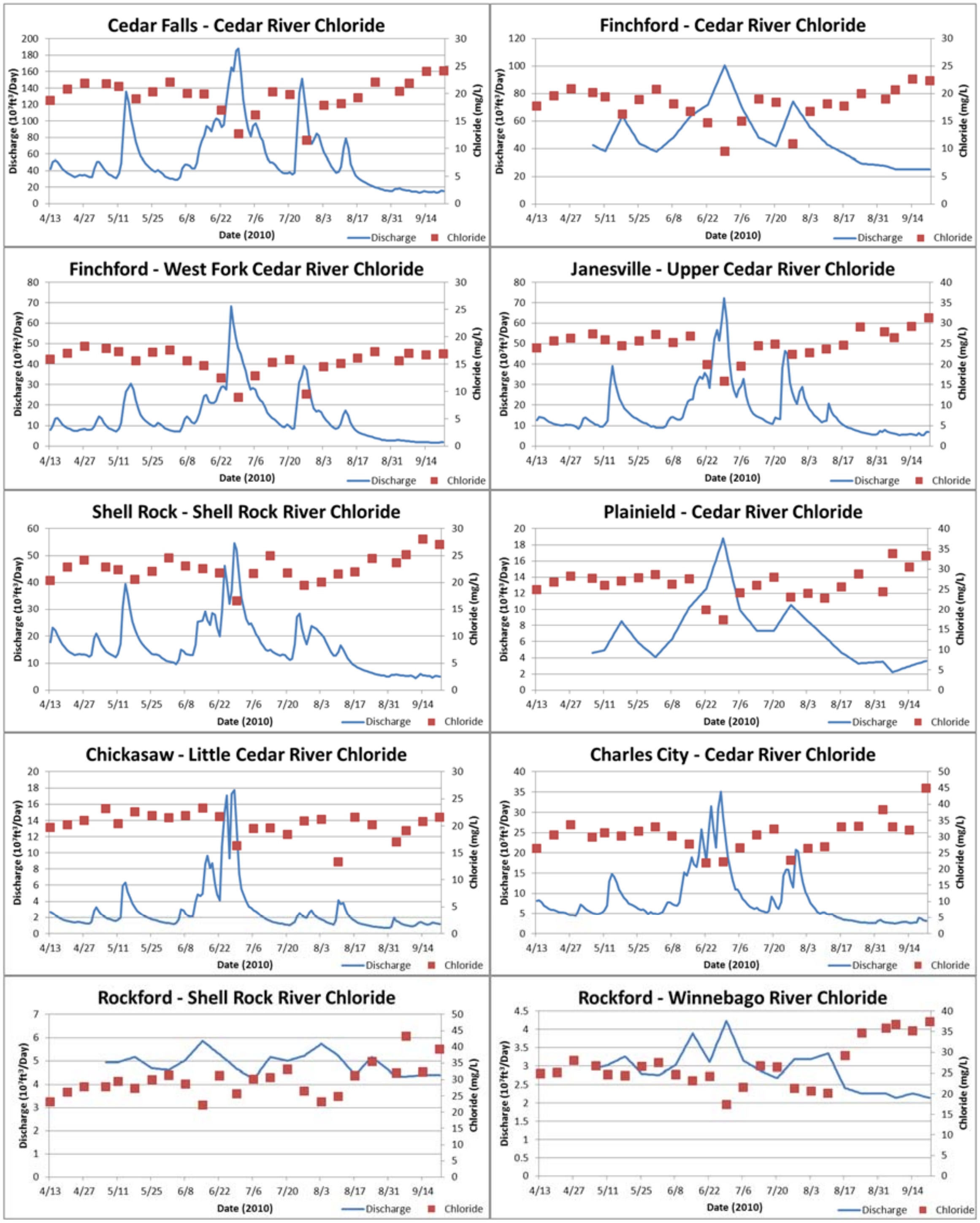

Figure 40. Hydrograph and chloride concentrations of the 10 sampling sites.

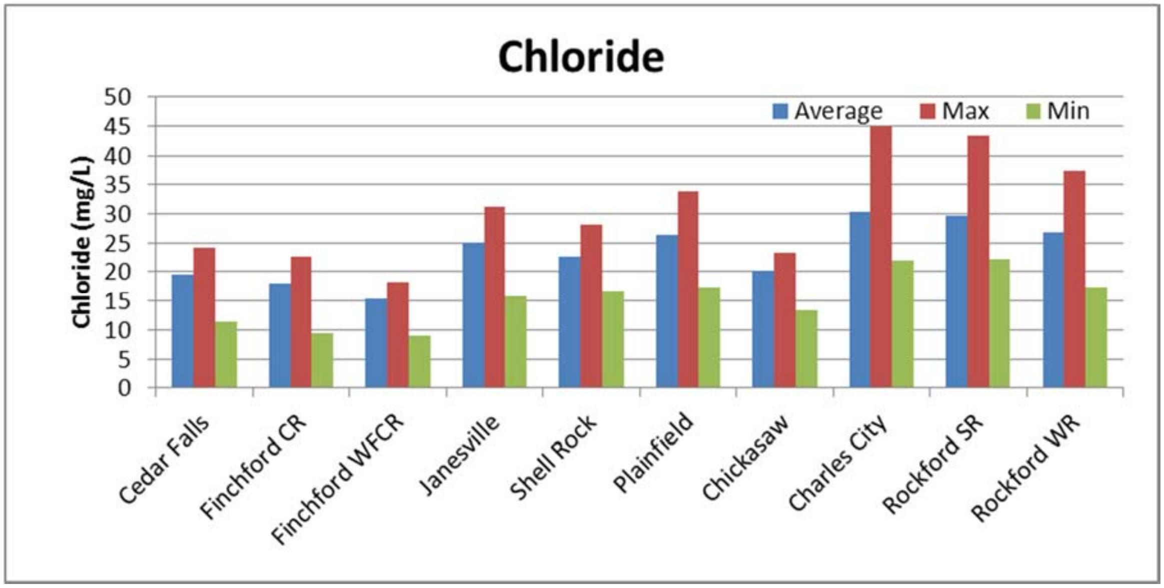

Figure 41. Average, maximum and minimum chloride concentration of the 10 sites.

Chloride by Subwatershed

There were two discernible trends of the chloride concentrations. One with relationship to discharge in that there was a dilution effect at high discharges and another that appears to be an increase in the chloride concentration during the end of the study period, which could possibly coincide with the washing out of pesticide by products (Figures 42-45). The average chloride concentrations of the subwatersheds were as follows: the highest was the Winnebago River with 27 ppm, followed by the Upper Cedar River with 25 ppm, the Shell Rock River with 23 ppm, and the West Fork Cedar River at 15 ppm.

Figure 46 shows both the contribution per acre and total load of chloride for the subwatersheds. The Upper Cedar River had the highest load with 19,766 tons, followed by the Shell Rock River with 17,910 tons, the West Fork Cedar River with 10,019 tons, and the Winnebago River with 3,268 tons. The pounds per acre contributions differed from this, with the Shell Rock River contributing the most with 52 lbs/acre, followed by the Upper Cedar River with 37 lbs/acre, the West Fork Cedar River with 36 lbs/acre, and the Winnebago River with 15 lbs/acre.

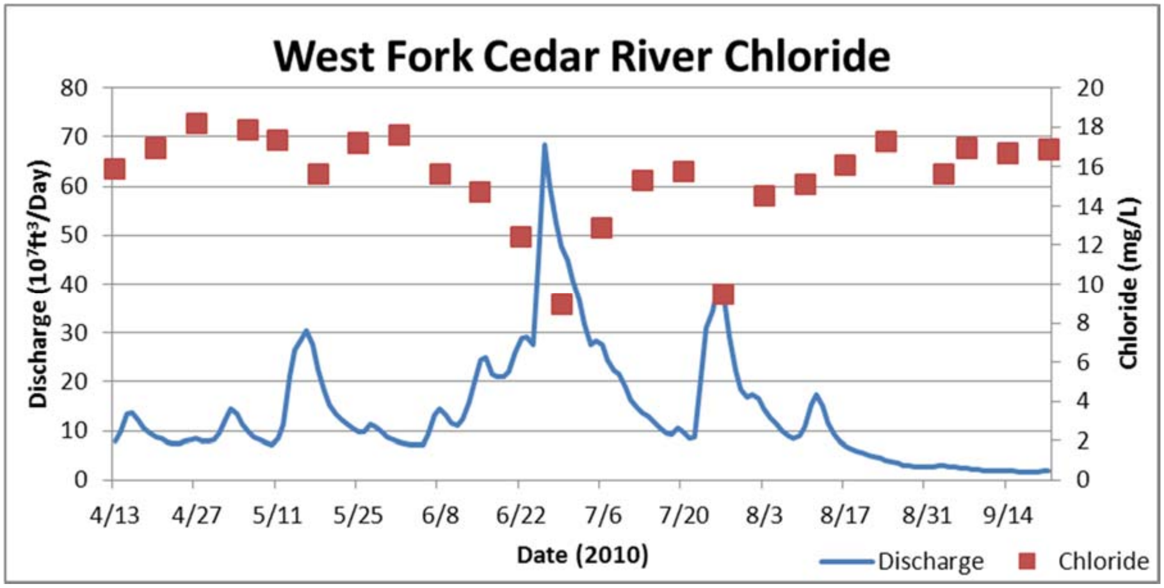

Figure 42. Hydrograph and chloride concentrations of the West Fork Cedar River.

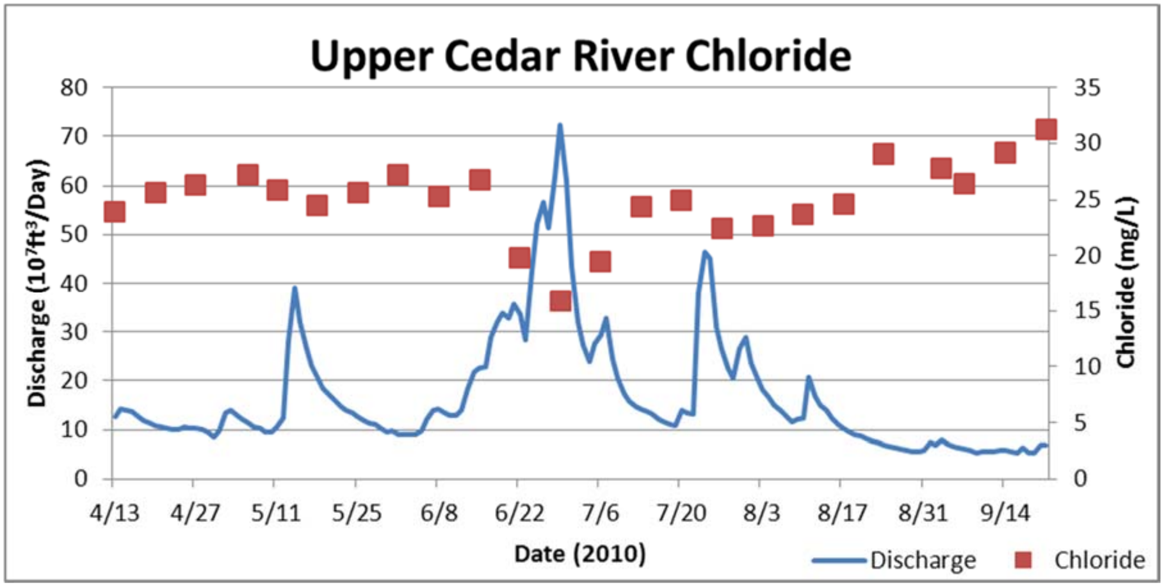

Figure 43. Hydrograph and chloride concentrations of the Upper Cedar River.

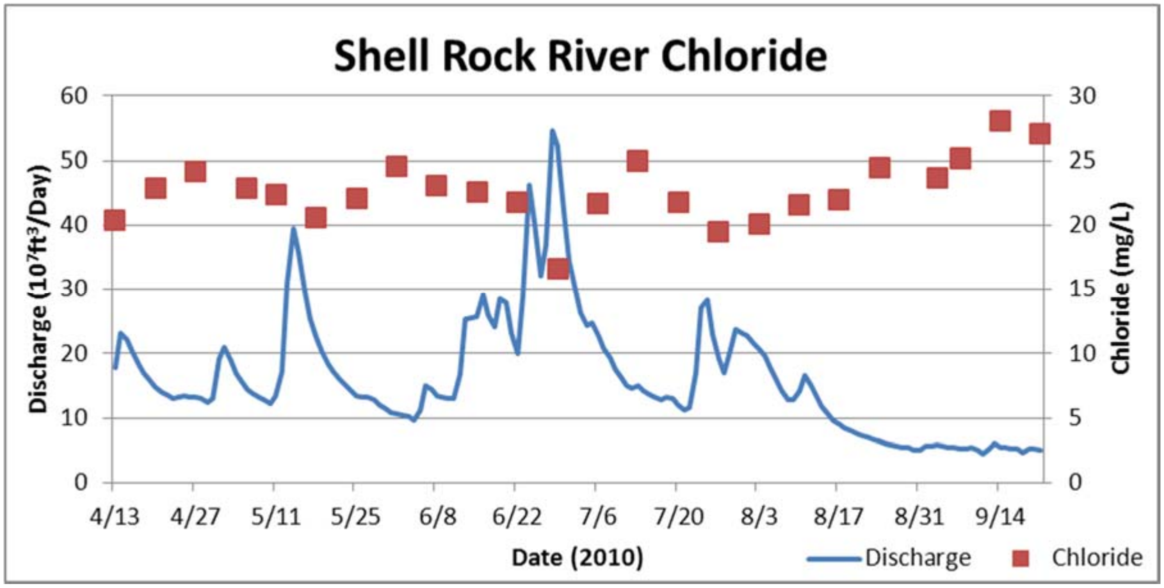

Figure 44. Hydrograph and chloride concentration of the Shell Rock River.

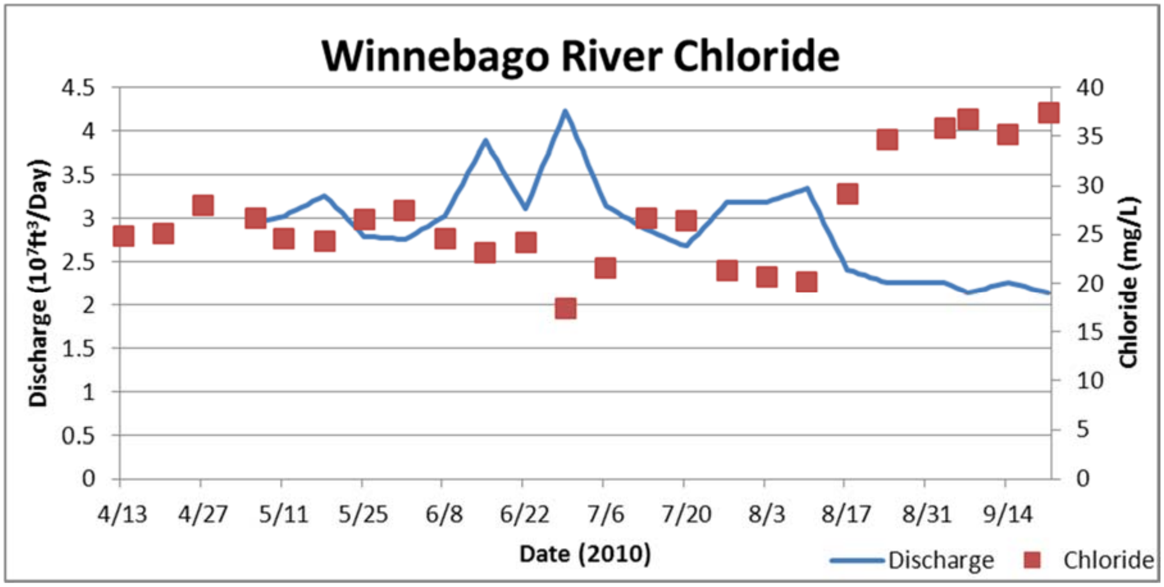

Figure 45. Hydrograph and chloride concentration of the Winnebago River.

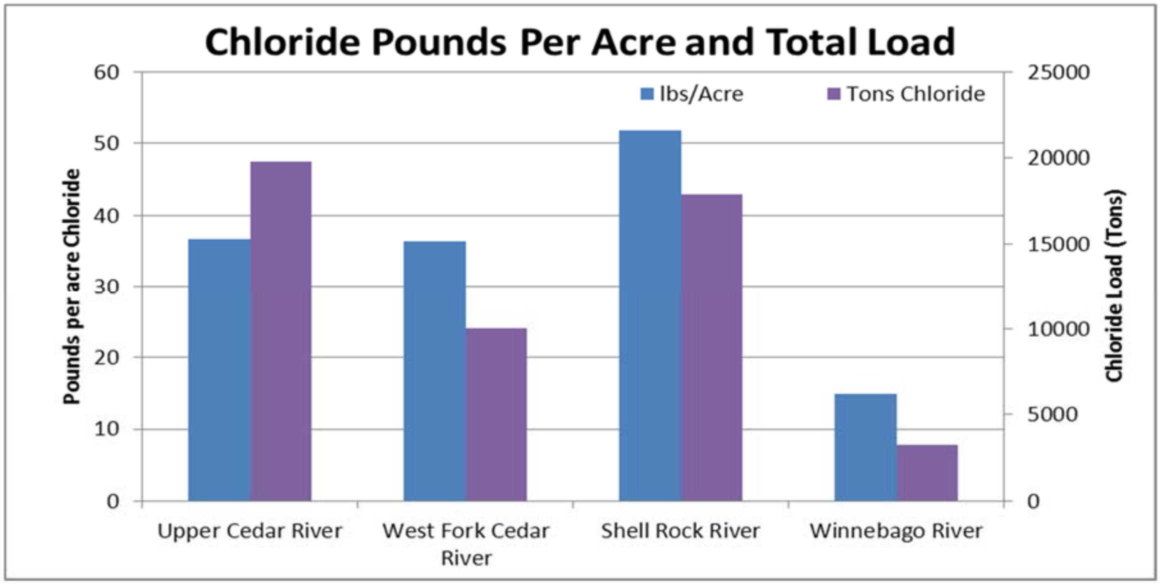

Figure 46. Chloride load and contribution per acre during study period.

Watershed Summary

Tables 4-7 show a ranking of the subwatersheds based upon each analyte and the different calculations that were made. These tables illustrate that knowing just one of the parameters such as average concentration does not give an accurate picture. Discharge is an important part of pollutant loading and it is seen by the total load rankings differing from the average concentration rankings. The contribution per unit area is of considerable interest because a small watershed could contribute more per unit area but still have a lower load and lower average contribution. This calculation can indicate pollution hotspots and suggest where further research and land management could take place.

Table 4. Watershed ranking from worst (1) to best (4) for Total Dissolved Solids

Watershed	Average TDS Concentration	Total TDS Load	TDS lbs/acre
West Fork Cedar River	3	3	3
Shell Rock River	2	1	1
Upper Cedar River	4	2	2
Winnebago River	1	4	4

Table 5. Watershed ranking from worst (1) to best (4) for Total Suspended Solids

Watershed	Average TSS Concentration	Total TSS Load	TSS lbs/acre
West Fork Cedar River	2	3	1
Shell Rock River	3	2	2
Upper Cedar River	1	1	3
Winnebago River	4	4	4

Table 6. Watershed ranking from worst (1) to best (4) for Nitrate

Watershed	Average Nitrate Concentration	Total Nitrate Load	Nitrate lbs/acre
West Fork Cedar River	1	2	1
Shell Rock River	3	3	2
Upper Cedar River	2	1	3
Winnebago River	4	4	4

Table 7. Watershed ranking from worst (1) to best (4) for Chloride

Watershed	Average Chloride Concentration	Total Chloride Load	Chloride lbs/acre
West Fork Cedar River	4	3	3
Shell Rock River	3	2	1
Upper Cedar River	2	1	2
Winnebago River	1	4	4

CHAPTER 6

CONCLUSION

This study was completed to identify nutrient loads from subwatersheds of the Cedar River from April 13, 2010- September 21, 2010. All of the watersheds are major contributors of nutrients to the Cedar River. When looking at Tables 4-7 it is apparent that knowing just one of the nutrient’s attributes doesn’t paint the whole picture. For example, based on average TDS concentration alone the Winnebago River would appear to be the most impaired. However when discharge is taken into account it had the lowest total load and also the lowest lbs/acre. The lbs/acre contribution is of particular interest because it illuminates pollution hotspots. Based upon that, the Shell Rock River and West Fork Cedar River would be good watersheds for further study at the smaller tributary level. For TDS, the Shell Rock River had the most impairment, then the Upper Cedar River, followed by the West Fork Cedar River and the Winnebago River. For TSS, the Upper Cedar River had the most impairment, then the West Fork Cedar River, followed by the Shell Rock River and the Winnebago River. For nitrate, the West Fork Cedar River had the most impairment, then the Upper Cedar River, followed by the Shell Rock River and Winnebago River. For chloride, the Upper Cedar River had the most impairment, then the Shell Rock River, followed by the Winnebago River and West Fork Cedar River. When all of these factors from each pollutant are taken into consideration it appears that the Upper Cedar River had the most impairment followed by the Shell Rock River, West Fork Cedar River, and finally the Winnebago River.

The load of nutrients and average concentrations are comparable with previous studies completed in the area (Fields, 2004 and IDNR, 2006). The average nitrate concentrations ranged from 24 ppm to 33 ppm during this study, 12 ppm to 32 ppm during Fields's (2004) study, and from 22 ppm to 29 ppm during the IDNR (2006) study. The loads differed somewhat though with the total load ranging from 3,500 tons to 32,000 tons during this study, 7,711 tons to 8,400 tons during Fields's (2004) study, and 23,000 tons to 60,600 tons during the IDNR (2006) study. This could be due to a drastic difference in discharge observed. The discharge ranged from 93,000 to 627,000 ac-ft during this study, 163,000 to 270,000 ac-ft during Fields's (2004) study, and 414,416 to 1,184,044 ac-ft during the IDNR (2006) study. This study and Fields's study were conducted over a similar time frame, while the IDNR study was a model based on a year.

When looking at the data it is clear that discharge is the most important variable when determining these loads. The Winnebago River discharge using the derived method was $4.05*10^9$ ft^3 while the upstream USGS gage showed a discharge of $6.99*10^9$ ft^3. Regardless of the actual discharge measurement, discharge in the Winnebago River is still an order of magnitude less than the discharge of the other rivers in this study. The discharge was, however, greatly underestimated in this study which in turn caused the loads to be underestimated. With this in mind, the method used to calculate discharge at the ungauged sites could be improved upon. Measuring surface velocity during high flows and using the water depth-velocity curve could calculate more reliable and accurate discharges. This is an area where future research could be pursued. A yearlong study would also be beneficial to calculate the annual average concentration, load, and lbs/acre contribution. A future study looking at each individual watershed and its major tributaries would aid in identifying the pollution hotspots within them, providing valuable information for natural resource managers attempting to reduce nutrient and sediment loss from the Iowa landscape and the associated downstream water quality effects.

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APPENDIX

DATA BY SITE

Date	pH	TDS (ppm)	Conductivity	DO (mg/L)	Temp (°C)	Time	TSS (mg/L)	Turbitity (NTU)	Discharge	Chloride	Nitrate	Sulfate
4/13/2010	8.35	258	516	10.59	11.4	8:22	25.11		4871	18.76	25.62	23.76
4/20/2010	8.45	212	419	10.54	13.7	8:40	29.44	16.70	4288	20.76	28.65	24.95
4/27/2010	8.48	252	502	10.79	12.2	8:25	19.56	13.30	4007	21.89	27.00	25.75
5/6/10	8.41	255	508	10.11	15.5	8:18	25.44	15.90	4405	21.80	32.66	24.01
5/11/10	8.44	202	428	10.13	10.9	8:15	16.78	10.68	4265	21.29	27.59	25.85
5/18/10	8.34	255	511	9.46	15.3	8:00	45.67	22.00	8600	18.99	43.77	18.46
5/25/10	8.21	252	506	8.77	22.6	8:10	39.00	14.9	4595	20.34	34.50	23.63
6/1/10	8.5	252	505	9.06	23	10:30	29.22	11.8	3497	22.10	31.03	25.34
6/8/10	8.26	241	482	9.1	20.1	8:23	38.63	24.2	5439	20.04	39.59	20.27
6/15/10	8.2	251	509	8.54	19.5	8:21	75.33	22.2	9530	19.94	51.57	17.62
6/22/10	8.17	251	500	8.14	21.2	8:30	57.67	31.5	10790	17.01	49.68	15.71
6/29/10	8.17	206	412	7.66	22.7	9:36	35.43	240.2	21670	12.66	35.88	11.10
7/6/10	8.23	232	464	8	22.3	9:22	64.20	29.9	10980	16.08	34.82	15.98
7/13/10	8.4	264	528	8.56	22.4	9:05	42.17	17.7	5732	20.30	34.19	23.80
7/20/10	8.6	262	524	8.71	24.1	9:18	25.00	14.6	4393	19.85	28.08	25.86
7/27/10	8.26	216	433	7.62	24.4	8:24	35.17	16.9	11810	11.50	25.41	11.59
8/3/10	8.32	281	564	8.16	23.4	9:10	51.67	20.5	7140	17.87	31.16	19.13
8/10/10	8.5	258	516	8.47	25	8:15	26.83	10.42	5109	18.19	24.79	23.44
8/17/10	8.4	257	515	9.14	22.6	8:08	25.83	9.23	3666	19.23	25.03	24.96
8/24/10	8.41	228	460	8.62	24.2	8:20	26.17	7.32	2465	22.06	19.39	28.53
9/3/10	8.6	241	481	9.14	19.5	8:14	24.17	7.87	2304	20.35	15.19	25.32
9/7/10	8.56	228	456	9.95	18.3	7:50	27.33	6.76	1940	21.85	15.23	27.68
9/14/2010	8.55	242	483	9.99	19	8:00	28.67	7.78	1816	24.03	14.40	31.67
9/21/2010	8.45	250	500	9.31	18.8	8:15	22.17	5.15	1913	24.17	18.24	28.81

Cedar Falls (42°32'17.0"N 92°26'38.3"W)– Cedar River Data

Date	pH	TDS (ppm)	Conductivity	DO (mg/L)	Temp (°C)	Time	TSS (mg/L)	Turbitity (NTU)	Discharge	Chloride	Nitrate	Sulfate
4/13/2010	8.33	264	534	10.06	12.1	8:50	22.89			17.72	23.48	27.31
4/20/2010	8.43	257	515	10.32	12.9	9:05	33.22	20.20		19.61	28.54	26.28
4/27/2010	8.50	260	522	10.49	12.3	8:45	25.11	15.30		20.86	27.53	27.86
5/6/10	8.49	267	534	9.53	14.9	8:55	41.00	25.40	4923	20.24	35.25	25.23
5/11/10	8.35	257	515	10.11	10.3	8:45	20.44	12.2	4411	19.39	28.86	28.31
5/18/10	8.2	260	520	8.99	15.2	8:30	31.00	16.90	7377	16.31	43.19	19.20
5/25/10	8.36	264	529	8.06	22.4	8:45	54.17	25.5	5063	18.92	34.02	25.79
6/1/10	8.46	260	522	9.18	22.4	11:00	43.78	15.1	4365	20.78	32.54	27.47
6/8/10	8.23	250	498	8.55	19.4	9:00	63.67	33.4	5582	18.12	44.54	20.20
6/15/10	8.11	249	495	8.23	19.5	8:48	50.17	16.1	7377	16.81	51.24	16.15
6/22/10	8.16	247	496	7.71	21.7	9:10	38.83	18.5	8310	14.69	45.23	14.65
6/29/10	8.07	193	387	7.35	22.6	10:10	17.44	10.59	11666	9.50	27.03	9.33
7/6/10	8.16	243	489	7.41	22.5	9:56	35.83	17.6	8124	14.97	31.79	17.61
7/13/10	8.36	271	544	8.09	22.5	9:35	42.17	21	5582	19.01	31.75	26.49
7/20/10	8.49	267	535	8.12	23.9	9:46	34.67	21.3	4829	18.40	28.65	26.39
7/27/10	8.2	221	442	7.3	24.1	8:46	34.83	14.5	8588	10.88	24.67	12.69
8/3/10	8.33	273	547	7.88	23.5	9:35	54.00	21.1	6434	16.77	27.80	21.35
8/10/10	8.51	265	531	7.76	24.9	8:37	51.83	16.5	4969	18.15	22.82	26.45
8/17/10	8.4	263	525	8.59	22	8:35	57.40	18.9	4227	17.70	22.42	28.57
8/24/10	8.48	236	477	8.28	23.4	8:40	37.67	9.32	3418	19.99	18.10	34.24
9/3/10	8.59	232	464	9.27	18.6	8:37	37.33	9.82	3200	19.03	13.47	32.90
9/7/10	8.49	238	478	9.41	17.3	8:15	35.67	9.94	2943	20.67	13.17	35.34
9/14/2010	8.44	247	493	9.24	17.9	8:25	31.50	7.65	2901	22.64	13.14	38.52
9/21/2010	8.42	262	524	8.48	18.5	8:40	20.00	5.07	2943	22.41	14.77	36.13

Finchford (42°36'43.9"N 92°29'43.9"W)– Cedar River Data

Date	pH	TDS (ppm)	Conductivity	DO (mg/L)	Temp (℃)	Time	TSS (mg/L)	Turbitity (NTU)	Discharge	Chloride	Nitrate	Sulfate
4/13/2010	8.22	262	519	9.87	12.1	9:09	15.78		835	15.87	27.56	23.39
4/20/2010	8.32	266	529	9.70	12.8	9:20	30.56	18.50	901	16.93	33.78	22.32
4/27/2010	8.35	262	525	10.12	11.5	9:00	24.67	21.00	852	18.20	33.61	22.30
5/6/10	8.32	270	541	9.19	14.5	9:10	49.22	34.00	1010	17.87	40.23	20.95
5/11/10	8.23	253	505	10.07	10.5	9:05	29.67	25.4	782	17.30	33.91	23.03
5/18/10	8.15	256	510	8.69	14.9	8:46	31.78	18.70	2700	15.61	44.93	16.94
5/25/10	8.35	264	528	7.79	22.6	9:00	66.00	25.1	993	17.17	39.91	22.84
6/1/10	8.32	266	534	7.77	22	11:20	60.33	23.4	770	17.60	41.83	23.96
6/8/10	8.2	246	492	8.58	19.3	9:20	57.14	51.6	1530	15.61	50.47	16.32
6/15/10	8.1	239	480	8.02	19.6	9:08	35.29	14.3	2755	14.74	52.44	13.48
6/22/10	8.02	249	495	7.31	23	9:52	27.00	16.8	3410	12.42	46.21	11.78
6/29/10	8.04	189	378	6.8	22.7	10:30	6.56	4.29	5640	8.96	24.81	8.96
7/6/10	8.07	235	468	6.99	22.4	10:13	28.00	14.1	3230	12.87	33.66	14.57
7/13/10	8.34	268	536	8	22.3	9:55	62.00	41.4	1630	15.28	38.27	22.07
7/20/10	8.42	269	540	7.71	23.9	10:22	59.00	30.1	1140	15.76	36.90	23.70
7/27/10	8.07	212	425	6.57	24.2	9:01	13.89	5.91	4380	9.48	23.80	10.81
8/3/10	8.33	280	562	7.72	23.3	9:50	62.00	26.3	1710	14.51	36.07	20.20
8/10/10	8.38	260	522	7.55	25.1	9:00	67.33	25.6	1200	15.10	29.71	24.63
8/17/10	8.49	282	564	8.33	22	10:18	51.17	23.6	906	16.10	31.52	27.19
8/24/10	8.55	269	538	7.89	23.9	8:56	33.83	10.45	611	17.26	25.19	30.82
9/3/10	8.55	254	508	8.92	18.3	8:55	27.17	8.42	474	15.61	18.06	26.85
9/7/10	8.54	265	530	9.01	17.1	8:35	22.33	6.82	399	16.93	18.92	30.57
9/14/2010	8.51	257	514	8.94	17.7	8:42	22.17	5.06	331	16.66	17.81	30.00
9/21/2010	8.47	264	525	8.44	18.8	8:55	20.67	5.73	308	16.89	17.58	30.08

Finchford (42°37'42.8"N 92°32'37.7"W) – West Fork Cedar River Data

Date	pH	TDS (ppm)	Conductivity	DO (mg/L)	Temp (℃)	Time	TSS (mg/L)	Turbitity (NTU)	Discharge	Chloride	Nitrate	Sulfate
4/13/2010	8.43	248	498	10.79	12.4	9:25	20.22		1400	23.89	29.04	22.51
4/20/2010	8.48	224	449	11.35	14.1	9:35	28.89	12.50	1290	25.60	28.62	23.30
4/27/2010	8.48	237	473	10.67	12.6	9:15	17.78	10.76	1180	26.30	26.04	23.52
5/6/10	8.58	230	460	10.93	15.6	9:30	23.11	11.50	1250	27.28	31.04	22.50
5/11/10	8.41	229	464	10.38	11.3	9:25	17.78	10.39	1110	25.88	26.48	22.50
5/18/10	8.29	250	499	9.27	16.3	9:06	32.78	16.70	2310	24.44	45.91	18.49
5/25/10	8.34	241	482	8.74	22.7	9:25	41.89	12.6	1380	25.61	34.52	21.64
6/1/10	8.53	236	470	10.35	23.6	11:45	25.67	10.38	913	27.22	23.61	23.37
6/8/10	8.44	237	476	8.39	20.6	9:40	43.67	13.9	1660	25.24	36.82	20.97
6/15/10	8.23	247	492	8.47	20.1	9:28	82.17	23.9	2790	26.81	51.33	18.47
6/22/10	8.12	231	466	7.76	23.2	10:15	70.33	35.1	3960	19.83	57.21	14.69
6/29/10	8.03	199	402	7.81	21.9	10:51	52.33	29.1	8570	15.86	46.93	11.09
7/6/10	8.14	231	466	7.96	22.8	10:30	131.33	48.1	3490	19.49	44.23	14.86
7/13/10	8.45	251	504	8.66	22.6	10:11	37.50	12	1650	24.40	37.43	21.87
7/20/10	8.63	240	481	9.43	24.5	10:45	48.17	13.7	1650	24.90	25.51	25.77
7/27/10	8.28	250	499	7.83	24.2	9:17	57.83	17.4	3120	22.41	35.14	17.25
8/3/10	8.31	265	527	7.84	23.6	10:05	46.33	17.2	2120	22.70	39.86	18.51
8/10/10	8.5	245	490	8.22	25.2	9:15	23.50	5.69	1400	23.72	27.72	22.01
8/17/10	8.51	244	488	9.32	22.2	10:34	31.17	8.25	1190	24.57	27.33	22.87
8/24/10	8.3	206	413	8.28	24.1	9:15	29.33	7.75	831	29.02	17.17	24.18
9/3/10	8.35	225	450	8.13	19.4	9:15	27.50	7.65	951	27.84	14.29	22.36
9/7/10	8.57	204	409	10.84	17.2	8:53	36.83	7.46	753	26.39	15.03	22.30
9/14/2010	8.5	196	392	10.15	18.2	9:00	39.33	9.19	753	29.13	13.67	23.84
9/21/2010	8.47	249	499	8.89	18.5	9:12	31.50	7.84	831	31.28	19.74	25.51

Janesville (42°38'57.3"N 92°27'57.6"W) – Upper Cedar River Data

Date	pH	TDS (ppm)	Conductivity	DO (mg/L)	Temp (℃)	Time	TSS (mg/L)	Turbitity (NTU)	Discharge	Chloride	Nitrate	Sulfate
4/13/2010	8.47	268	527	10.35	12.6	9:55	21.89		1900	20.44	20.73	32.25
4/20/2010	8.48	256	508	11.07	13.4	9:55	32.11	12.60	1650	22.90	26.79	30.40
4/27/2010	8.53	268	534	10.94	12.5	9:35	19.00	10.40	1440	24.21	23.06	34.71
5/6/10	8.56	260	518	10.46	15.9	9:50	22.78	10.53	1600	22.89	29.19	30.63
5/11/10	8.42	269	533	9.91	10.6	9:45	11.11	4.58	1450	22.34	24.18	33.83
5/18/10	8.39	276	552	9.36	15.4	9:26	32.44	13.30	2580	20.58	40.04	25.55
5/25/10	8.46	263	527	9.06	22	9:45	36.00	10.25	1570	22.08	27.68	30.81
6/1/10	8.61	262	524	11.49	22.5	12:05	25.83	11.8	1300	24.53	24.44	32.58
6/8/10	8.27	271	542	8.36	19.8	10:00	33.56	12.4	1660	23.13	38.28	28.42
6/15/10	8.28	275	551	8.67	18.6	9:48	55.83	15.2	2800	22.57	51.81	22.49
6/22/10	8.27	287	566	7.85	21.9	10:36	40.50	18.2	2330	21.77	45.83	23.54
6/29/10	8.17	244	484	8.11	21.7	11:11	67.33	37	6090	16.62	45.87	14.64
7/6/10	8.34	276	552	8.12	22.3	10:53	33.33	10.78	2580	21.67	31.79	26.78
7/13/10	8.47	278	558	8.16	22.7	10:30	25.67	6.78	1670	24.93	24.70	32.87
7/20/10	8.72	267	538	9.62	23.9	11:05	26.00	9.35	1330	21.74	20.16	32.16
7/27/10	8.42	279	558	7.84	23.9	9:36	33.17	16.7	2180	19.46	28.64	24.21
8/3/10	8.4	281	561	7.52	26.3	10:35	36.50	10.69	2330	20.11	20.17	23.77
8/10/10	8.72	266	532	8.01	25.1	9:35	28.50	8.18	1520	21.57	14.64	32.09
8/17/10	8.49	228	456	11.33	22.1	10:52	56.20	16.6	989	21.97	12.38	32.40
8/24/10	8.46	214	429	9.8	23.5	9:33	38.67	9.7	691	24.45	10.21	40.49
9/3/10	8.59	225	451	9.11	18.7	9:33	51.33	12.2	625	23.71	9.06	42.15
9/7/10	8.43	225	451	10.36	16.6	9:13	47.50	11.8	585	25.16	7.87	42.00
9/14/2010	8.32	525	505	9.89	17.7	9:18	30.17	7.17	601	28.09	8.73	46.13
9/21/2010	8.44	273	546	8.42	18.3	9:32	16.50	5.02	555	27.06	11.27	43.56

Shell Rock (42°42'44.6"N 92°34'56.5"W)- Shell Rock River Data

Date	pH	TDS (ppm)	Conductivity	DO (mg/L)	Temp (℃)	Time	TSS (mg/L)	Turbitity (NTU)	Discharge	Chloride	Nitrate	Sulfate
4/13/2010	8.50	249	501	10.72	12.8	10:27	23.33			24.90	30.53	24.16
4/20/2010	8.56	235	466	10.94	14.2	10:20	26.11	12.10		26.82	29.78	24.40
4/27/2010	8.56	246	492	10.39	13.0	10:00	16.89	8.47		28.25	25.98	25.62
5/6/10	8.59	241	485	10.15	15.3	10:15	28.00	19.50	530	27.72	33.10	22.86
5/11/10	8.46	239	482	10.28	11.1	10:10	23.22	13.6	574	26.00	27.28	23.92
5/18/10	8.54	253	507	9.49	16.9	9:56	30.56	11.60	985	27.09	46.44	19.74
5/25/10	8.46	239	478	8.7	23.7	10:15	36.56	10.35	677	27.91	34.71	22.53
6/1/10	8.65	232	466	10.6	24	12:26	30.50	13.8	474	28.67	23.54	24.25
6/8/10	8.32	245	490	8.68	20.8	10:26	43.00	13.7	736	26.23	42.73	21.61
6/15/10	8.25	251	503	9.11	19.2	10:11	52.83	16.4	1184	27.61	57.94	18.04
6/22/10	8.13	237	475	8.24	22.8	11:00	48.50	28.8	1451	19.83	64.21	16.00
6/29/10	8.2	216	431	8.21	22.4	11:37	65.00	33.8	2175	17.36	55.82	12.58
7/6/10	8.45	262	533	8.87	24	11:20	37.00	15.4	1142	24.19	51.23	20.96
7/13/10	8.49	250	500	9.54	23	11:00	37.33	13.9	851	26.00	36.15	24.42
7/20/10	8.65	249	498	9.61	25.3	11:30	41.33	19.5	851	28.00	26.32	27.20
7/27/10	8.38	243	487	8.18	24.9	10:00	48.17	18.1	1226	23.04	38.17	16.75
8/3/10	8.4	287	574	8.16	24.7	10:53	34.33	10.55	985	24.02	42.57	20.10
8/10/10	8.4	231	460	7.64	26.4	9:55	32.00	7.09	766	22.86	28.12	22.69
8/17/10	8.52	236	473	9.09	22.7	11:15	29.17	8.84	536	25.59	26.76	24.25
8/24/10	8.36	212	425	7.53	24.1	9:55	31.33	9.74	381	28.83	16.09	25.69
9/3/10	8.52	186	375	8.42	20.1	10:00	50.17	16.2	406	24.43	10.93	20.85
9/7/10	8.54	210	421	9.16	16.7	9:38	55.20	23.8	257	33.80	14.45	25.05
9/14/2010	8.61	216	431	9.54	18.7	9:40	33.50	11.2	343	30.57	18.76	24.26
9/21/2010	8.61	253	506	8.84	18.6	9:58	38.83	14.8	419	33.26	20.98	26.11

Plainfield (42°50'51.7"N 92°31'16.3"W)– Upper Cedar River Data

Date	pH	TDS (ppm)	Conductivity	DO (mg/L)	Temp (℃)	Time	TSS (mg/L)	Turbitity (NTU)	Discharge	Chloride	Nitrate	Sulfate
4/13/2010	8.12	203	402	9.83	13.0	11:00	30.67		340	19.71	32.26	19.10
4/20/2010	8.19	220	451	10.05	13.0	10:55	8.33	5.86	198	20.24	34.10	23.06
4/27/2010	8.39	224	446	10.88	12.4	10:30	4.00	2.85	171	20.97	29.06	23.99
5/6/10	8.41	235	467	9.63	14.0	10:50	10.89	6.88	251	23.14	47.00	21.21
5/11/10	8.3	220	439	10.16	10.6	10:45	10.67	8.21	214	20.37	34.98	21.40
5/18/10	8.19	241	482	9.12	15.2	10:26	28.78	13.30	401	22.57	59.13	18.51
5/25/10	8.3	232	463	8.24	22.7	10:50	13.33	3.45	222	21.86	42.00	21.25
6/1/10	8.46	226	450	9.4	22.5	1:00	8.89	1.32	163	21.46	31.43	23.39
6/8/10	8.14	242	486	8.62	18.8	11:00	40.88	15.5	300	21.90	74.54	20.17
6/15/10	8.03	245	486	8.95	17.8	10:45	82.00	25.7	553	23.28	83.75	17.17
6/22/10	8.2	253	502	8.26	21.5	11:53	77.67	27.7	502	21.68	84.03	17.11
6/29/10	7.92	222	439	7.79	20	12:21	76.00	40.9	1550	16.30	75.58	12.08
7/6/10	8.17	242	482	7.81	23.2	11:50	33.17	17.4	373	19.48	59.56	19.38
7/13/10	8.41	240	480	8.4	23.1	11:37	11.78	3.35	214	19.62	42.99	22.87
7/20/10	8.6	217	439	9.68	23.1	12:05	21.33	3.62	156	18.39	24.06	24.68
7/27/10	8.38	247	500	8.08	24.4	10:33	33.50	19.1	286	20.89	47.46	18.58
8/3/10	8.38	268	535	8.21	23.6	11:23	27.83	10.85	242	21.19	47.08	19.16
8/10/10	8.19	160	320	7.34	24.7	10:30	176.33	77	560	13.29	26.82	12.68
8/17/10	8.6	250	500	9.23	21.4	1:45	21.33	15.2	200	21.59	43.28	21.31
8/24/10	8.46	205	411	8.46	22.9	10:30	20.67	10.05	122	20.24	19.73	25.06
9/3/10	8.47	209	420	8.73	18.6	10:40	26.83	13.6	206	16.98	27.16	17.04
9/7/10	8.43	239	476	9.23	16.4	10:21	11.67	5.24	140	19.08	33.01	20.62
9/14/2010	8.54	246	492	9.48	17.2	10:22	13.67	3.84	174	20.78	38.39	18.57
9/21/2010	8.54	245	490	8.83	19.1	10:35	12.17	3.35	158	21.57	42.16	19.35

Chickasaw (43°02'00.9"N 92°30'14.3"W)– Upper Cedar River Data

Date	pH	TDS (ppm)	Conductivity	DO (mg/L)	Temp (℃)	Time	TSS (mg/L)	Turbitity (NTU)	Discharge	Chloride	Nitrate	Sulfate
4/13/2010	8.36	254	510	10.16	13.7	11:30	11.33		945	26.35	32.21	24.01
4/20/2010	8.68	257	507	11.71	14.5	11:15	10.22	6.04	696	30.45	29.26	26.49
4/27/2010	8.69	270	535	11.47	13.8	10:55	8.56	4.56	594	33.64	27.24	28.08
5/6/10	8.73	258	518	11.10	15.4	11:15	8.67	4.86	584	29.77	30.00	24.58
5/11/10	8.58	261	525	10.6	11.1	11:10	9.00	3.96	627	31.21	26.51	26.38
5/18/10	8.69	261	541	9.87	16.2	10:48	10.00	4.64	1080	30.12	44.71	21.62
5/25/10	8.6	263	528	9.13	23.6	11:25	14.22	4.23	627	31.60	36.08	24.33
6/1/10	8.68	263	529	9.75	23.6	1:17	17.67	5.65	506	33.00	25.48	25.97
6/8/10	8.28	259	518	8.57	20.2	11:22	16.67	10.77	769	30.22	36.31	21.86
6/15/10	8.06	269	535	8.94	18.1	11:06	34.83	9.44	1680	27.70	53.77	20.25
6/22/10	8.16	257	519	8.15	21.9	12:21	46.00	19.8	1940	21.93	69.81	18.84
6/29/10	8.2	249	510	8.6	20.2	12:48	56.80	29.8	3120	22.15	60.99	15.88
7/6/10	8.48	277	555	8.74	24.3	12:15	21.00	7.46	1100	26.52	50.50	22.95
7/13/10	8.62	276	556	9.41	23.5	12:05	14.67	4.2	708	30.51	36.60	26.71
7/20/10	8.68	264	525	9.1	25	12:30	21.00	6.03	959	32.31	26.81	26.15
7/27/10	8.33	258	515	8.04	24.4	10:54	31.67	16.2	1530	22.67	44.04	17.76
8/3/10	8.46	304	607	8.48	23.9	11:45	18.67	5.59	1100	26.43	44.48	22.33
8/10/10	8.67	262	524	8.2	26.4	10:55	16.67	4.38	644	26.82	30.23	24.36
8/17/10	8.68	254	509	9.6	23	2:03	14.17	3.25	421	33.03	25.95	27.01
8/24/10	8.67	234	469	9.66	25.4	10:50	17.83	3.61	356	33.13	16.42	29.53
9/3/10	8.99	227	454	11.15	20.2	11:03	31.00	9.51	366	38.26	11.65	28.40
9/7/10	8.75	249	501	10.63	17.7	10:46	19.83	3.91	321	33.04	13.08	27.90
9/14/2010	8.8	266	533	10.91	19.7	10:47	16.67	3.46	326	31.95	15.89	30.31
9/21/2010	8.59	290	581	9.35	18.9	10:58	15.33	6.17	387	44.86	24.60	29.53

Charles City (43°03'43.1"N 92°40'22.3"W) – Upper Cedar River Data

Date	pH	TDS (ppm)	Conductivity	DO (mg/L)	Temp (°C)	Time	TSS (mg/L)	Turbitity (NTU)	Discharge	Chloride	Nitrate	Sulfate
4/13/2010	8.41	242	485	12.24	13.9	12:00	16.67			23.14	17.74	25.34
4/20/2010	8.85	227	458	15.19	15.6	11:55	18.11	7.19		26.14	14.92	27.16
4/27/2010	8.72	258	514	12.73	13.6	11:25	10.22	4.37		27.83	13.58	28.40
5/6/10	8.81	254	509	12.28	15.8	11:45	9.22	5.79	572	27.83	16.46	26.10
5/11/10	8.59	252	507	11.19	10.8	11:55	7.89	4.32	572	29.58	15.33	26.44
5/18/10	8.68	252	505	11.32	17.2	11:20	12.89	5.43	598	27.30	22.27	24.47
5/25/10	8.59	260	518	9.87	25.2	11:45	8.56	7.76	542	30.03	15.73	25.48
6/1/10	8.93	249	495	12.68	24.4	1:47	11.89	4.4	533	31.35	13.54	23.97
6/8/10	8.47	256	515	7.58	20.4	11:52	10.44	3.19	585	28.69	24.50	20.67
6/15/10	8.1	232	465	8.43	19.4	11:35	107.00	53.4	677	22.28	36.64	16.56
6/22/10	8.54	270	538	10.36	26	1:45	10.56	1.51	611	31.18	20.92	22.62
6/29/10	8.18	268	536	9.07	21.8	1:26	24.25	9.31	540	25.71	32.01	19.19
7/6/10	8.45	261	524	9.7	26.1	12:53	9.22	0.94	490	30.11	14.44	23.72
7/13/10	8.66	249	500	10.42	25.4	12:46	6.33	1.27	598	30.71	7.52	24.52
7/20/10	9.07	239	478	15	26.4	1:05	16.33	2.9	578	33.24	2.50	25.05
7/27/10	8.64	258	518	10.3	26.9	11:25	16.17	6.79	604	26.55	11.00	22.99
8/3/10	8.26	252	503	8.2	24.8	12:17	21.17	1.33	664	23.15	11.09	18.19
8/10/10	8.52	246	492	8.21	27.3	11:25	16.33	3.1	604	24.88	11.18	21.66
8/17/10	9.29	218	437	16.64	23.4	2:35	42.60	6.56	508	31.18	2.86	25.82
8/24/10	9.1	209	419	13.67	23.8	11:23	52.00	26.4	598	35.48	0.00	27.38
9/3/10	9.02	230	460	14.01	18	11:40	29.50	4.6	502	31.96	1.80	28.03
9/7/10	8.64	276	552	10.53	15.8	11:19	12.67	5.38	502	43.26	5.01	31.40
9/14/2010	8.66	275	553	9.73	18.7	11:20	6.00	0.54	508	32.36	5.36	30.23
9/21/2010	8.54	292	585	8.72	18.8	11:30	6.17	0.1	508	39.34	7.11	29.17

Rockford (43°03'08.6"N 92°56'37.1"W)– Shell Rock River Data

Date	pH	TDS (ppm)	Conductivity	DO (mg/L)	Temp (°C)	Time	TSS (mg/L)	Turbitity (NTU)	Discharge	Chloride	Nitrate	Sulfate
4/13/2010	8.21	277	559	10.10	13.1	12:25	33.56			24.89	23.24	34.11
4/20/2010	8.63	298	589	12.45	14.2	12:21	10.56	5.39		25.07	24.41	38.01
4/27/2010	8.62	301	595	12.15	13.0	11:50	9.44	6.61		28.04	21.81	41.47
5/6/10	8.59	292	588	11.84	14.6	12:25	15.22	7.27	342	26.67	27.39	38.13
5/11/10	8.33	265	530	10.11	10.1	12:15	19.00	11.8	351	24.62	24.19	36.01
5/18/10	8.43	303	608	9.58	16.1	11:50	22.78	9.20	378	24.27	35.96	33.17
5/25/10	8.5	300	602	9.2	23.9	12:15	22.67	7.16	324	26.49	27.65	39.20
6/1/10	8.58	295	593	10.02	22.8	2:08	26.33	8.54	319	27.47	26.54	40.02
6/8/10	8.32	302	605	8.35	20	12:15	50.17	18.1	351	24.54	39.95	34.13
6/15/10	8.28	295	595	8.57	18.5	11:51	73.40	19.1	450	23.16	49.18	27.16
6/22/10	8.36	316	634	8.68	23.9	2:04	41.50	15.7	360	24.21	38.21	32.78
6/29/10	8.15	278	555	8.12	20.6	1:45	46.67	19.8	490	17.43	45.25	19.61
7/6/10	8.34	301	604	7.87	24.3	1:10	35.00	12.4	364	21.56	30.21	31.16
7/13/10	8.43	307	614	8.1	23.7	1:05	33.17	17.3	333	26.64	27.52	38.94
7/20/10	8.55	310	628	8.43	25	1:20	30.67	9.5	310	26.42	24.94	39.86
7/27/10	8.42	312	616	8.02	25.2	12:00	42.50	17.6	369	21.28	27.66	30.31
8/3/10	8.45	318	636	8.11	24.8	12:30	32.83	12.1	369	20.71	23.41	29.73
8/10/10	8.41	272	544	7.59	26.1	11:40	63.50	30.7	387	20.17	20.45	27.21
8/17/10	8.79	324	645	10.19	22.9	2:56	22.83	8.3	279	29.12	17.33	42.03
8/24/10	8.78	296	592	10.77	24.6	11:40	20.83	9.69	261	34.64	9.98	55.69
9/3/10	8.67	297	596	10.96	19.5	11:53	24.17	15.9	261	35.80	6.78	57.24
9/7/10	8.62	322	644	10.49	16.7	12:10	14.17	4.88	248	36.75	10.77	56.47
9/14/2010	8.74	315	630	10.18	19.3	11:35	14.67	3.6	261	35.19	10.11	55.48
9/21/2010	8.61	337	675	9.58	19.2	11:45	6.50	8.18	248	37.43	13.59	59.44

Rockford (43°04'01.6"N 92°59'53.3"W)– Winnebago River Data