Total Maximum Daily Load
For Nitrate
Cedar River
Linn County, Iowa

2006

Iowa Department of Natural Resources
Watershed Improvement Section

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Summary

The Federal Clean Water Act requires the Iowa Department of Natural Resources (IDNR) to develop a total maximum daily load (TMDL) for waters that have been identified on the state's 303(d) list as impaired. A section of the Cedar River has been identified as impaired by excess nitrate. The purpose of the TMDL for the Cedar River is to calculate the maximum allowable nitrate loading for the river associated with levels that will meet the drinking water standard of 10 mg/L NO_3-N.

Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature and sources of water quality impairments are not well understood. In Phase 1, the waterbody load capacity, existing pollutant load in excess of this capacity, and the source load allocations are estimated based on the limited information available. A monitoring plan is then developed to determine if prescribed load reductions result in attainment of water quality standards and whether or not the target values are sufficient to meet designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling.

Section 7 of this TMDL includes a description of planned monitoring. The TMDL will have two phases. Phase 1 will consist of setting specific and quantifiable targets for nitrate loading to the Cedar River. Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed.

Monitoring is essential to all TMDLs in order to:

- assess the future beneficial use status
- determine if the water quality is improving, degrading or remaining status quo
- evaluate the effectiveness of implemented best management practices

The additional data collected will be used to determine if the implemented TMDL and watershed management plan are effective in addressing the identified water quality impairment. The data and information can also be used to determine if the TMDL has accurately identified the required components (i.e. loading/assimilative capacity, pollutant allocations, in-stream response to pollutant loads, etc.) and if revisions are appropriate.

This TMDL has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7. These regulations and consequent TMDL development are summarized below:

1. **Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:** Cedar River, McCloud Run (S16, T83N, R07W) to Bear Creek (S21, T84N, R08W).

2. **Identification of the pollutant and applicable water quality standards:** The pollutant causing the water quality impairment is nitrate. Designated uses for the impaired segment are significant resource warm water (Class B(WW)), primary contact recreational use (Class A1) and drinking water supply (Class C). Excess nitrate loading has impaired the drinking water supply water quality criteria (567 IAC 61.3(3)) and hindered the designated use.

3. **Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:** The target of this TMDL is the drinking water nitrate concentration standard of less than 10.0 mg/L NO_3-N.

4. **Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:** The existing nitrate load is 14.7 mg/L . The estimated nitrate loading capacity is 9.5 mg/L. The targeted reduction is 35%. This would equal a yearly reduction of 9,999 tons nitrate-N/year from the current loading of 28,561 tons nitrate-N/year.

5. **Identification of pollution source categories:** The load duration curve specifies nonpoint sources of nitrate as the cause of impairments to the Cedar River. Major constituents of nonpoint sources are fertilizer, legume crops, and manure.

6. **Wasteload allocations for pollutants from point sources:** The wasteload allocation for point sources is 9%, (2,521 tonsN/yr) of the total load as listed in Appendix C.

7. **Load allocations for pollutants from nonpoint sources:** The load allocation for nonpoint sources is 91%, (26,040 tonsN/yr) listed in Table 17.

8. **A margin of safety:** An explicit margin of safety of 5% has been included to ensure that the required load reduction will result in attainment of the water quality target. An implicit margin of safety was also included in the TMDL, comprised of no denitrification in NPDES permitted sites, and conservation of nitrate-N in the water column.

9. **Consideration of seasonal variation:** This TMDL was developed based on the daily nitrate loading that will result in attainment of the nitrate target throughout the year.

10. **Allowance for reasonably foreseeable increases in pollutant loads:** No allowance for increase in nitrate-N load, as the primary source of nitrate is from nonpoint sources. Similarly, increases in point source pollution are not allowed. Pollutant loads will increase and decrease based on the precipitation and hydrology of the Cedar River.

11. **Implementation plan:** An implementation plan is outlined in section 6 of this report. Implementation will be incentive-based, best management practices (BMPs) focused on reducing surface water nitrate-N concentration. These practices include fertilizer reduction, wetland construction, and conservation reserve program (CRP) enrollment. Practices will focus more heavily on sub-basins that have higher nitrate loading per unit area.

Acknowledgements

The Cedar River TMDL report and monitoring was supported, in part, by the U.S. Environmental Protection Agency, Region VII, Kansas City. The Iowa Department of Natural Resources provided both monitoring data and staff for colleting data and writing the report. The U.S. Geological Survey, Iowa City office provided stream monitoring data. Dan Christiansen and Doug Schnoebelen, from the USGS, provided work on the model, and model write up for this TMDL.

1 Introduction

1.1 Cedar River Watershed - Geology and Landscape

The Cedar River watershed extends from the headwaters in southern Minnesota to Conesville, Iowa, where it joins the Iowa River and subsequently flows into the Mississippi River. The total drainage area of the Cedar River is 7,815 mi^2, 87% of which is located in Iowa (Iowa Department of Environmental Quality, 1976). There are eight major tributaries to the Cedar River, with many smaller, first order streams throughout (Squillace et al., 1996). The study area for the Cedar River TMDL includes the main channel and all major (5^{th}-order) tributaries upstream of the impaired segment north of Cedar Rapids; this includes about 6,530 mi^2, or 83%, of the entire watershed (Fig. 1).

The oldest bedrock in the Cedar River watershed includes Ordovician-age sandstones and dolostones found in the central part of the watershed, near the city of Cedar Falls, IA. The youngest bedrock includes limestone and dolostone of the Devonian system. Silurian and Devonian bedrock encompasses most of the Cedar River watershed area. Both the Ordovician and Silurian-Devonian systems are important aquifers throughout the region. Shallow bedrock, often with Karst features, including caves, sinkholes, and springs, is prevalent in the upper third of the watershed above the city of Cedar Falls. Karst conditions allow for leaching of nitrate to the aquifers. The shallow aquifers serve as a significant nitrate reservoir, potentially transporting nitrate to the stream.

The major landform regions included in the watershed are the Des Moines Lobe, located on the western edge of the drainage basin, and the Iowan Surface, located in the middle and east of the drainage basin. The Des Moines Lobe is the youngest landform region in Iowa, formed by glaciation in the Late Wisconsinan period 12,000-15,000 years ago (Prior, 1991). The poorly drained, ‘knob and kettle’ terrain of the Des Moines Lobe was initially marked by many low-lying marshes, sloughs, and wetlands. Surface drainage in the Des Moines Lobe was initially limited because of a lack of an integrated stream network. This area is poorly suited for row-crop agriculture due to high water table levels. However, over the past 150 years, man-made drainage basins have been implemented, removing the original wetlands and lowering the water level to provide excellent cropland for mono-agricultural establishments. These man-made structures are typically channelized, high-energy streams that have direct contact with the agricultural landscape via subsurface drain tiles. Row crop agriculture on the Des Moines Lobe has dramatically increased over the past hundred years. Row crop agriculture in the Des Moines Lobe was estimated to be 41% in 1900, which has increased to 72% in 1992 (Brown and Jackson, 1999).

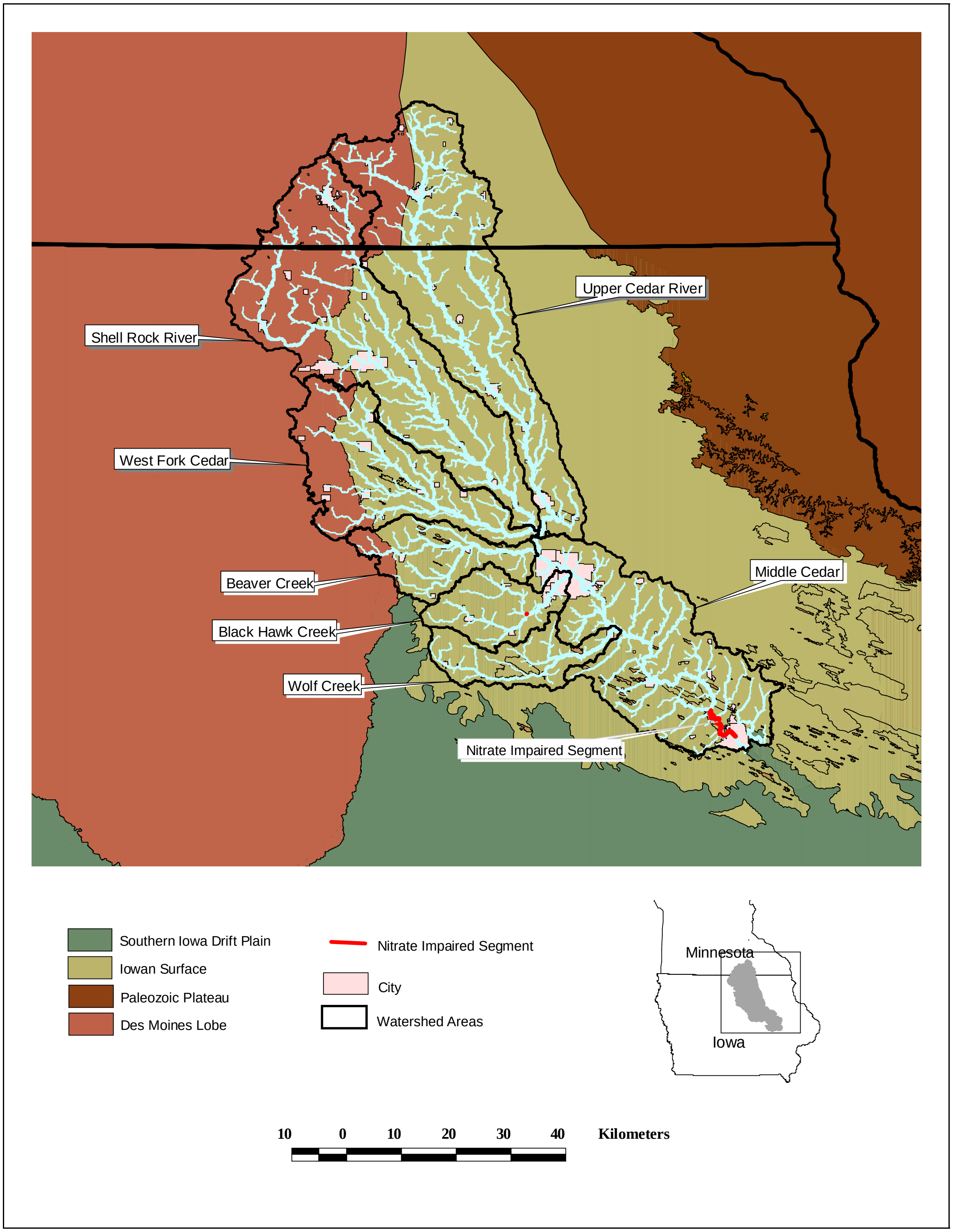

Figure 1. Cedar River watershed and landforms above the nitrate impaired segment

The central and eastern part of the Cedar River is located on the Iowan Surface, which is characterized by gently rolling landscapes and mature, dendritic drainage patterns. This landscape was initially part of the Southern Iowa Drift Plain, but underwent extensive erosion in Wisconsinan time from 21,000 to 16,500 years ago. Much colder than today, tundra conditions prevailed in these areas around 17,000 years ago. The regular freeze-thaw pattern and turbulent winds eroded the landscape rather dramatically and formed a stone-line or pebble band within the first few feet of the surface. Discontinuous loess deposits lie above these areas in some places, but most loess was blown off the surface by strong winds. Topography in the Iowan Surface tends to be gently rolling, with highly meandering low-gradient streams (Prior, 1991). Rowcrop agriculture dominates 60% of the Iowan Surface (Brown and Jackson, 1999).

Landsat 2002 imagery specifies land use in the Cedar River watershed as predominantly agricultural (81%), with rowcrop agriculture prevailing (73%) (Fig. 2, Table 1). The two major crops harvested in the watershed are corn and soybeans. Along with rowcrop agriculture, several confined and unconfined livestock operations are scattered throughout the watershed, including beef and dairy cattle, hogs, sheep, and poultry. There are many major urban establishments located along the Cedar River, including Albert Lea and Austin in Minnesota, and Mason City, Cedar Falls, Waterloo, and Cedar Rapids in Iowa. Many small towns are also scattered throughout the watershed. The 2000 census estimates that of the 516,000 people living within the watershed, 431,000 are within incorporated cities, and 85,000 are located in rural or non-incorporated areas. The watershed includes 125 incorporated communities, 102 of which are located within the Iowa portion of the watershed.

Climate in Iowa and southern Minnesota is considered continental, with temperatures ranging from as high as 38.8° C (102° F) in the summer to as low as -27.8° C (-18.4° F) in the winter (Squillace et al., 1996). Precipitation in the watershed ranges from 91 cm/yr (35.8 in/yr) in the southwestern region to 81 cm/yr (31.9 in/yr) in the northeastern region, with pronounced annual variation (Olcott, 1992). Most precipitation falls in the spring and summer months. Average seasonal growing period is 161 days long (Squillace et al., 1996).

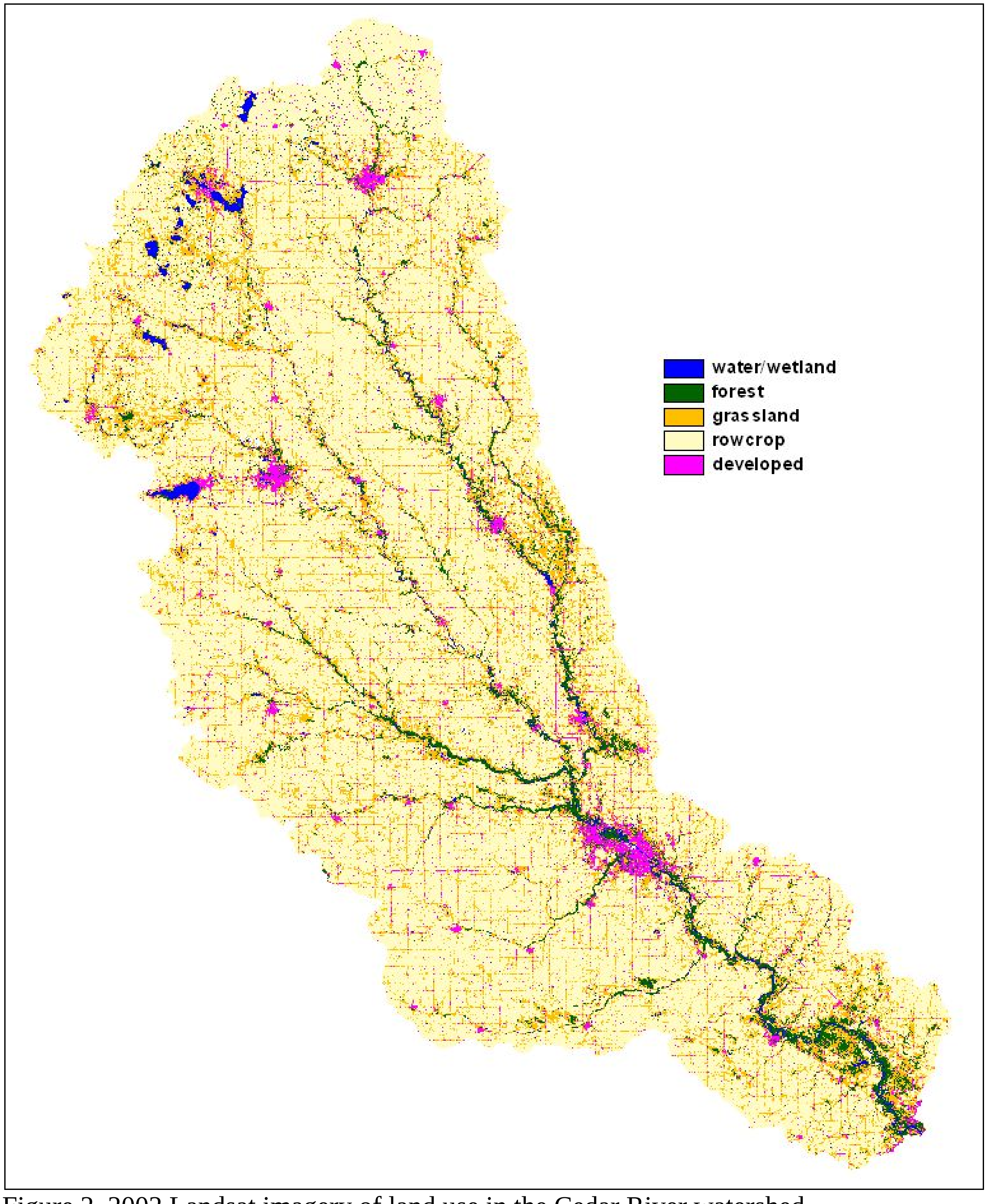

Figure 2. 2002 Landsat imagery of land use in the Cedar River watershed.

Table 1. 2002 Landsat imagery land use percentage in the Cedar River watershed.

Sub-basin	Area (mi^2)	Rowcrop	Forest	Grassland	Developed	Water	Other
Upper Cedar*	1,441	72.6	4.5	18.0	3.5	0.8	0.5
Shell Rock*	1,756	72.8	2.9	18.7	3.1	2.2	0.3
West Fork	858	77.1	2.9	16.9	2.4	0.6	0.1
Beaver Creek	399	79.8	2.3	15.0	2.5	0.4	0.0
Black Hawk	339	81.2	1.7	12.6	4.2	0.3	0.1
Wolf Creek	333	80.9	2.4	14.3	2.1	0.3	0.0
Middle Cedar	1,223	62.8	7.4	20.9	7.0	1.7	0.2
Total	6,349	72.7	4.0	17.9	3.8	1.2	0.3

*Landsat imagery unavailable for the extreme upper portion of watershed

1.2 Impairment and 303(d) Listing

The Cedar River is designated for the following uses: primary contact recreation; significant resource warm water; and as a drinking water supply. The Clean Water Act (CWA) requires states to identify, prioritize, and report to the U.S. EPA any water bodies that have been impaired from their designated uses. The impaired use and subsequent 303(d) listing is for high nitrate concentrations in the drinking water supply for the City of Cedar Rapids. The listed impaired segment starts at the water intake located along the Cedar River and goes upstream 11.6 miles, parallel to Cedar Rapids' shallow alluvial wells.

The Cedar Rapids water utility provides drinking water to over 120,000 residents. This TMDL and load reduction is for a segment of the river extending from its confluence with Bear Creek near the City of Palo, Iowa, to where McLoud Run enters the river at Cedar Rapids. The Cedar River is a "high priority" on the list of TMDL development in the 2002 303(d) listing because of the excess levels of nitrates and use of the water in the river.

Nitrate in drinking water can cause many problems. It is especially harmful to infants, as excess concentrations may cause methemoglobinemia, or blue baby syndrome, a potentially fatal blood disorder that limits the intake of oxygen and can lead to suffocation (USEPA, 1996). Because of nitrate's harmful effects, the U.S. EPA has set a drinking water concentration standard of 10.0 mg/L nitrate as nitrogen.

1.3 Nitrogen and Nitrate in the Environment

Although almost 80% of air is composed of nitrogen, the triple bond of nitrogen gas (N_2) makes it unusable to a majority of organisms. These organisms are dependent on outside sources to convert nitrogen gas into biologically usable forms like nitrate, ammonia, and amino acids. The process through which nitrogen moves through these many forms is explained by the nitrogen cycle (Fig. 3).

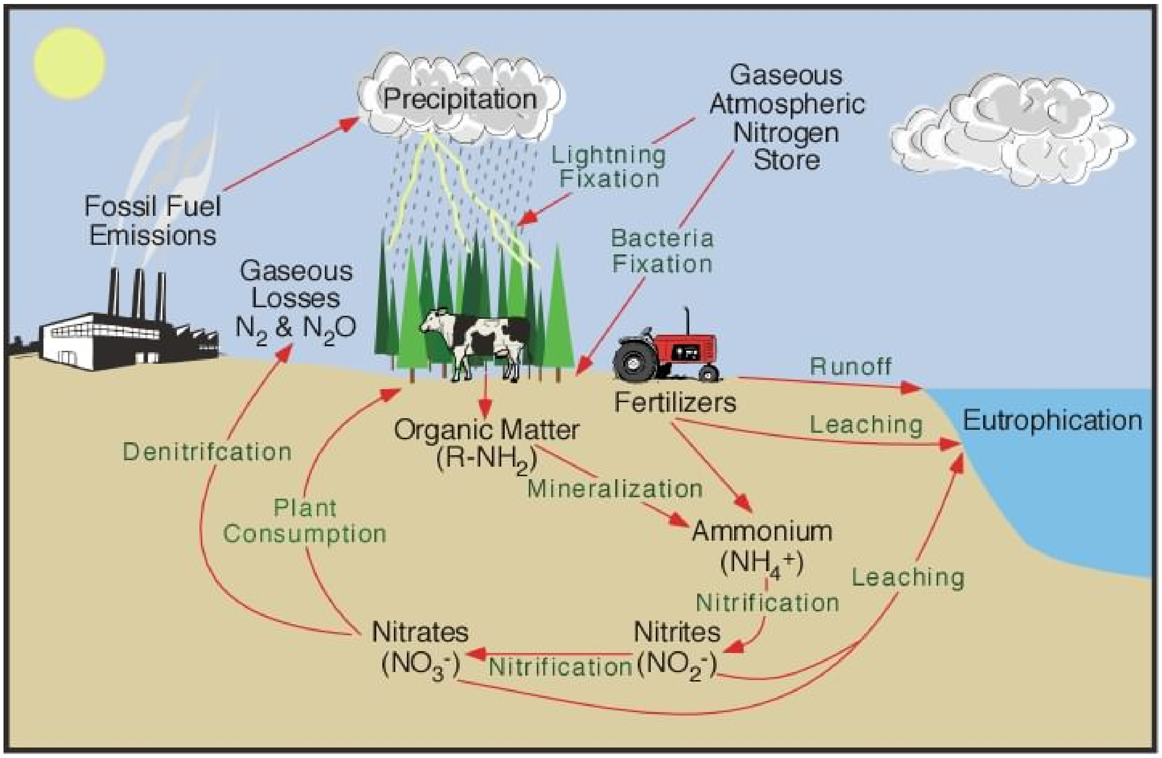

Figure 3. The nitrogen cycle (from physicalgeography.net, 2005).

The most abundant form of nitrogen in the land surface is as organic nitrogen, found in living and dead organic matter in the soil. This large reservoir of total nitrogen must first be converted to nitrate by mineralization and nitrification before becoming available to most plants and wildlife. These biological processes are dependent on the season, and increase during the warmer spring and summer months. Once converted from its organic form, inorganic nitrogen will leach into the groundwater if not first consumed by plants or bacteria.

Nitrogen (N) in surface water and groundwater comes in both dissolved and particulate forms, and may exist in both inorganic and organic compounds. Organic N in surface water can be in both dissolved and particulate forms. Surface water inorganic N is found exclusively as either nitrate (NO_3), ammonium (NH_4) or, nitrite (NO_2) (DeBusk, 1999). In an aerobic surface water environment, the largest inorganic source of N is in the inorganic form of nitrate (Seelig and Nowatzki, 2001).

Figure 4 details monthly total nitrogen concentrations as NOx (NO_3 and NO_2) and Total Kjeldahl Nitrogen, or TKN ($R-NH_2$ and NH_4) at Cedar Rapids from 2001-2004. NOx values, mostly in the form of nitrate, tended to increase during the spring and early summer due to wet conditions and limited biological uptake. TKN values, mostly as organic N, had an increase during the summer and early fall. This is due to phytoplankton converting dissolved inorganic nitrogen to organic nitrogen. Throughout the year, TKN is about 20% of the total nitrogen in the Cedar River at Cedar Rapids. In the Cedar River tributaries, TKN averages 10% of the total nitrogen concentration.

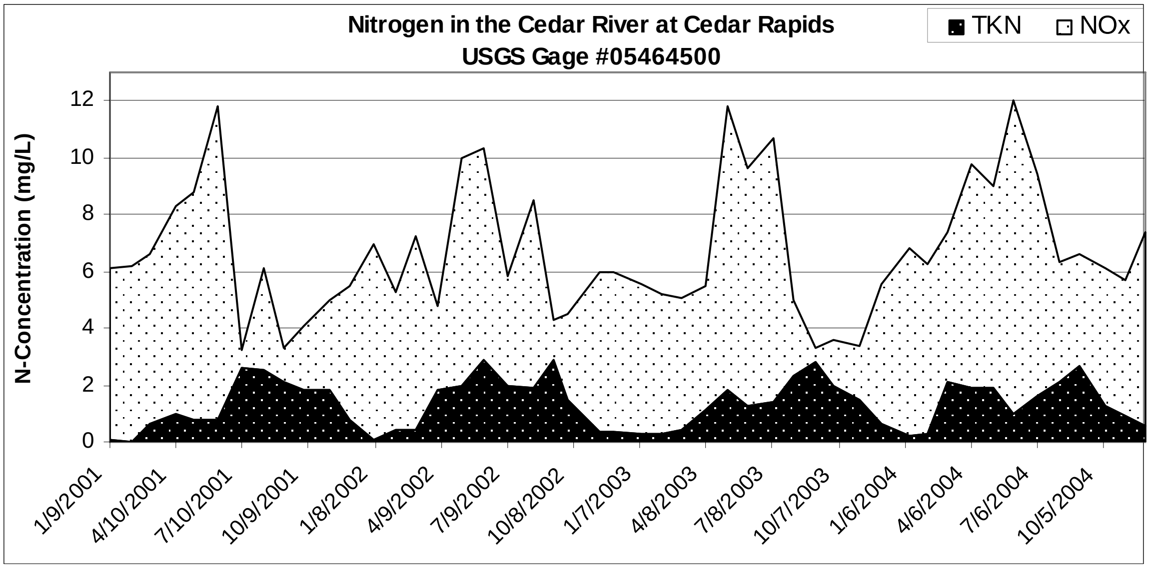

Figure 4. Total nitrogen concentrations in the Cedar River as TKN and NOx.

The primary source for surface water nitrate in Iowa is agriculture, specifically from the widespread use of anhydrous ammonia, application of livestock manure, legume fixation, and mineralization of soil nitrogen (Hallberg, 1987; Goolsby et al., 1999). If not taken up by plants or bacteria after application, nitrate typically leaches from the fields and moves with shallow groundwater to the streams. Previous studies have concluded that baseflow and agricultural tile drainage are the main conduits for nitrate to enter Iowa's streams (Hallberg, 1987, 1989).

1.4 Total Maximum Daily Load Calculation

A Total Maximum Daily Load (TMDL) is described as the maximum amount of a pollutant a water body can handle while still being able to meet designated uses. It is the sum of the loads of the selected pollutant from all contributing point and nonpoint sources. TMDLs must include the following elements to be approved by the U.S. Environmental Protection Agency (EPA).

The TMDL must:

- be designed to implement applicable water quality criteria
- include a total allowable load as well as individual waste load allocations
- consider the impacts of background pollutant contributions
- consider critical environmental conditions
- consider seasonal environmental variations
- include a margin of safety
- provide opportunity for public participation
- have a reasonable assurance that the TMDL can be met

The general equation for a TMDL is:

TMDL = Waste Load Allocation (point sources) + Load Allocation (background and nonpoint sources) + Margin of Safety

Using the best available data, this report uses an empirical method to estimate the Waste Load Allocation (point) and Load Allocation (nonpoint and background) sources of nitrogen entering the Cedar River and its watershed. In general, waste load allocation sources are directly controlled by National Pollutant Discharge Elimination System (NPDES) permits. Load allocation sources are more dispersed than point sources, and are controlled by field and watershed scale best management practices (BMPs), Conservation Reserve Programs (CRP) and the Conservation Reserve Enhancement Programs (CREP). In addition to the load allocations, an explicit margin of safety (MOS) is included to provide a level of protection and account for uncertainty and variability in the data.

Although this TMDL is for nitrogen in the form of nitrate only, this report uses inputs of total nitrogen, as most nitrogen travels down an oxygenated stream as nitrate, regardless of its initial form (Fig. 4). In many instances, nitrogen is not deposited or monitored in the form of nitrate. Once in the stream most nitrogen will nitrify and form nitrate. These chemical processes are not extensively monitored, and modeling nitrogen mineralization and nitrification is data intensive. In this report, nonpoint sources are considered 'potential' as chemical processes may affect each source differently.

The ultimate purpose of a TMDL is to provide a foundation for establishing long-term, realistic watershed management plans. A TMDL must establish in-stream goals or endpoints to ensure that adequate water quality levels are achieved. These goals usually are given as numeric concentration levels in water. For the Cedar River TMDL, the goal is derived from the nitrate-N drinking water standard, adjusted with a 5% margin of safety. This makes the in-stream concentration for all flows at or below 9.5 mg/L nitrate-N, with no exceedances within the 11.6-mile impaired segment.

1.5 Model Resolution

The Cedar River nitrate TMDL report and model uses calendar years 2001-2004. This period was chosen to incorporate all seasonal variations in flow and nitrate concentrations. Flow in the Cedar River from 2001-2004 varied from some of the driest periods (2002) to one of the wettest (2001), incorporating a variety of flow regimes. This period also has a high abundance of nitrate monitoring data from multiple projects.

The Cedar River was divided into seven major segments for this study. This includes six major tributaries: the Upper Cedar River, Shell Rock River, West Fork Cedar, Beaver Creek, Black Hawk Creek, Wolf Creek, and the Middle Cedar (Fig 5). These tributaries were chosen to better understand the priority areas of concern in the watershed. These tributaries were also chosen because the U.S. Geological Survey continuously gages discharge in each of the streams, leading to easier modeling and better quality data.

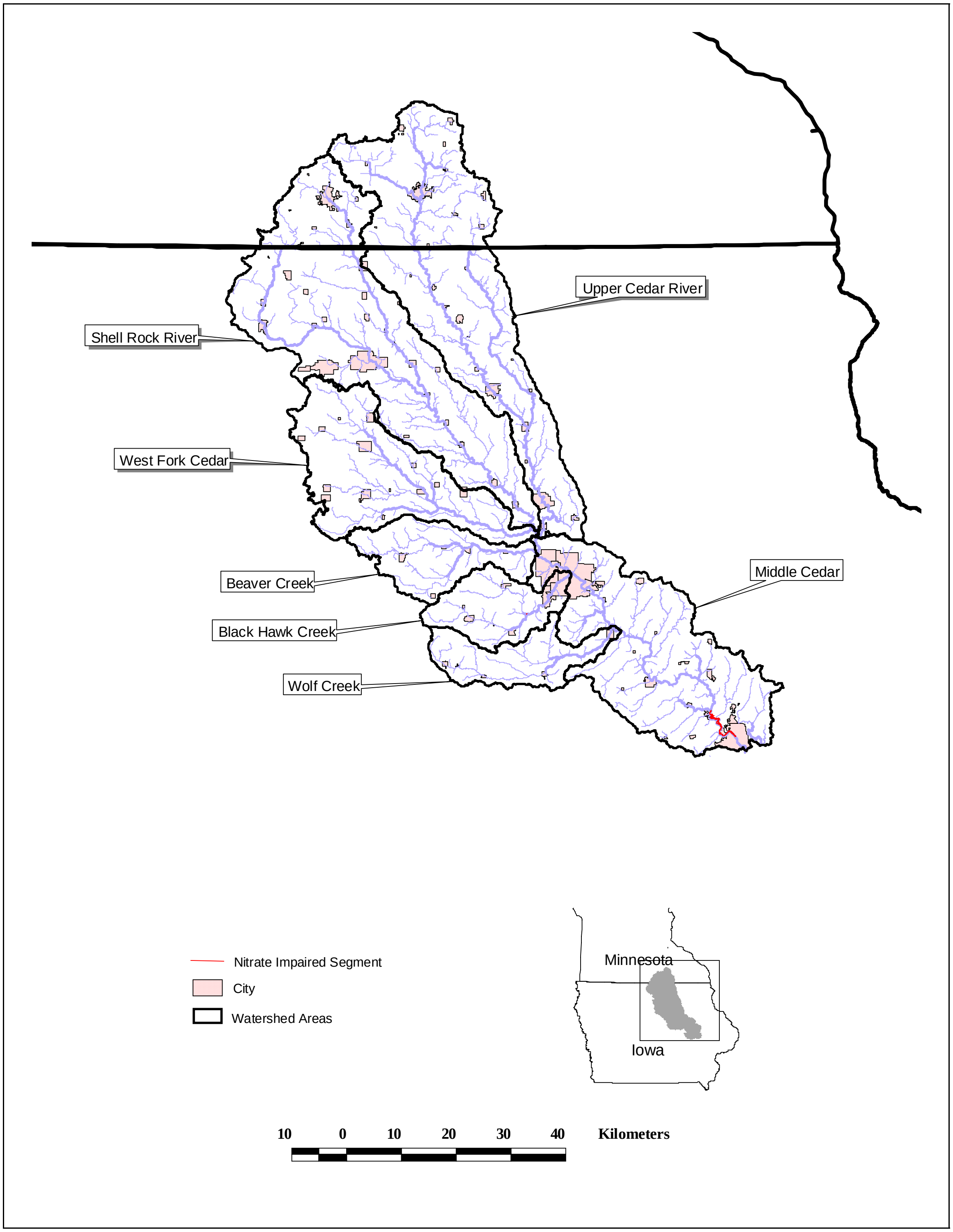

Figure 5. The Cedar River and tributaries.

2 Monitoring in the Cedar River

2.1 Water Discharge

Currently, there are 12 active USGS stream monitoring stations within the watershed, six of which are located directly on the main channel of the Cedar River. The gage at Cedar Rapids (USGS stream gage # 05464500) is the closest station to the impaired segment. The average annual streamflow at this station since 1903 is 3,759 cubic feet per second (cfs). Annual and monthly mean streamflow statistics for the gage are shown in Figures 6 and 7, respectively. Streamflow in the Cedar River is highly seasonal, with higher flows in the spring and early summer.

A recent study has shown an increase in the baseflow portion of the Cedar River, measured at Cedar Rapids USGS Gage # 05464500, from 1927-2000. The baseflow portion of streamflow has increased from 58.6% at the beginning of record to 65.5% at the end of record, or an increase of 6.9% (Schilling, 2005). The increase in baseflow is also strongly correlated with the increase in rowcrop agriculture and stream nitrate concentrations.

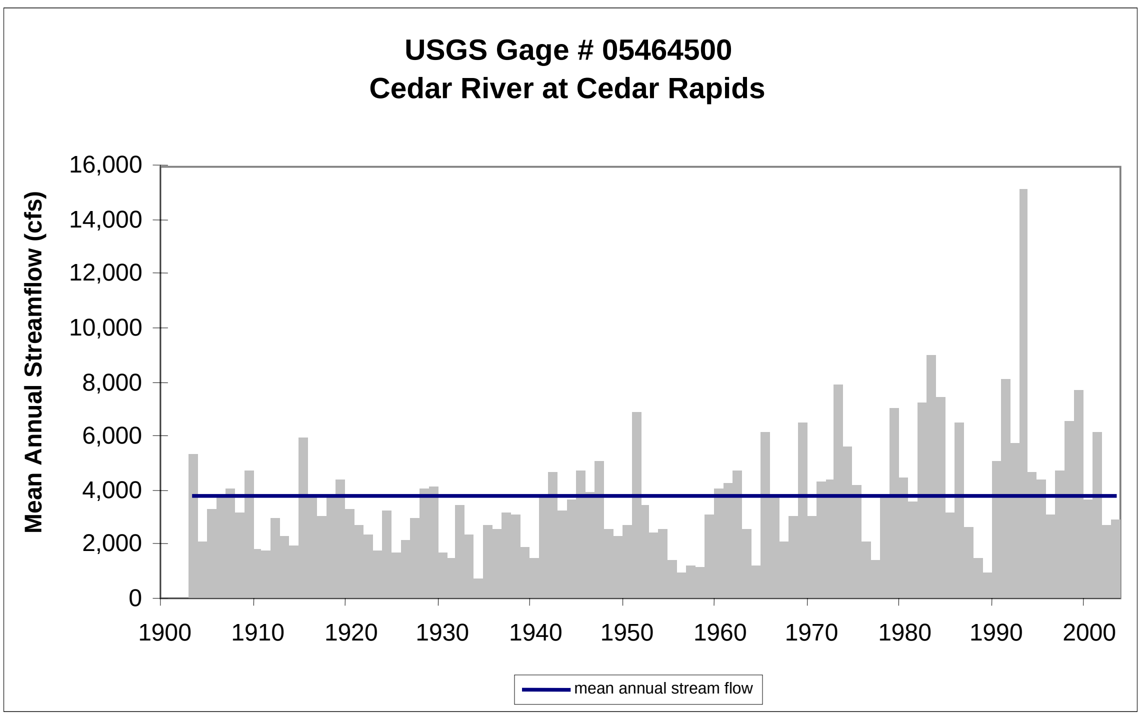

Figure 6. Annual mean streamflow, 1903 – 2003.

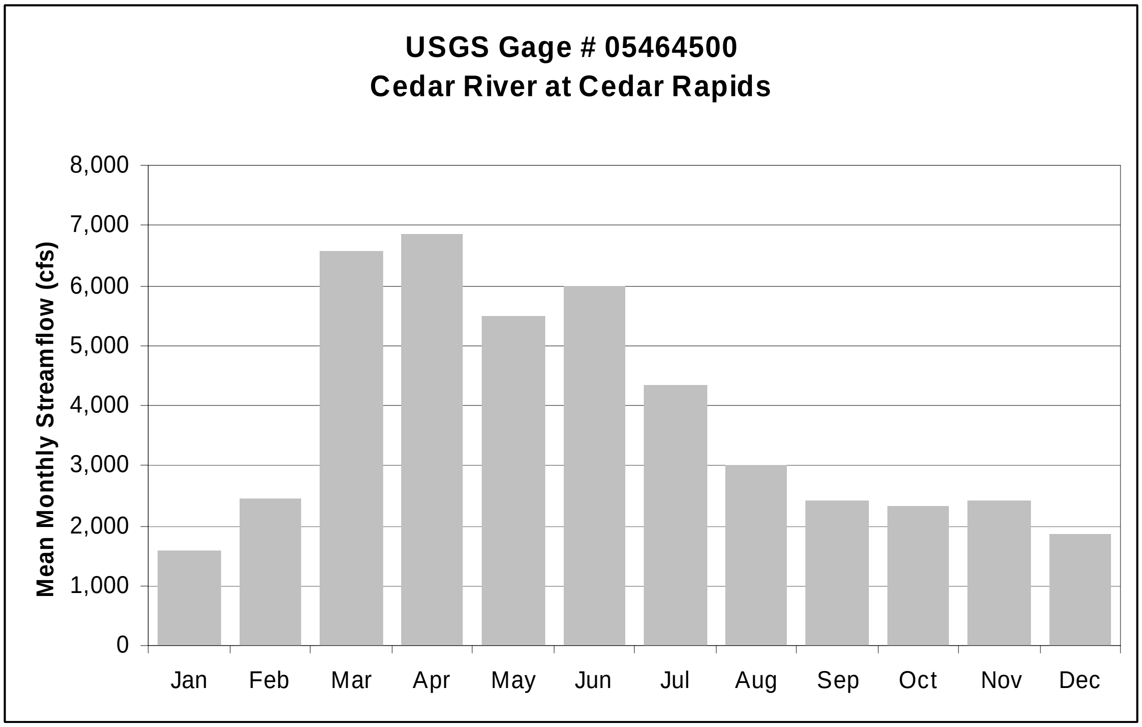

Figure 7. Mean monthly streamflow, October 1902 - September 2004.

2.2 Water Quality

Water quality data used in this report were taken from the following sources:

- Iowa DNR's Ambient Monitoring Program
- Iowa TMDL Targeted Monitoring Program
- IOWATER volunteer monitoring of the Cedar River
- *A Comparison of Land Use and Nonpoint Source Pollution in the Cedar River Tributaries in Iowa*, (Fields, 2004)
- Cedar Rapids Water Treatment Plant Monitoring
- USGS surface water sampling

Iowa DNR, TMDL, IOWATER and USGS used EPA method 353.2 (automated colorimetry) for determining nitrate+nitrite-N concentrations. EPA method 300.0 (ion chromatography) was used in the master's thesis, and the Cedar Rapids Water Treatment Plant used Standard Method 4500 NO3 D (Ion Selective Electrode). Although EPA method 353.2 measures the combined concentration of nitrate and nitrite, and EPA method 300.0 and Standard Method 4500 NO3 D measure the nitrate concentration, it is assumed in an oxygen rich environment such as the Cedar River that very little, if any, nitrogen is in the nitrite form.

Nitrate concentration in the Cedar River is highly seasonal, with most peaks occurring during the spring months of May and June (Fig. 8). Concentrations measured during 2001-2004 varied between a high of 14.66 mg/L on June 13, 2003, to a low of 0.36 mg/L on September 3, 2003. The mean concentration of nitrate-N measured at Cedar Rapids water treatment plant from 2001-2004 was 6.75 mg/L. Along with the distinct increase during the spring, there are also lesser concentration increases during the late fall months of October-December, reaching over 10 mg/L in October of 2002 and December of 2004. This increase is likely due to fall application of fertililizer in the watershed, and the release of ammonia from decaying organic matter on the streambed (Seelig and Nowatzki, 2001).

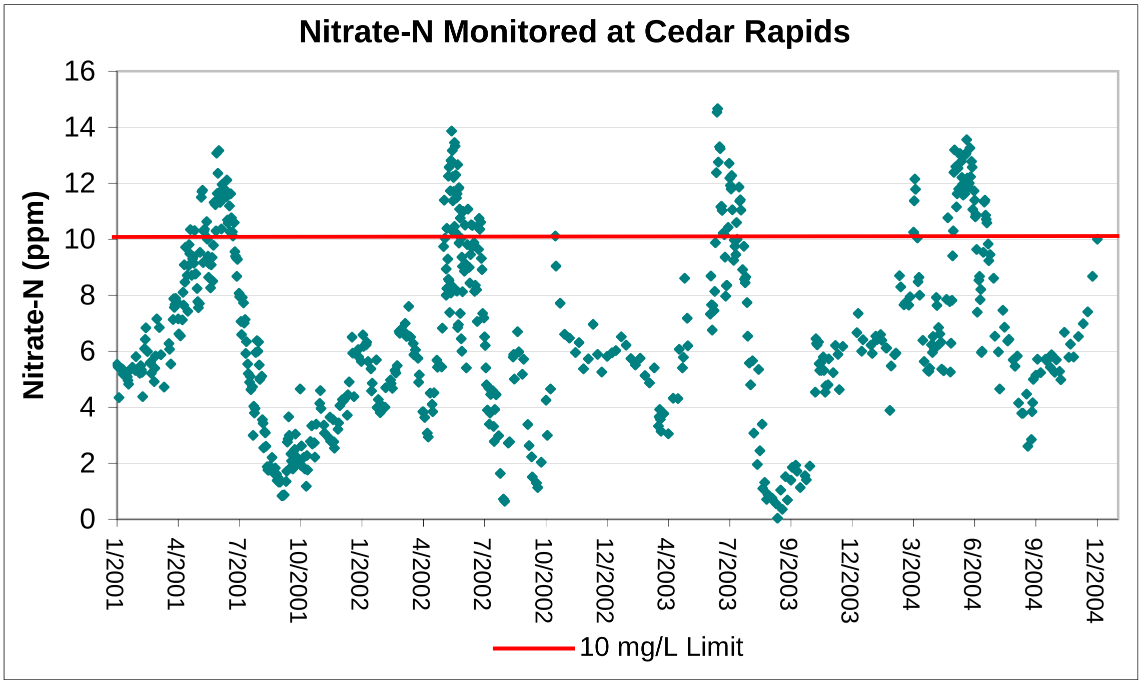

Figure 8. Nitrate-N measured at Cedar Rapids from 2001-2004.

Figure 9 shows nitrate and flow measured in the Cedar River in the form of a load duration curve. A load duration curve incorporates both the concentration and discharge. A load duration curve is beneficial when looking at past concentration exceedances and flow trends in the water quality in the Cedar River. The load duration curve is a graphical representation of a daily load across a variety of flow regimes, or percent exceedances. In general, different sources of pollution can be estimated by looking at the load duration curve.

Streams impaired by point source pollution have critical conditions associated with low flow and dry conditions. Conversely, critical conditions for systems dominated by nonpoint source pollution generally are correlated with wet conditions and high flow brought on by precipitation and snowmelt. The load duration curve clearly indicates that nitrate-N exceedances occur only during wetter conditions and high flows of the Cedar River, and therefore caused by nonpoint source pollution (Fig. 9). In addition, the historical data indicate that nitrate loads in the Cedar River have increased dramatically in the past century (Iowa Geological Survey, 1955). The lowest nitrate values were measured at the beginning of the 20th century, and the highest values taken more recently, specifically during the intensive 2001-2004 monitoring period.

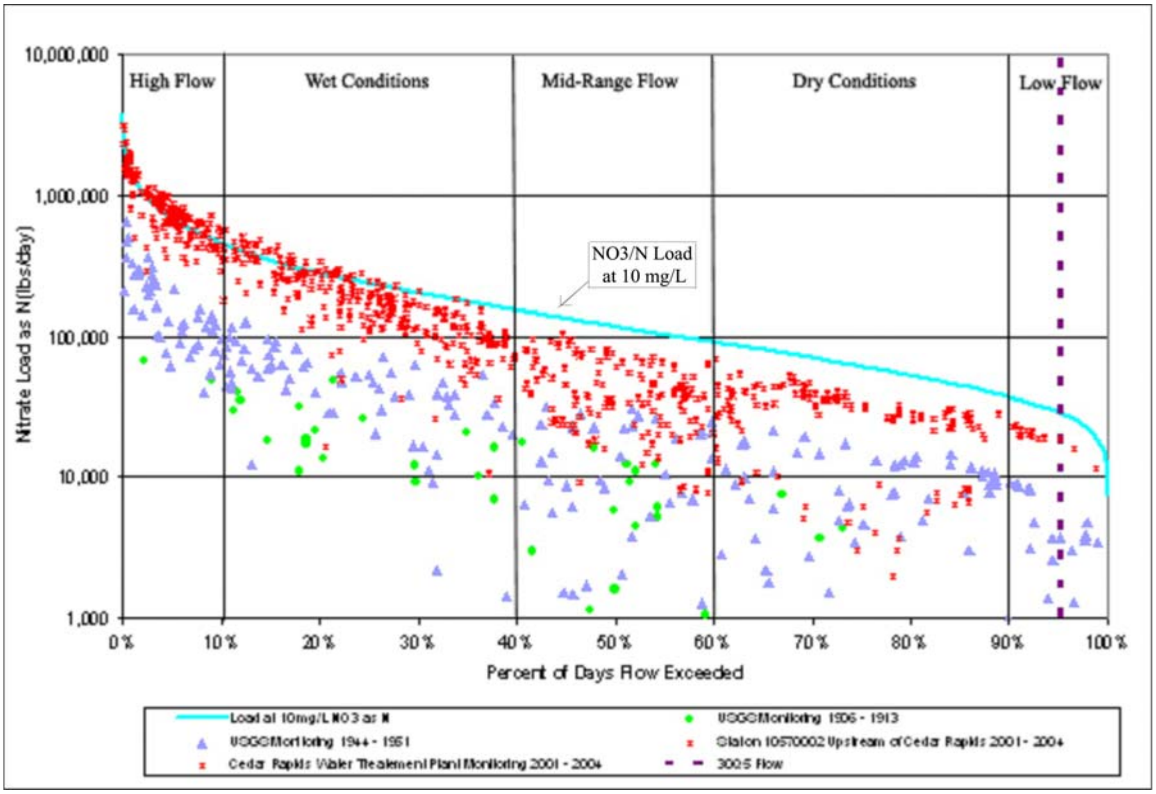

Figure 9. Load duration curve of nitrate-N.

3 Modeling the Cedar River

3.1 Defining Load

The purpose of modeling the Cedar River was to understand the sources and inputs of the nitrate-nitrogen load. The definition of a pollutant load is the mass of the pollutant that passes through a cross-sectional area over a period of time, in this case, one day. The end result is a basic unit mass, in pounds, kilograms, tons, etc. Ideally, loads are equivalent to flux, the instantaneous composite of the streamflow and the pollutant concentration (Fig. 10).

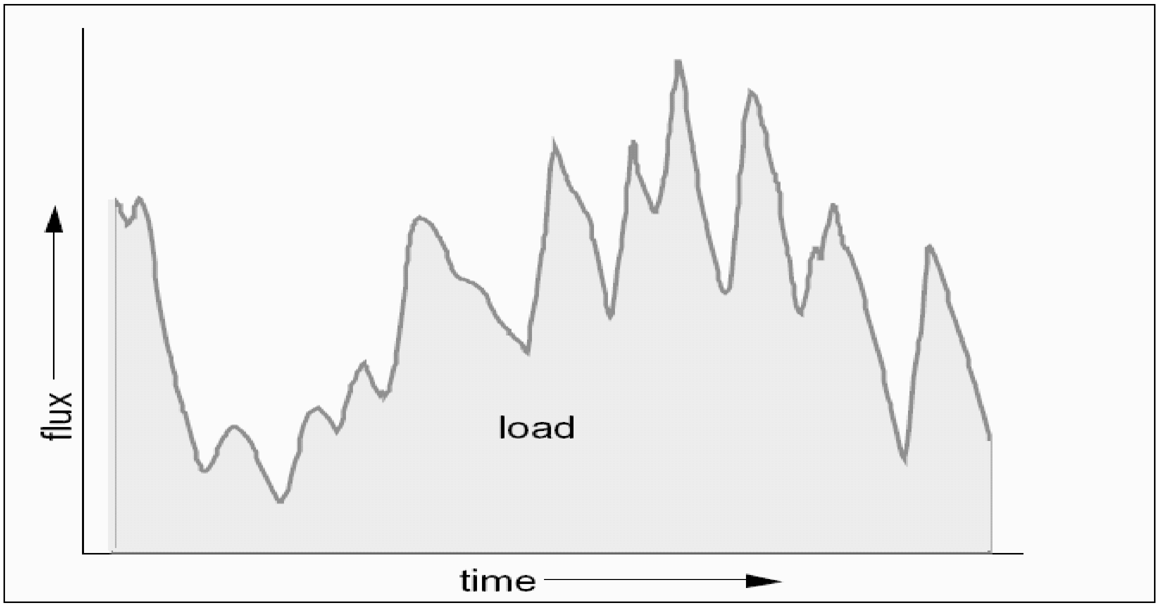

Figure 10. A hypothetical graph of flux over time. Shaded area represents total load.

A load could be measured by calculating the total area of flux on a graph like figure 10. The basic equation for calculating loads is:

$$L = flux(t)dt$$

Where *flux* is the instantaneous mass of pollutants that pass through a cross-sectional area and *dt* is total time passed. Unfortunately, a true measurement of flux is not possible because there are currently no cost effective methods of taking continuous measurements of discharge and concentration together. Therefore, loads are calculated by breaking the flux equation into two separate components:

$$L = k\Sigma c_i \, q_i \, t_i$$

Where k is the basic unit conversion factor, c_i is the concentration of the nutrient in question, q_i is the discharge, and t_i is the passage of time given in the *i*th sample. Since concentration is usually measured less often than discharge, certain extrapolations must be done to the measured pollutant concentration to “fill the gap” of missing time periods. This can be done in many ways; including modeling the average between the two sampling periods and combining them with measured discharge, modeling a linear regression of the concentration curve to a hydrograph, or by modeling the chemical and biological processes in stream. Whatever method is used, however, it is important to remember that the result is not an exact duplicate of the flux or the load, but an estimation.

3.2 Model Selection

Two models were used for simulating flow and concentrations of nitrate in the Cedar River. The Diffusion Analogy Surface Water Flow (DAFLOW) model is a hydrodynamic model for routing streamflow using the diffusion analogy form of the flow equations in conjunction with a Lagrangian solution scheme. Details of the Langrangian study are detailed in Appendix A. The DAFLOW model routes flow through a system of interconnected one-dimensional channels, and subdivides the system into a series of branches, with each branch divided into a grid of cells (Jobson and Harbaugh, 1999). The DAFLOW model allows for a stable solution using a minimal amount of field data and calibration. The program is simple and stable. The DAFLOW model has been used by the U.S. Geological Survey (USGS) since its development in the mid 1980s (Jobson, 1987; Jobson and Schoellhamer, 1987). A number of projects have documented the use of DAFLOW (Broshears and others, 2001; Bulak and others, 1993; California Water Resources Control Board, 1994; California Water Resources Control Board, 1995; Conrads, 1998; Jobson and Harbaugh, 1999). The DAFLOW model can be used for flow routing and to provide hydrodynamic data for a variety of chemical transport models which simulate the fate and movement of dissolved water-quality constituents in streams. An accurately calibrated flow model is critical for all chemical transport models.

The DAFLOW model was used with the chemical transport model WASP (Water Quality Simulation Program) documented by Di Toro and others (1983) and Wool and others (2005). Both models simulate the fate and movement of dissolved water-quality constituents. The WASP model helps users to interpret and predict water-quality parameters in various aquatic systems. In particular, the WASP model is a dynamic transport model that the U.S. Environmental Protection Agency (EPA) has developed for assisting States, specifically for calculating TMDLs. WASP can model many different water-quality parameters; the model was constructed for nitrate--the constituent on the impaired water list for the Cedar River above Cedar Rapids, Iowa. WASP has a user-friendly graphic interface and a graphical post processor for viewing model results.

A modeling framework for the Cedar River Basin has been established using DAFLOW and WASP. The two models provided one of the best combinations for meeting the objectives of the project within the given timeline and in building a framework for any future work in the Cedar River Basin. If additional data becomes available, various scenarios can be run given the modeling framework that has been built.

3.3 Model Basics

The basic principle of both DAFLOW and WASP is the conservation of mass. In other words, the water volume and water-quality constituent masses being studied are tracked and accounted for over time and space using a series of mass balancing equations. Models are typically used to run simulations (scenarios) in order to make predictions. All models make assumptions and are typically limited by the amount and quality of data available. In general, the DAFLOW model uses the channel geometry, streamflow, and Manning's "**n**" (roughness of streambed) to compute flow routing simulations. The flow data are the most critical component. Actual stream gaging data over a period of at least 10 years are critical to all surface water models. In the case of the Cedar River Basin, there are 11 gages, nine of which have a record of over 10 years. Limitations of the DAFLOW model (and all surface water models) are that it does not do well in areas of backwater (not the case in the Cedar River Basin) and in predicting large floods with extreme out-of-bank areas.

The WASP model is a complete water-quality model that has been enhanced and upgraded since it was developed (Di Toro et al., 1983; Ambrose, et al., 1988). Complete documentation of the model can be found in Wool and others (2005). In general, WASP is a dynamic model (time varying or non-steady state) and can be used to interpret and direct water quality responses to natural and man-made inputs of chemicals. Water-quality processes are represented in special kinetic subroutines that can account for advection, dispersion, and point and diffuse loading. Reactions can be specified both within the water-column and underlying benthos. The WASP model can be constructed with many water quality reactions provided that the water-quality data are available. Detailed water quality for the initial or boundary segments is an important condition for WASP. In dynamic models, the user must specify initial conditions for each variable in the segment. Typically, the more detailed the water quality data (quantity and quality) at the initial conditions, the better the modeling results. All available water quality data in the Cedar River Basin were used, no new data were collected for the model. In the future, detailed water-quality data on a daily basis for segments in the Basin would improve modeling results.

3.4 Model Data

DAFLOW used streamflow data from USGS stream gages for the period of January 1, 2001 to December 31, 2004. Streamflow data were reconstructed as needed from discontinued gaging sites in the Basin. Reconstructed data were developed for Black Hawk Creek at Hudson (USGS station 05463500) and Wolf Creek at Dysart (USGS station 05464220). Regression equations were developed for each of theses two gages by relating daily-value discharge from each gage to those of another gage with a corresponding record for the selected time period. Using the regression equations, daily values were estimated for these two gages for the selected time periods of unavailable data within the four calendar-year period as shown in Table 2. Table 3 lists stream gages within the Cedar River Basin that were used in the DAFLOW model of streamflow. Figure 11 shows a schematic of the DAFLOW model.

Table 2. Regression analysis details.

Discharge data used in regression	**Discharge data estimated from regression**
Beaver Creek at New Hartford (05463000) and Black Hawk Creek at Hudson (05463500) 1/1/04 to 9/30/04	Black Hawk Creek at Hudson (05463500) 1/1/01 to 9/6/01
Beaver Creek at New Hartford (05463000) and Wolf Creek near Dysart (05464220) 1/1/04 to 5/31/04	Wolf Creek near Dysart (05464220) 1/1/01 to 5/15/01

Table 3. Model gaging station locations.

Stream Name	Gage Station Number	Calibration Point(Yes,No) Boundary (Yes,No)
Cedar River at Cedar Rapids	05464500	Yes, No
Wolf Creek at Dysart	05464220	No, Yes
Black Hawk Creek at Hudson	05463500	No, Yes
Beaver Creek at New Hartford	05463000	No, Yes
West Fork Cedar River at Finchford	05458900	No, Yes
Little Cedar River at Ionia	05458000	No, Yes
Cedar River at Waterloo	05464000	Yes, No
Cedar River at Janesville	05458500	Yes, No
Cedar River at Waverly	05458300	No, No
Cedar River at Charles City	05457700	No, Yes
Shell Rock River at Shell Rock	05462000	No, Yes

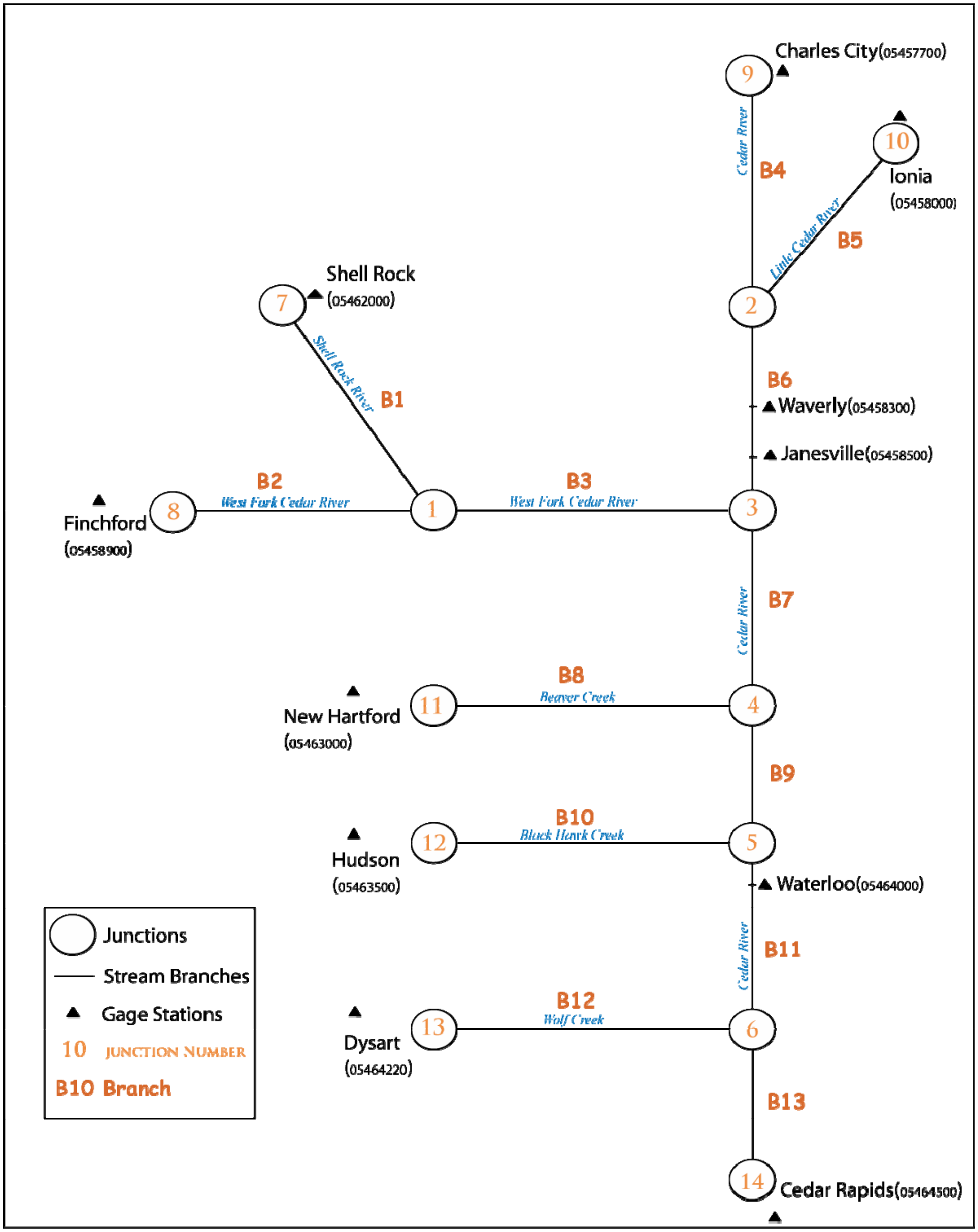

Figure 11. Model schematic.

Initially the DAFLOW model was run for a three-month period from August 1, 2002 to October 31, 2002 to calibrate. This period was selected because when all the streamflow gage data were compared, there were no variations in storm sequencing or any other anomalies. Then DAFLOW was tested on streamflow for calendar year 2002 (Fig. 12). Finally, the DAFLOW model was run on streamflow data for a 4-year period (January 1, 2001 to December 31, 2004). The 4-year period (January 1, 2001 to December 31, 2004) had a typical range of streamflow values. Figure 13 shows the predicted versus the observed data at Cedar Rapids, Iowa, for the entire 4-year period. The DAFLOW model calibrated flow file for the 4-year study period was used as input into the WASP model as the hydrodynamic linkage.

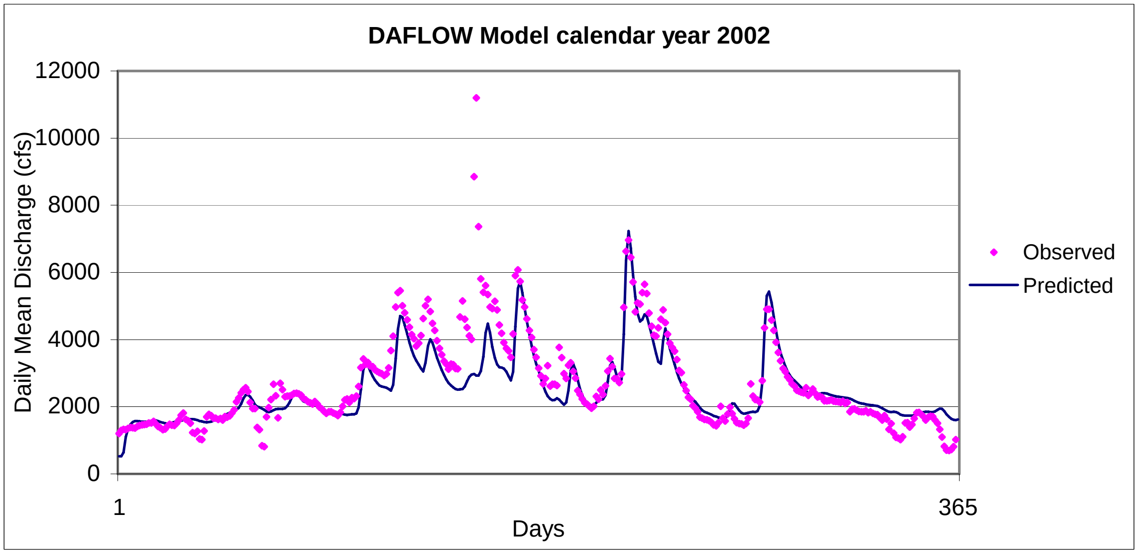

Figure 12. DAFLOW model run calendar year 2002.

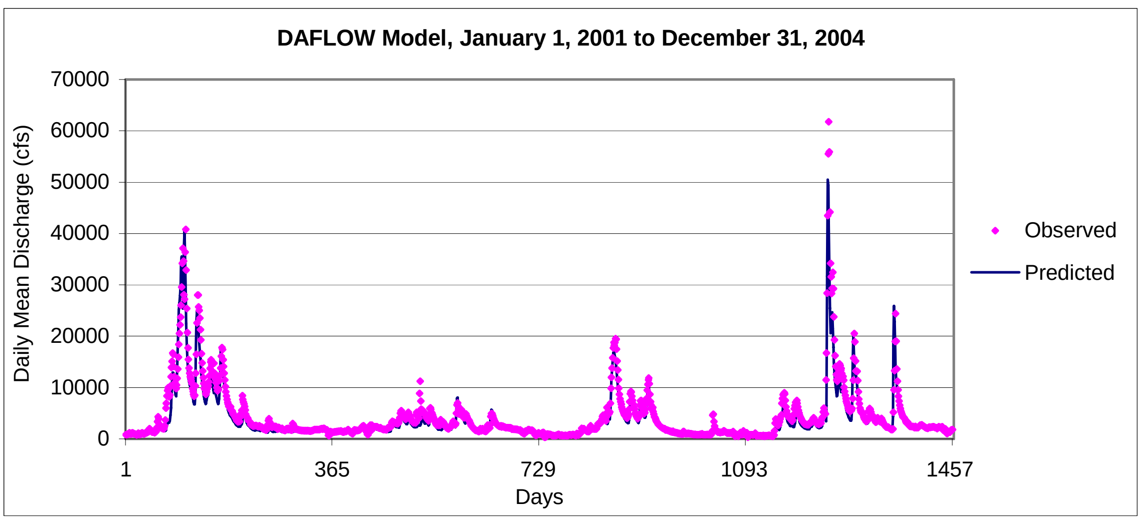

Figure 13. DAFLOW model run, 4-year period (January 1, 2002 – December 31, 2004).

The WASP model was schematically set up similar to DAFLOW, with added nodes along stream lengths for better dispersion. All available nitrate data were added for initial boundary conditions along all boundary locations (Table 2). This included all USGS and Iowa Geological Survey (IGS) water samples from synoptic and longer term monitoring studies. Typically the amount of nitrite and ammonia is small (a few tenths of milligrams per liter) when compared to nitrate (milligrams per liter) in a stream. The nitrate concentration data used were reported as dissolved (filtered) concentrations in milligrams per liter. All nitrogen-containing compounds used were reported as equivalent amount of elemental nitrogen (milligrams per liter as N). Water temperature was set to a default 20 degrees Celsius in the model. WASP was run for the 4-year period using the available nitrate data. Figure 14 shows a graph of observed versus predicted.

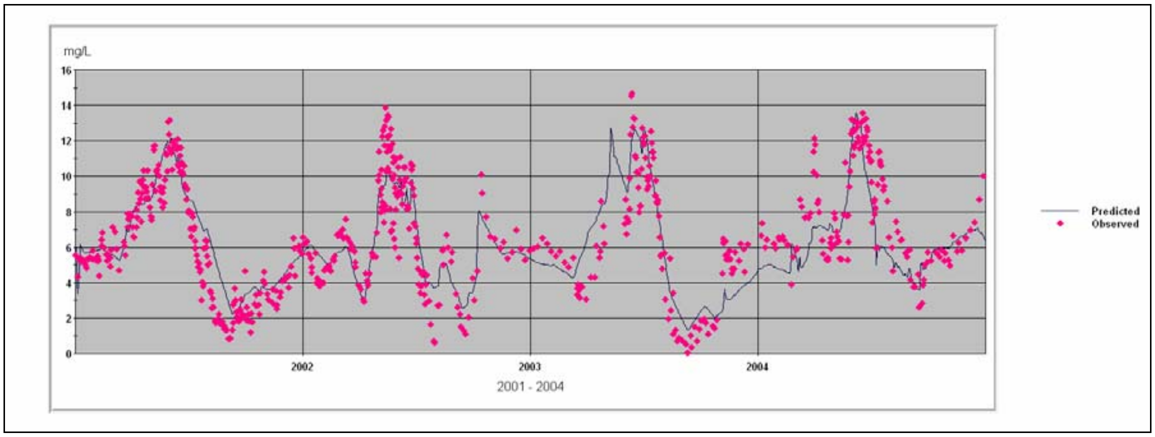

Figure 14. WASP model run, 4-year period.

3.5 Model Calibration

The objectives in the calibration were to first get a good visual correlation and then the best statistical Coefficient of Efficiency (COE) between the observed and the predicted values as possible. COE can be represented in percentage or decimal form. A value of 0.7 to 0.8 usually indicates a fairly good fit for a streamflow simulation (Krysanova et al., 1998). A value of 0.5 and above indicates a good fit for stream nutrients export simulation (Rosenthal and Hoffman, 1999). Using the observed and predicted values from DAFLOW, the COE was approximately 86% or 0.86. This statistic was computed on the WASP model and the COE was approximately 78% or 0.78. A slightly lower COE was observed from the WASP model due to the lack of daily water-quality boundary conditions, unlike the DAFLOW model, which had more data available.

3.6 Model Results

Tributaries

All six major tributaries of the Cedar River above the impaired segment were modeled for discharge, nitrate concentration, and nitrate load. Including the Upper Cedar, Shell Rock River, West Fork Cedar, Beaver Creek, Black Hawk Creek, and Wolf Creek. Excluded in these results is the Middle Cedar, as both discharge and nitrate loads are influenced by the upper six tributaries. Figure 15 details the estimated contribution of average flow and nitrate load to the Middle Cedar River, along with nitrate-N loads, contributions per unit area, and concentrations from each of the six major tributaries.

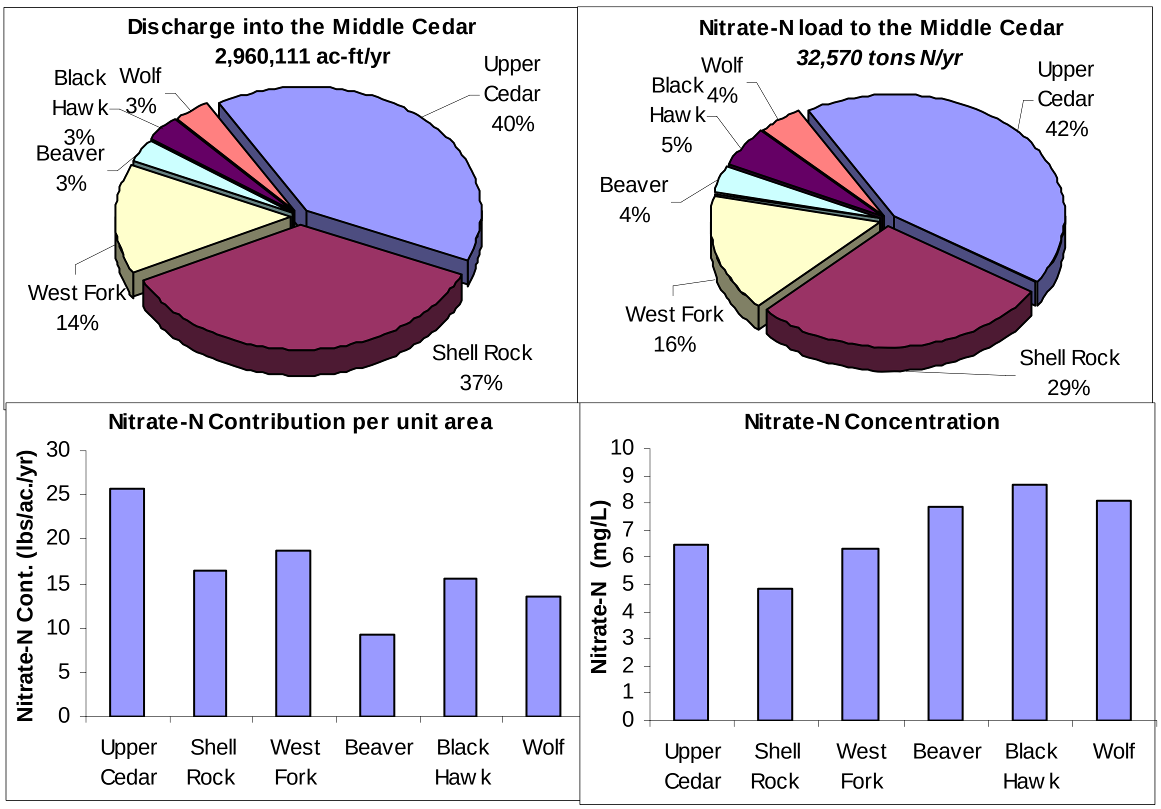

Figure 15. Estimated tributary contribution of flow and nitrate-N to the Middle Cedar.

Model results indicate that during 2001-2004 the Upper Cedar River was the largest contributor of both flow and nitrate to the Middle Cedar River. Both discharge and nitrate loads were connected to watershed size (Fig. 15, Table 1). Nitrate concentrations were inversely related to watershed size, with the largest values measured at the smallest tributaries. This is likely due to nitrate dilution from the deeper baseflow contribution in deeper cut (larger) streams. In addition, larger streams have a greater portion of nitrogen in the organic form.

Interestingly, the Shell Rock River had substantially smaller amounts of nitrate load than discharge would indicate. The decrease in nitrate concentration in the Shell Rock River could be due to a dam located upstream of the gaging and discharge stations. Biological processes such as algal and plant uptake in the dam waters may decrease the amount of nitrate exported from the river.

The large discrepancy in load per area for Beaver Creek is due to the smaller flow per unit area than the other streams, although it has one of the higher concentrations (Fig. 15). The smaller load in Beaver Creek is potentially due to the wetland preserves near the mouth of the river. These wetland areas convert nitrate nitrogen to organic nitrogen, and remove the nitrate from the system. Wetlands also evaporate and transpirate much of the water near the surface of the land.

Cedar River
The entire Cedar River, including the Middle Cedar, was modeled to the downstream end of the listed segment. Model results are as follows:

- Discharge = 2,683,908 ac-ft/yr
- Nitrate-N load = 28,561 tons/yr
- Watershed contribution = 13.7 lbs/ac/yr
- Daily mean concentration = 6.1 mg/L

Watershed contribution and daily mean concentration of the entire Cedar River are towards the lower range when comparing with the values from the major tributaries. This is expected, as concentration and watershed contribution is comprised of a mixture of the tributaries and the contribution from the Middle Cedar River.

Interestingly, the model results indicate that the load of nitrate-nitrogen entering the Middle Cedar River is greater than the load of nitrate leaving the Middle Cedar by 4,000 tons annually, or 12%. A large majority of the reduction is most likely due to plant uptake, evaporation, transpiration, and industry decreasing the discharge of the water. Annual water discharged from the Middle Cedar River had a 10% reduction from water entering the Middle Cedar River. In addition, monitoring data indicates that a further decrease in nitrate might also be due to the doubling (10% to 20%) of nitrogen in the organic form in the main channel of the Cedar River.

4 Pollutant Source Assessment

4.1 Point Sources

Point sources calculated in this report do not include small ‘Category 4’ NPDES permitted systems that serve populations of less than 16 people. These systems are usually in rural areas, and were included in the septic system contribution. A total of two confined animal feeding operations (CAFOs) with NPDES permits were included, though permitted loading from CAFOs are zero tons/year (no discharge). Nitrogen contributions from livestock sources are categorized as a load allocation (nonpoint source pollution) and are discussed in Section 4.1.

The Cedar River watershed has 111 unique facilities with National Pollutant Discharge Elimination System (NPDES) organic waste permits. Ninety-five of these facilities are located in Iowa and 16 are located in Minnesota. Seven municipalities in the Iowa portion of the watershed are large enough to have Municipal Separate Storm Sewer System (MS4) NPDES permits.

Available data used in this report for point source facilities include:

- IDNR database NPDES Discharge Monitoring Reports (DMRs) and facility information
- 2000 Census urban population information
- Selected outfall monitoring performed by the Cedar River Watershed Group (Waterloo, Cedar Falls, Charles City, Mason City, Grundy Center, Vinton and Hampton municipal wastewater treatment facilities)
- Discharge monitoring data submitted by the Clear Lake Sanitary District for their municipal wastewater treatment facility
- Minnesota Pollution Control Agency (MPCA) effluent monitoring reports

There are four different methods (Type 1-4) used to calculate the total nitrogen effluent from a NPDES permitted facility. A screening procedure that considered the following factors was used to determine which method to use on the facility:

- Whether or not total nitrogen monitoring data was available
- Whether or not the facility has industrial contributors contributing a significant organic load
- If the facility had industrial contributors, whether or not they were monitored

Type 1 method – If a NPDES facility had no monitoring data, and no unmonitored industrial waste input, the Type 1 method was used to calculate effluent total nitrogen. A per capita value of 0.027 lbs/day Total Kjehldal nitrogen (TKN) (EPA, 1993) was used in conjunction with the 2000 census population to estimate influent TKN loading for facilities that do not have significant organic industrial waste contributions. TKN is considered to account for most of the total nitrogen excreted by a human. Total nitrogen was assumed to be conserved through the treatment process, and therefore equivalent to the average daily effluent total nitrogen load. The general equation:

Influent TKN = (2000 census pop.) x 0.027 lbs/day = Effluent Total Nitrogen

The Type 1 method also included facilities that have monitored organic industrial waste input. The effluent total nitrogen from the industry was added to the per capita total nitrogen for effluent total nitrogen. For facilities where census population data was not available, the long-term average flow for the facility was determined from IDNR DMRs and a population was estimated based on a typical residential flow contribution of 100 gallons per capita per day. For facilities with no flow data available, the population was estimated based on the construction permit design loading. Table 4 lists 45 facilities estimated in this manner.

Table 4. NPDES facility and county that used the Type 1 method for total nitrogen load.

Ackley (Hardin)	Gold Key Motel (Franklin)
Adams (MN)	Greene (Butler)
Aplington (Butler)	Hudson (Black Hawk)
Atkins (Benton)	Janesville (Bremer)
Beeds Lake S.P. (Franklin)	Jesup South (Buchanan)
Benton Commerce Village (Benton)	Jesup Southeast (Buchanan)
Blooming Prairie (MN)	La Porte City (Black Hawk)
Brandon (Buchanan)	Lehigh Cement Co. (Cerro Gordo)
Center Point North (Linn)	New Hartford (Butler)
Center Point South (Linn)	Newhall (Benton)
Conrad (Grundy)	Nora Springs (Floyd)
Country Aire Trailer Court-S	Northwood (Worth)
Denver (Bremer)	Palo (Linn)
Dike (Grundy)	Reinbeck (Grundy)
Dumont (Butler)	Sheffield (Franklin)
Emmons (MN)	Shell Rock (Butler)
Evansdale (Black Hawk)	Shellsburg (Benton)
Floyd (Floyd)	St. Ansgar (Mitchell)
Forest City (Winnebago)	Timber Ridge Mobile Home
Gilbertville (Black Hawk)	Traer (Tama)
Gladbrook (Tama)	Urbana (Benton)
Gold Key Dining Room (Franklin)	Wellsburg (Grundy)
	Willow Pointe (Cerro Gordo)

Type 2 method - For NPDES permitted facilities with population input and unmonitored organic industrial waste and without monitored effluent, a couple of different methods were used to estimate unmonitored industrial inputs to the municipal wastewater treatment plant. The first method uses the per capita TKN input as above, but also uses ammonia monitoring from INDR DMRs to estimate total mass effluent from industry. The load estimates for these facilities were calculated on a monthly basis as follows:

$$\textit{Effluent Total Nitrogen} = \textit{Per Capita TKN} + \textit{30-day average industrial } NH_3 \textit{ mass}$$

Where significant industrial loads were apparent but not monitored adequately to estimate their TKN contribution, a biological oxygen demand (BOD) to TKN ratio was applied to the monitored influent BOD, with the assumption that the industrial waste stream(s) were roughly equivalent to domestic sewage in terms of BOD/TKN. The load estimates for these facilities were calculated on a monthly basis as follows:

$$\textit{Effluent Total Nitrogen} = \textit{30-day average influent BOD} \times (0.027/0.167) + \textit{30-day average industrial TKN}$$

Table 5 lists the 17 facilities estimated in this manner.

Table 5. NPDES facility and county that used the Type 2 method for total nitrogen load.

Albert Lea (MN)		Magellan Pipeline (Black Hawk)
Allison (Butler)		Magellan Pipeline (Floyd)
Austin (MN)		Magellan Pipeline Co. (MN)
Cambrex Inc. (Floyd)		Nashua (Chickasaw)
Duane Arnold Energy Center		Oakland Sanitary District (MN)
Elk Run Heights (Black Hawk)		Osage (Mitchell)
Golden Oval Eggs (Winnebago)		Osmundson Brothers, Inc. (MN)
Jim's Motor Mart (MN)		Waverly (Bremer)
Lake Mills (Winnebago)		

Type 3 method - Forty-one of the NDPES facilities are controlled discharge lagoons (Table 6). These facilities do not discharge on a continuous basis, therefore load estimates must correspond with periods of recorded discharge. As with the previous estimation methods, nitrogen is assumed to be conserved through the treatment process and discharged in “batches” when the lagoons are released. For these facilities, the population equivalents were determined in the same manner as for Type 1 estimates and matched with DMR discharge records to determine cumulative influent loads and corresponding average daily load estimates for discharge periods.

Table 6. NPDES facility and county that used the Type 3 method for total nitrogen load.

Beaman (Grundy)		Myre Big Island S.P. (MN)
Benton Care Facility (Benton)		Northwood Rest Area (Worth)
Cedar Falls MHP (Black Hawk)		Orchard
Clarksville (Butler)		Parkersburg (Butler)
Dewar Sanitary (Black Hawk)		Pilot Knob S.P. (Floyd)
Dietrick MHP (Grundy)		Plainfield (Bremer)
Elkton (MN)		Plymouth (Cerro Gordo)
Fertile (Worth)		Rock Falls (Cerro Gordo)
Garrison (Benton)		Rockford (Floyd)
Glenville (MN)		Rockwell (Cerro Gordo)
Grafton (Worth)		Rudd (Floyd)
Hickory Hills Park (Benton)		Swaledale (Cerro Gordo)
Holland (Grundy)		Terrace Hill (Black Hawk)
Hollandale (MN)		Thompson (Winnebago)
Latimer-Coulter (Franklin)		Thornton (Cerro Gordo)
Leland (Winnebago)		Twin Lakes (MN)
Lyle (MN)		Walker (Linn)
Manly (Worth)		Waltham (MN)
Marble Rock (Floyd)		Washburn Area STP (Blackhawk)
Mitchell)		Winnebago Industries (Winnebago)
Mount Auburn (Benton)		

Type 4 method – Some facilities have effluent monitoring for total nitrogen (Table 7). The average monitored total nitrogen mass load for the sampling period was used as the load estimate. The number of samples for all but one of these facilities (at the time the estimates were made) was limited to 2 to 5 samples and more extensive sampling will be necessary to increase the accuracy of the estimates. The Clear Lake Sanitary District regularly monitors total nitrogen and achieves significant denitrification through their treatment process.

Table 7. NPDES facility and county that used the Type 4 method for total nitrogen load.

Charles City (Floyd)		Cedar Falls (Black Hawk)
Mason City (Cerro Gordo)		Waterloo (Black Hawk)
Clear Lake S.D. (Cerro Gordo)		Grundy Center (Grundy)
Hampton (Franklin)		Vinton (Benton)

In addition to NPDES permitted wastewater treatment facilities, NPDES permits are also issued for livestock feeding operations that exceed 1,000 animal units. The discharge from livestock operations is set at zero tons per year (IAC – Chapter 65). There are two permitted facilities located in the Cedar River watershed, Sunnybrook Farms in Grundy County, and Tidy No. 1 Family Farm Partner in Grundy County.

Existing Wasteload Contributions

Table 8 lists the point source total nitrogen contribution for each sub-basin in the Cedar River. Monthly Minnesota and Iowa point source loads are detailed in Appendix B. Appendix C lists the wasteload contributions for all NPDES permitted point sources.

Table 8. Average daily point source contributions of total nitrogen to the Cedar River.

Sub-basin	Contribution (lbsN/day)
Upper Cedar River	4,351
Shell Rock River	2,541
West Fork Cedar	245
Beaver Creek	157
Black Hawk Creek	152
Wolf Creek	166
Middle Cedar	6,203
Total	13,815

4.2 Nonpoint and Background Sources

Nonpoint sources of nitrogen species in the Cedar River watershed originate from agricultural, residential, atmospheric and natural sources. Agricultural sources include manure, fertilizer, and legume fixation. Residential sources include septic tanks, and residential turf and garden fertilizers. Atmospheric sources of nonpoint source nitrogen include wet deposition and dry deposition. Natural, or background, sources of nitrogen in the environment are the result of decomposing organic matter and excrement from wildlife.

Nonpoint nitrogen sources are more complex to incorporate in a TMDL model than point sources, as point sources are direct inputs, and the load is added directly to the stream. Instead, nonpoint sources contribute nitrogen diffusely over the land's surface, where it can infiltrate the stream through either baseflow, or surface runoff and erosion into the tributaries. Nonpoint sources therefore undergo many processes before entering the stream, these processes will decrease the amount of nonpoint source nitrogen from entering the stream from 100% of the input. Many processes, such as soil mineralization, plant uptake, volatilization, nitrification, and denitrification can influence the level of nitrate input from any source, and might influence each source differently and to greater or lesser extents. The following nonpoint sources are estimated and discussed in this section:

Background sources:
- Atmospheric deposition
- Wildlife

Human-influence sources:
- Septic systems
- Animal manure
- Fertilizer
- Legume fixation

Each nonpoint source of nitrogen is estimated from the best available data and aggregated for inclusion in the final summation. Unlike the more easily quantifiable point sources, considered direct loads to the stream, nonpoint sources are given a specific load estimate (*total load* less *point sources*) and apportioned based upon the percentage of load within the nonpoint source load. Thus, nonpoint source loads are considered potential estimates, as the true processes cannot be estimated using an empirical approach such as the one used in this TMDL.

Atmospheric Deposition

Atmospheric deposition of nitrogen can be either wet or dry. Wet deposition containing excess nitrogen is commonly called acid rain. Acid rain occurs due to nitrogen and sulfur lowering the pH in the rain droplets, causing the water to be acidic. The National Acid Deposition Program (NADP) measures wet deposition nitrogen concentration and accumulation throughout America. Although there are no NADP monitoring sites located within the Cedar River watershed, there are two locations in the state of Iowa. The closest NADP site to the Cedar River watershed is the Big Spring fish hatchery monitoring site in Clayton county in northeast Iowa. Quarterly wet inorganic nitrogen deposition data, in kg/ha, from 2001-2004 was multiplied with watershed area to estimate total nitrogen input from wet deposition to the Cedar River watershed.

Dry deposition of particles containing nitrogen is also a significant portion of the atmospheric deposition of nitrogen. Automobiles and farm machinery contribute a large portion of dry deposition. Dry deposition is measured by the Clean Air Status and Trends Network (CASTNET), through locations scattered throughout the continental United States. As with wet deposition, no dry deposition monitoring stations are located directly in the Cedar River basin. The closest CASTNET monitoring station is in the town of Stockton, IL, over 100 miles east of the Cedar River watershed. The Stockton, IL, CASTNET site measured quarterly deposition rates of HNO_3-, NO_3-, and NH_4 from 2001-2004. These values were averaged from 2001-2004 and multiplied by the watershed area to sum the contribution of dry deposition nitrogen to the watershed.

Table 9 indicates the average contribution of inorganic nitrogen from total atmospheric deposition in each sub-basin.

Table 9. Average contribution of nitrogen from atmospheric deposition.

Sub-basin	Winter (lbsN/day)	Spring (lbsN/day)	Summer (lbsN/day)	Fall (lbsN/day)
Upper Cedar River	17,482	32,627	25,845	14,282
Shell Rock River	18,309	34,185	27,066	14,938
West Fork River	8,906	16,628	13,149	7,274
Beaver Creek	4,141	7,735	6,123	3,387
Black Hawk Creek	3,515	6,560	5,197	2,871
Wolf Creek	3,457	6,449	5,112	2,826
Middle Cedar	12,847	23,673	18,680	10,307
Total	68,657	127,857	101,172	55,885

Wildlife

Wild animal waste nitrogen and nitrogen from forested areas also can contribute some nitrogen and nitrate to the land surface, and therefore to the stream channel. Actual total nitrogen inputs from wildlife are unknown, as measurements from each species and natural source, along with the numbers of animals, are needed to give a true estimation of the wildlife inputs to nitrogen in the stream channel. In Iowa, no such records are kept. The closest approximation available is Iowa DNR deer population studies. Deer populations are estimated yearly for each county in Iowa for hunting and licensing purposes. It is estimated that per capita nitrogen contribution from a single deer is 0.05 lbs/deer/day. Total wildlife in the watershed was estimated by taking the deer population in the watershed and multiplying it by a factor of 1.5 to account for other, unmeasured wildlife. This estimate is the closest approximation of total wildlife input to the watersheds. Table 10 shows the average daily contribution of nitrogen from wildlife per watershed.

Table 10. Daily contribution of total nitrogen from wildlife per sub-basin.

Sub-basin	Deer Population	Wildlife Contribution (lbsN/day)
Upper Cedar River	7,711	578
Shell Rock River	4,700	353
West Fork Cedar	2,270	170
Beaver Creek	866	65
Black Hawk Creek	622	47
Wolf Creek	868	65
Middle Cedar	10,878	816
Total	27,915	2,094

Septic Systems

Rural septic tank systems can be a significant source of total nitrogen to groundwater, and eventually surface water. Information detailing the specific number of septic systems, or effluent total nitrogen concentration that discharges from them is not available for the Cedar River watershed or its sub-basins. However, the vast majority of the Cedar River watershed is in rural areas outside of incorporated boundaries of cities.

Rural residents are not hooked up to waste water treatment plants that are regulated by NPDES permits and considered point sources.

Although specific information regarding septic systems in the Cedar River watershed is not known, estimates of the rural population from the 2000 US Census is available. Literature estimates put total nitrogen discharge from septic systems around 9.0-9.9 lbs/person/year (Porter, 1980, Libra et al., 2004). For this report, the estimated yearly per capita discharge of 9.9 lbs/person/year was chosen from Libra and others, (2004) as the study was done in Iowa. Loads were calculated based on the U.S. Census rural population and estimated daily contribution of nitrogen per person. These numbers were then divided by sub-basin. Table 11 shows the estimated septic load for each sub-basin.

Table 11. Sub-basin populations and septic tank nitrogen contributions.

Sub-basin	Rural Population	Septic Contribution (lbsN/day)
Upper Cedar River	23,091	626
Shell Rock River	18,215	494
West Fork River	7,298	198
Beaver Creek	4,473	121
Black Hawk Creek	3,112	84
Wolf Creek	3,016	82
Middle Cedar	26,468	718
Total	85,672	2323

Manure

In Iowa and Minnesota, confined feeding operations, feedlots, and pastures contain hundreds to thousands of animals, producing nutrient-rich waste. This animal waste (manure) is usually applied to agricultural land as a fertilizer for crops and pasture. Many different types of livestock animals are raised in the Cedar River basin, including sheep, pigs, dairy cattle, beef cattle, chicken, and turkeys. There is no estimate of the number of animals per watershed sub-basin. Estimates of hogs, chicken, and turkeys were taken from the IDNR animal feeding operation (AFO) database, using locations within the Cedar River watershed. These facility numbers were summed by sub-basin and animal type. For cattle and sheep, 2002 animal county census data was taken from the U.S. Department of Agriculture. USDA data for each animal per county were then divided by the percent of the sub-watershed in each county. No distinction was made between confined feeding operations and open feedlots. Only the number of animals in the watershed was used. Table 12 shows the estimated number of livestock per watershed.

Table 12. Estimated livestock population for each watershed.

Sub-basin	Sheep Population	Chicken Population	Turkey Population	Hog Population	Beef Cattle Population	Dairy Cattle Population
Upper Cedar River	5,281	427,310	0	493,375	68,570	11,467
Shell Rock River	5,506	829,214	119,504	411,689	40,965	2,995
West Fork Cedar	3,934	990,000	0	478,307	26,631	1,096
Beaver Creek	2,074	128,000	0	222,456	12,577	618
Black Hawk Creek	1,702	0	124,100	96,678	8,539	319
Wolf Creek	1,038	0	0	46,847	8,759	323
Middle Cedar	5,240	560,000	36,500	137,060	50,161	3,959
Total	24,775	2,934,524	280,104	1,886,412	216,202	20,777

Total nitrogen produced by livestock varies for each species. Assumed in the calculations was that no significant portion of manure was transported either inside or outside of the watershed. Estimates of daily total nitrogen export from each animal are from the Midwest Planning Service (MWPS-18, 2000). Table 13 shows the estimated contribution of nitrogen to the Cedar River watershed and tributaries from each animal.

Table 13. Average contribution of total N from livestock.

Sub-basin	Hog (lbsN/day)	Poultry (lbsN/day)	Beef Cattle (lbsN/day)	Dairy Cattle (lbsN/day)	Sheep (lbsN/day)	Total Manure (lbsN/day)
Upper Cedar River	39,470	1,282	22,628	8,027	211	71,618
Shell Rock River	32,935	3,993	13,518	2,097	220	52,764
West Fork Cedar	38,265	2,970	8,788	767	157	50,947
Beaver Creek	17,796	384	4,150	433	83	22,846
Black Hawk Creek	7,734	1,564	2,818	223	68	12,407
Wolf Creek	3,748	0	2,890	226	42	6,906
Middle Cedar	10,965	2,140	16,553	2,771	210	32,639
Total	150,913	12,333	71,345	14,544	991	250,127

Fertilizer

While the majority of fertilizer deposited in the watershed is used for agricultural purposes, some commercial fertilizer is used for homes, gardens, and landscaping. Currently, there is no database that details actual fertilizer application rates, in lbs/acre, in Iowa. However, there is county wide data of total dollars spent on fertilizer.

For agricultural fertilizer, input rates involved using IDNR's 2000 30-meter land cover grid, 1997 statewide nitrogen load, and 1997 county expenditures for agriculture fertilizer. A uniform statewide fertilizer price was assumed, making an equal value for dollars spent. This value apportioned tons of fertilizer per county. It was also assumed that fertilizer inputs on rowcrop land was equal on rowcrop acres throughout the county. County wide fertilizer rates were placed on row cropped ground. Urban/turf fertilizer was estimated from the 1999 county-wide turf grass fertilizer expenditures and 1999 statewide nitrogen loads. Turf fertilizer was applied equally to all grassland within all incorporated areas. Table 14 details the fertilizer input per watershed in the Cedar River.

Table 14. Average fertilizer contribution per source in the Cedar River.

Sub-basin	Turf Fertilizer (lbsN/day)	Rowcrop Fertilizer (lbsN/day)	Total Fertilizer (lbsN/day
Upper Cedar River	15,648	165,464	181,155
Shell Rock River	20,552	192,114	212,722
West Fork Cedar	5,258	97,202	102,475
Beaver Creek	1,758	45,821	47,584
Black Hawk Creek	7,532	39,428	46,981
Wolf Creek	1,333	40,822	42,159
Middle Cedar	36,477	112,112	148,689
Total	88,558	692,963	781,764

Legume Fixation

Nitrogen fixation by legume crops such as soybeans and alfalfa is also a significant source of nitrogen in any largely agricultural watershed. Instead of direct deposition from anthropogenic sources, legume fixation relies on symbiotic bacteria around the roots of a plant to fix nitrogen from its elemental form (N_2) to a more usable form by living organisms (inorganic nitrogen). This adds to the available nitrogen in the watershed, and may be washed downstream with a significant rainfall, or may seep into the groundwater for baseflow input to the nitrate concentration in the stream.

Legume fixation nitrogen rates are different depending on the type of plant and environment. Soybean N fixation was estimated to be 2 lbs N/bu. of crop. Alfalfa fixation was estimated to be 50 lbs. N/ton alfalfa. Other hay and pasture is estimated to be 90 lbs. N/acre (NCT-167). Using 30-meter resolution 2000 landcover grid and 2000 county-wide soybean and alfalfa production, the watershed area was cut out of each county and estimates were made. Other hay and pasture estimates used acreage of other hay from the 2000 Iowa landcover grid. The three values of nitrogen fixation were then summed to generate total pounds of nitrogen fixed by legumes in each watershed. Table 15 details the estimated input by legume fixation in each watershed.

Table 15. Average legume fixation of Total N.

Sub-basin	Soybean (lbsN/day)	Alfalfa (lbsN/day)	Pasture (lbsN/day)	Total Fixation (lbsN/day)
Upper Cedar River	97,220	12,426	12,006	121,652
Shell Rock River	109,179	8,489	9,360	127,028
West Fork Cedar	52,020	4,359	5,888	62,267
Beaver Creek	25,886	1,874	2,745	30,505
Black Hawk Creek	23,550	1,120	1,821	26,491
Wolf Creek	21,734	1,750	2,223	25,707
Middle Cedar	61,814	10,478	10,088	82,379
Total	391,403	40,496	44,131	476,029

5 Load Reduction and Allocation

5.1 Approach

A TMDL is the greatest amount of a pollutant that a waterbody can receive and still meet water quality standards. A total maximum daily load is the sum of individual waste load and load allocations for nonpoint, point, and background sources. Included in the calculation is a margin of safety that accounts for the uncertainty about future conditions and about the relationship between the pollutant loads and the water quality of the receiving waterbody.

Load reductions in the Cedar River nitrate TMDL are designed to be proportional to contribution, and also must be reducible. For example, humans do not directly influence wet deposition of nitrogen (although there might be a secondary influence). Therefore, it is unreasonable to assume any direct load decrease from this and other natural or background sources.

The Cedar River nitrate TMDL load reductions are designed to reliably meet the drinking water standard for nitrate, with an explicit margin of safety of 5%. This gives an end concentration value of 9.5 mg/L nitrate-N within the 11.6-mile segment listed as impaired. Currently, measured values in the impaired segment of the Cedar River have reached as high as 14.66 mg/L on June 13, 2003. The following sections will focus on determining the necessary load reductions within the Cedar River watershed to bring nitrate-N concentrations in the impaired segment down to 9.5 mg/L. Also included will be an evaluation of the major tributaries contributing the most nitrate load into the Cedar River.

5.2 Current Wasteload and Load

Nitrate loading into the Cedar River was estimated from the best available data. Current loads from point sources were considered a direct load to the stream, and therefore were considered a direct part of the total nitrate load. Current loads from nonpoint and background sources were totaled for each section of the Cedar River and solved for after subtracting the point source load from the total exported.

Nonpoint source inputs to each sub-basin are summarized in Table 16. In general, the highest input of nitrogen to the watershed is fertilizer. Quarterly atmospheric deposition rates were averaged throughout the year to get the average daily contribution.

Table 16. Current yearly watershed total nitrogen inputs from point and nonpoint sources.

Sub-basin	Point (TonsN/yr)	Wildlife (tonsN/yr)	Septic (tonsN/yr)	Atm. Dep. (tonsN/yr)	Manure (tonsN/yr)	Legume (tonsN/yr)	Fertilizer (tonsN/yr)
Upper Cedar River	794	105	114	4,117	13,070	22,201	33,061
Shell Rock River	464	64	90	4,312	9,629	23,183	38,822
West Fork Cedar	45	31	36	2,097	9,298	11,364	18,702
Beaver Creek	29	12	22	976	4,169	5,567	8,684
Black Hawk Creek	28	9	15	828	2,264	4,835	8,574
Wolf Creek	30	12	15	814	1,260	4,692	7,694
Middle Cedar	1,132	149	131	2,989	5,957	15,034	27,136
Total	2,521	382	424	16,132	45,648	86,875	142,672

The nonpoint sources of nitrate nitrogen discharged in the stream were apportioned using the following equation. Total load was derived from the DAFLOW and WASP model at Cedar Rapids (Section 3.6).

Total nitrate load (28,561 tons nitrate-N/yr) – point source load (2,521 tons nitrate-N/yr) = nonpoint source load (26,040 tons nitrate-N/yr)

As nonpoint source loads are much greater than the total export from the Cedar River, and undergo many more processes than point sources, nonpoint sources were apportioned by percentage of total. The following equation shows this method. This method assumes an equal opportunity for all chemical and biological processes to occur to all nonpoint sources. The values for manure input and total nps are taken from Table 16.

*Manure nps load = (manure input [45,648 tonsN/yr] / total nps input [292,133 tonsN/yr]) * nps load (26,040 tons nitrate-N/yr) = 4,070 tons nitrate-N/yr*

This value was then divided by the total modeled nitrate load to find the percentage contribution of that source.

*Manure load percentage = manure load (4,070 tons nitrate-N/yr) / total nitrate load (28,561 tons nitrate-N/yr) * 100% = 14%*

Figure 16 shows the contribution of total nitrogen from sources in the Cedar River. Nonpoint source loads are considered potential sources, as important chemical and biological processes within the watershed were not modeled. It is assumed that the processes are roughly equal, or that there is an equal opportunity for the processes to happen to any or all sources. Background information for load sources and amounts are described in section 4.

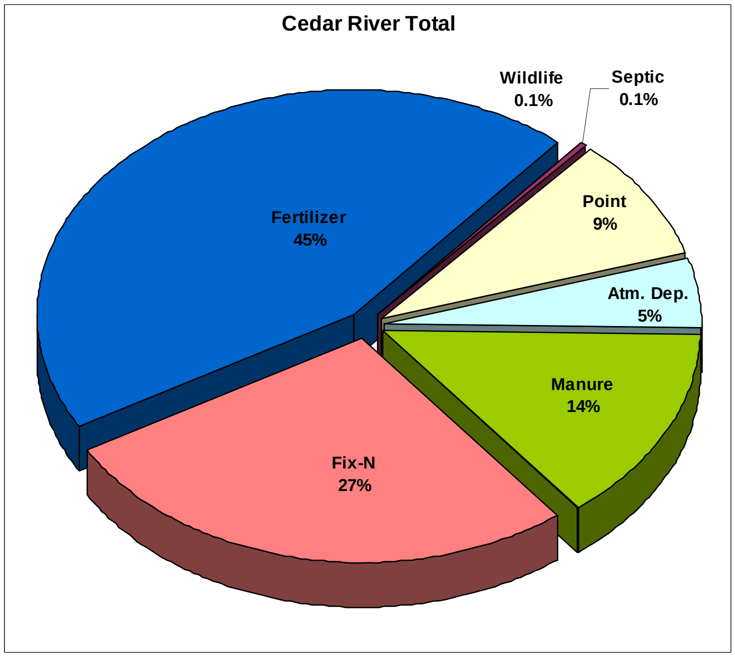

Figure 16. Average potential in-stream nitrate contributions from all sources in the Cedar River watershed.

5.3 Seasonality

Figure 17 shows the high seasonality of nitrate-nitrogen export from the Cedar River at Cedar Rapids. Most of the load is seen discharging during the spring months of April - June. The high seasonality of nitrate transportation results from a number of factors, including manure and fertilizer application, snow melt, and wetter conditions. Similarly, most high nitrate concentration values occur during the spring and summer months, although there also seems to be a slight rise to near 10 mg/L during the late November, early December time period (Fig. 8).

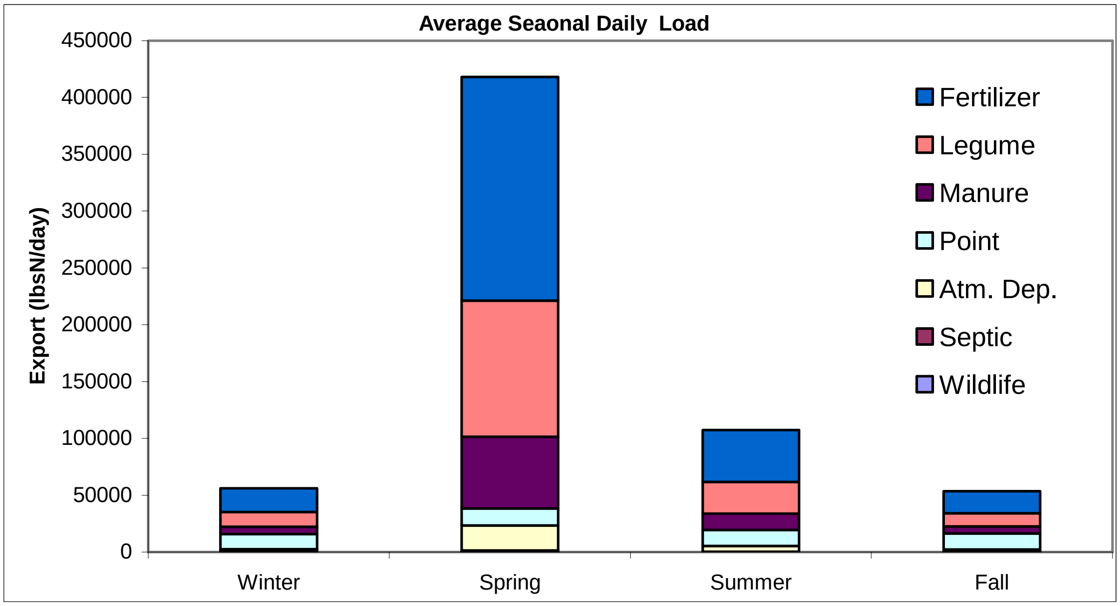

Figure 17. Average seasonal daily nitrate-N load at Cedar Rapids from 2001-2004.

5.4 Margin of Safety

The Margin of Safety (MOS) is both implicit and explicit in this TMDL. The explicit MOS is a 5% buffer for the 10 mg/L nitrate-N concentration limit. This explicit margin of safety is incorporated over the entire Cedar River watershed. The MOS is also reinforced through conservative assumptions implicit in the representation and modeling of point and non-point sources. For example, point source contributions were calculated under the conservative assumption of no total nitrogen loss (denitrification) between the input and effluent of each NPDES permitted facility.

5.5 Nitrate Reduction

The end objective of the Cedar River TMDL is a reasonable, reliable daily load reduction that yields a target concentration no higher than 9.5 mg/L nitrate-nitrogen in the impaired area. It should be noted that this is a single target concentration and not an average or median of multiple samples. It was decided that reducing the concentration from its highest value was to be the most effective method for estimating load reduction. The highest nitrate-N concentration measured in the impaired segment was 14.66 mg/L on June 13, 2003.

- Maximum measured concentration = 14.66 ppm NO_3
- TMDL maximum concentration = 9.5 ppm NO_3
- = **35% reduction**

The concentration-based 35% reduction is equal to a yearly load reduction of 9,996 tons nitrate-N/year from the current average modeled load of 28,561 tons nitrate-N/yr.

The annual nitrate load was established using the WASP and DAFLOW modeling conducted with daily time steps. Further, the TMDL is also expressed as a Load Duration Curve based on flow records from the USGS gage 05464500 (Cedar River at Cedar Rapids, IA) and in-stream nitrate measurements taken at Cedar Rapids. This Load Duration Curve is a continuous daily expression of the target load for all flow conditions. Figure 18 presents this curve; the solid red line is the TMDL and the dashed lined is an estimate of the current conditions. The curve demonstrates that nitrate problems are generally associated with higher flow conditions. As the flow increases, the percent of the flow from surface runoff and the pounds per day load also increase.

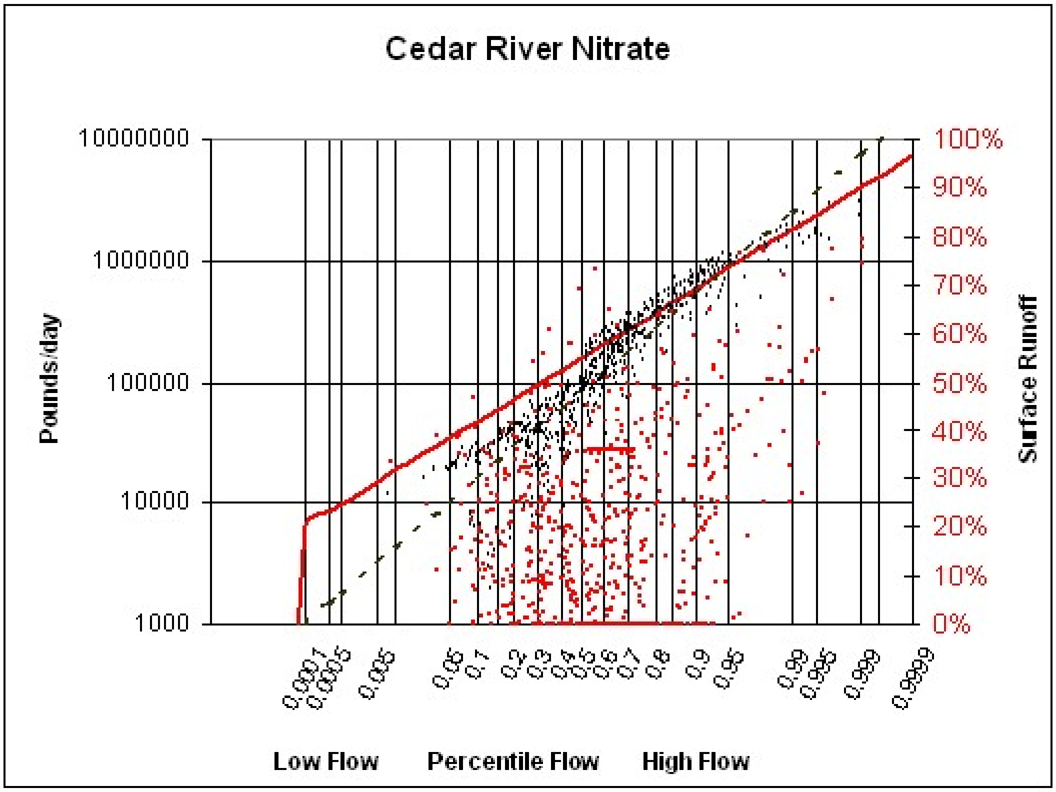

Figure 18. Load Duration curve for nitrate in the Cedar River at Cedar Rapids.

5.6 Pollutant Allocation

A large majority of the nitrate delivered downstream is from nonpoint sources. Thus, any reduction in nitrate in the Cedar River must also have a decrease in nonpoint source pollution. There are a number of speculative load reduction scenarios that could decrease the nitrate levels in the water to the proposed level. As seen in figures 9 and 16, nonpoint source pollution is the major pollutant in the watershed. Also, all nitrate-N exceedances occur during wetter conditions, when the majority of flow is from nonpoint sources. For these reasons, load reductions were made entirely in the nonpoint source realm. Table 17 lists the existing loading and TMDL load allocations of total nitrogen needed to receive a 35% reduction in nitrate-N at the impaired site. Excluding wildlife, atmospheric deposition, and point sources, the relative decrease to each remaining nitrogen input is

37%. The 37% reduction should be seen as an indicator of reductions in each source, are based from *average quarterly or yearly estimates*, and include many variations in deposition. Presumably, fertilizer and manure deposition and transportation to the stream is very high in the spring months, and decreases during the summer. Therefore, reductions should be prioritized during the spring months.

Table 17. Existing nitrogen input and TMDL input for the Cedar River watershed.

Sub-basin	Point (TonsN/yr)	Wildlife (TonsN/yr)	Atm. Dep. (TonsN/yr)	Septic (TonsN/yr)	Manure (TonsN/yr)	Legume (TonsN/yr)	Fertilizer (TonsN/yr)
Upper Cedar River Existing	794	105	4,117	114	13,070	22,201	33,061
Upper Cedar TMDL (Iowa)	*138*	*NA*	*NA*	*71*	*8,162*	*13,864*	*20,645*
Shell Rock River Existing	464	64	4,312	90	9,629	23,183	38,822
Shell Rock TMDL (Iowa)	*210*	*NA*	*NA*	*56*	*6,032*	*14,523*	*24,320*
West Fork Cedar Existing	45	31	2,097	36	9,298	11,364	18,702
West Fork TMDL	*45*	*NA*	*NA*	*23*	*5,865*	*7,168*	*11,796*
Beaver Creek Existing	29	12	976	22	4,169	5,567	8,684
Beaver Creek TMDL	*29*	*NA*	*NA*	*14*	*2,630*	*3,512*	*5,478*
Black Hawk Creek Existing	28	9	828	15	2,264	4,835	8,574
Black Hawk Creek TMDL	*28*	*NA*	*NA*	*10*	*1,428*	*3,050*	*5,408*
Wolf Creek Existing	30	12	814	15	1,260	4,692	7,694
Wolf Creek TMDL	*30*	*NA*	*NA*	*9*	*792*	*2,947*	*4,833*
Middle Cedar Existing	1,132	149	2,989	131	5,957	15,034	27,136
Middle Cedar TMDL	*1,132*	*NA*	*NA*	*81*	*3,689*	*9,310*	*16,804*
Total Existing	2,521	306	16,132	424	45,648	86,875	142,672
Total Cedar TMDL	*2,521*	*306*	*16,132*	*265*	*28,572*	*54,376*	*89,301*

Although Figure 16 and Table 16 estimate the total nitrogen contributions, each source contributes different ratios of nitrate, ammonium, and organic nitrogen. In-stream and land surface chemical reactions will occur and allow total nitrogen to continue to change forms. Some total nitrogen sources, presumably initially in the nitrate form, will probably have more of an impact than sources that are deposited in another form.   There is also an inherent difference between point source pollution and nonpoint source pollution in that nonpoint source pollution is spread out throughout the watershed. This is why extensive monitoring is vitally important, even after the initial TMDL is complete.

5.7 Minnesota Nitrate Loading

Two sub-basins of the Cedar River extend into Minnesota: the Upper Cedar River and the Shell Rock River. Loading from Minnesota was assumed to be based on percentage of watershed in the state, and apportioned by point and nonpoint sources. Although Iowa has no authority in regulating pollution from Minnesota, a 35% reduction in total nitrate-N loading is assumed in this TMDL scenario. Table 18 represents nitrate-N loads and TMDL reductions from Minnesota:

Table 18. Existing and TMDL allocation from Minnesota.

Sub-Basin	Percent in MN	MN Load	TMDL
Upper Cedar River	42%	5,811 tonsN/yr	3,777 tonsN/yr
Shell Rock River	18%	1,653 tonsN/yr	1,075 tonsN/yr

Clearly, reductions in nitrate loading in Minnesota are critical for meeting water quality standards in Iowa.

6 Implementation

6.1 Prioritization

Along with reducing the individual inputs of nitrogen on the watershed, another method of nitrate reduction is influencing the chemical processes that form nitrate. Two of the more important processes are mineralization and plant uptake. Studies have shown that mineralization rates increase with exposed bare soil (Sainju et al., 2002), such as rowcropped land during the late winter and early spring months. Effective ways of limiting excess mineralization and increasing plant uptake include no-till and cover crops. These methods reduce the bare soil and limit leaching from mineralization by having plant roots absorb water and nitrate from the soil. Wetlands are known for their high nitrate retention rates (Spieles and Mitsch, 1999; Phipps and Crumpton, 1994) and have often been used as a ‘sink’ for capturing surface runoff nitrogen. These and other best management practices can reduce the chemical processes that produce nitrate by keeping nitrogen in the organic form.

Tile drainage has been shown to reduce plant uptake and increase leaching by increasing water and nitrate transport to the stream channel. Reducing tile line drainage, especially on the Des Moines Lobe region of the watershed, has great potential in reducing nitrate levels in the Cedar River.

Nearly seventy-three percent of the total Cedar River watershed is used for rowcrop production. Previous studies (Schilling and Libra, 2000; Taraba and Dinger, 1998) have shown that nitrate concentrations in streams are significantly correlated to the percentage of rowcrop within the watershed. This relationship also exists within the six major tributaries of the Middle Cedar River. Figure 19 details tributary mean daily concentrations with standard deviations and 2002 land cover percentages for the four-year modeling period (2001-2004, n=1461). Mean nitrate-N concentrations in the tributaries varied between a high of 8.7 mg/L in Black hawk Creek to a low of 4.8 mg/L in the Shell Rock River. Percentage rowcrop varied by 8.6%, from 72.6% in the Upper Cedar watershed to 81.2% in Black Hawk Creek watershed. The positive slope and high correlation ($p = 0.017$) suggests that reducing rowcrop agricultural land on the watershed surface will decrease nitrate concentrations in the tributaries. Ranking the most impaired sub-basins of the Cedar River, the nitrate-N contribution per unit area is highest in the Upper Cedar River, in part due to higher flow. Following the Upper Cedar River is West Fork Cedar, Shell Rock River, Black Hawk Creek and Wolf Creek. Beaver Creek has a high average concentration, but total load to the Middle Cedar River is low due to lower discharge (Fig. 15).

Recent studies have shown that an increase in rowcrop intensity not only yields an increase in nitrate input to the stream, but also a corresponding increase to the baseflow contribution to the stream (Schilling, 2005). Historical data indicates that during the past 60 years, nitrate-N concentrations have become increasingly dependant on discharge (Fig. 20). Increasing baseflow and baseflow percentage of discharge over the second half of the century has resulted in increasing surface-water nitrate concentrations, particularly during wetter conditions.

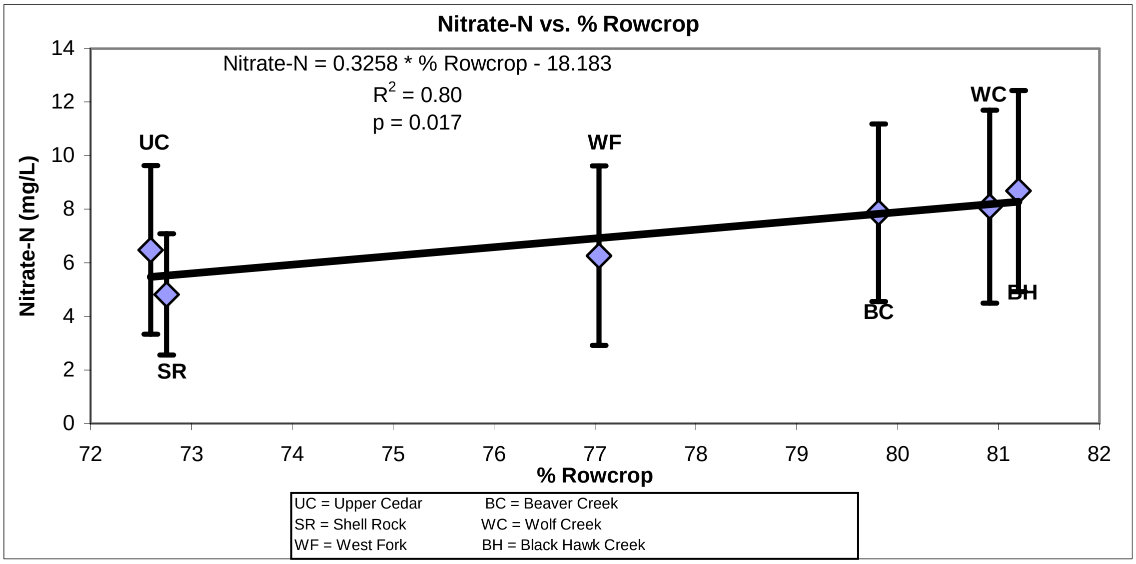

Figure 19. Relationship of percent rowcrop to mean nitrate-N concentrations in 5th-order Cedar River tributaries.

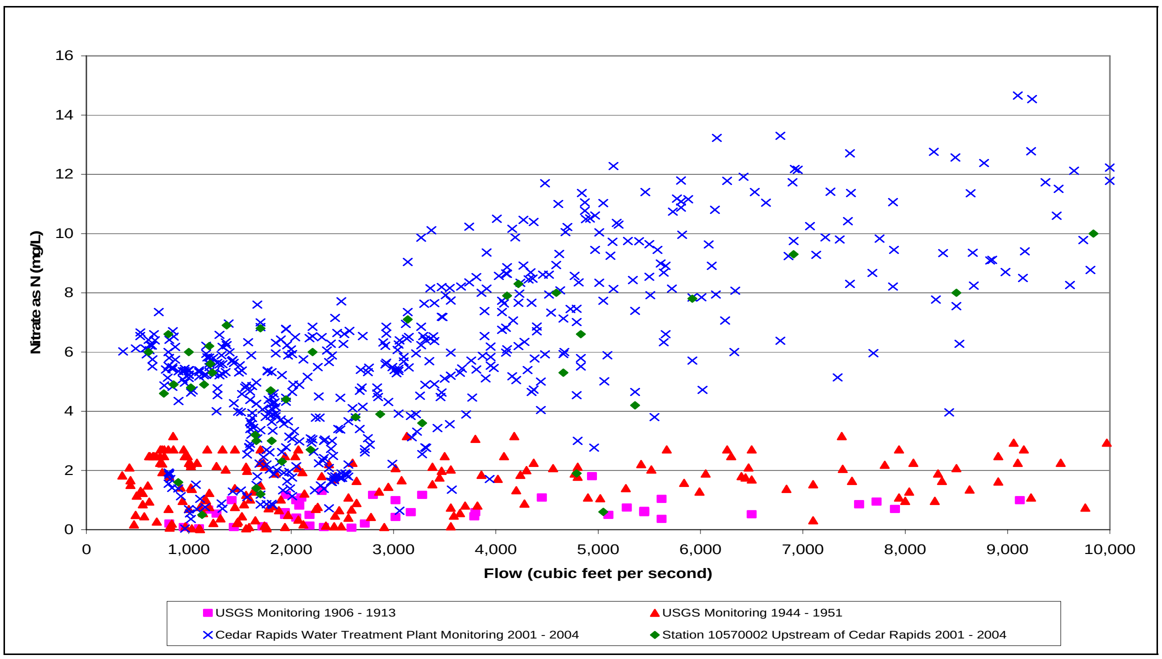

Figure 20. Nitrate concentrations vs. flow - Cedar River at Cedar Rapids.

The increase in stream nitrate levels and the greater dependence of concentrations as a function of stream flow are the result of a number of factors that are prevalent throughout Iowa. Since the mid-1900s, the area of the Iowa in corn production has seen only a modest increase, from approximately 10.4 million acres harvested in 1944 to 12.3 million acres harvested in 2004. However, during the same period, land use for soybean production has increased from 1.9 to 10.2 million acres while land use for oats has declined from 4.7 to 0.14 million acres. The increase of over 8 million acres of soybeans has likely had a major impact on the amount of soil-nitrogen mineralized annually. In addition, while total livestock numbers, and therefore manure-nitrogen has increased only modestly, chemical-nitrogen application has increased from virtually none to almost one million tons per year statewide. In areas with shallow bedrock, such as in the Upper Cedar basin, an increased amount of leaching will increase both the chemical and manure-nitrogen entering the shallow groundwater supply. This nitrate-enriched groundwater will eventually flow to the stream channel. Finally, increased use of artificial tile drainage systems is believed to be a significant contributing factor. The tile drainage systems bypass natural drainage ways that may otherwise provide some attenuation of nitrate in shallow soil water and runoff through biological uptake or denitrification.

6.2 Strategy

Point Sources

Current TMDL NPDES permitted Waste Load Allocations (WLAs), found in Appendix C, are to remain in place for each facility. These WLAs will remain static to limit the further influence of point sources on nitrate levels in the Cedar River. Point sources will also be responsible for maintaining water quality standards during low flow and dry conditions.

Wastewater point sources in the watershed have been found to be a relatively minor fraction of the total nitrogen load to the Cedar River, particularly during the high-flow conditions when violations of the 10 mg/L water quality standard are occurring. However, point source inputs are by nature delivered directly to surface waters and can be a significant portion of the total load during low-flow conditions. To assure that point source contributions do not cause future violations of the water quality standard, the wasteload allocations presented in Appendix C of this report will be implemented as needed through each facility’s individual NPDES discharge permit. The wasteload allocations allow for reasonable increases in nitrate loading attributable to population growth and original plant design capacities. For most facilities, major nitrogen-contributing industries are absent and effluent total nitrogen loads can be estimated based on influent Carbonaceous Biological Oxygen Demand (CBOD) or the population equivalent served. Where significant industrial contributors are present, monitoring of effluent total nitrogen will be required. Total nitrogen limits will be incorporated into the NPDES permits if influent or effluent monitoring data demonstrates that the facility is approaching its wasteload allocation.

Like wastewater point sources, urban storm water point sources (and urban storm water nonpoint sources, i.e., those which do not require an MS4 NPDES permit) in the watershed comprise a small portion of the total nitrogen load to the river. Like nonpoint sources, the loads attributable to storm water are highly dependent upon climatic conditions and also correspond with high stream flows when violations of the water quality standard are occurring. Although urban runoff makes up only a small portion of the nitrate load, Best Management Practices (BMPs) for controlling nitrogen delivery from these sources should be considered. These practices include:

- Addition of landscape diversity to reduce runoff volume and/or velocity through the strategic location of filter strips, rain gardens, grass waterways, etc.
- Installation of terraces, ponds, and other control structures at appropriate locations to aid in attenuating nitrogen delivery through biological uptake or denitrification processes.
- Appropriate use of fertilizers on residential and commercial lawns.

For the municipalities in the watershed that do have an NPDES MS4 permit, development of a Storm Water Pollution Prevention & Management Program (SWMP) is required. The SWMP includes requirements for implementation of BMPs including controls to reduce pollutants in discharges from municipal application of fertilizers and operation of a public education and outreach program to inform the public of storm water impacts on water quality and measures that can be implemented to reduce water quality degradation from storm water. As recommended by the EPA, the Waste Load Allocations for urban storm water point sources in the watershed will be implemented through the NPDES MS4 permits and will attempt to utilize best management practices in lieu of numeric limits.

Nonpoint Sources

As TMDL modeling and research indicates, nonpoint source pollution is the greatest contributor of nitrate to the Cedar River. Nutrient management on rowcrop areas in the Cedar River watershed is likely to be a predominant factor affecting nitrate loading to the river and management practices that will reduce source loading. In particular, practices to improve the timing of nitrogen application, the incorporation of nitrogen in the soil, and matching application rates to crop demand are critical. Such practices include:

- Spring or split nitrogen application (in lieu of fall application) to better time nitrogen availability with crop demand.
- Use nitrogen application rates based on the Late-Spring Soil Nitrate Test (LSNT).
- Adoption of no-till or strip-till systems combined with injection of nitrogen fertilizers to improve soil adsorption of nitrogen, crop nitrogen use efficiency and decrease leaching of nitrogen-laden soil water through macropores.
- Ensuring that an appropriate nitrogen credit is subtracted from application rates for corn when rotating from a legume crop such as soybeans or alfalfa.
- Addition of perennial species to crop rotation to reduce both nitrate and water losses to subsurface drainage systems and groundwater.

In addition to better management of rowcropped areas, replacing targeted rowcrop agriculture with select best management practices such as CRP and wetlands may also have an influence on nitrate concentrations. These practices not only reduce the amount of fertilizer applied on the soil, they also have a high rate of nitrogen uptake in the early phases, thus limiting nitrate leaching to the groundwater. Comparing the six major (5th–order) tributaries of the Middle Cedar, decreases in nitrate concentration were significantly correlated with increasing CRP and wetland land use (Fig 20). Mean nitrate concentrations were derived from daily modeled data from DAFLOW and WASP modeling results from the four-year period (2001-2004, n=1461). Land use data was derived from 2002 Landsat imagery. Ranges of CRP acres varied from a high of 2.1% in the Shell Rock watershed, to a low of 0.67% in the Black Hawk Creek watershed. Ranges of wetland varied from 0.63% in Shell Rock, to 0.14% in Black Hawk.

The highly significant ($p<0.001$, $p=0.007$) results suggests that slight increases in conservation practices have a significant impact on nitrate concentrations in the stream. Both of these best management practices reduce the exposed soil and mineralization in rowcrop agriculture during the spring, during the period in which there are the greatest nitrate concentrations. These practices also increase plant uptake of nitrogen and convert highly mobile inorganic forms of nitrogen to less mobile organic forms. In addition, wetlands have an added advantage of slowing water discharge by increasing evaporation and transpiration in the watershed, thus reducing the nitrate load to the stream.

For the greatest benefit, wetlands, CRP, and other BMP's should be installed at locations that have the greatest ability to influence both nitrate and the water flow. Usually for wetlands, these areas are in smaller watershed that have lower topography. Historically, the regions in the Cedar River watershed that are most ideal for wetlands are in the Des Moines Lobe, located in the extreme western portions of the Shell Rock and West Fork Cedar sub-watersheds. This area has also undergone the most tile drainage in the past 100 years, draining most of the original wetlands that were part of the landscape.

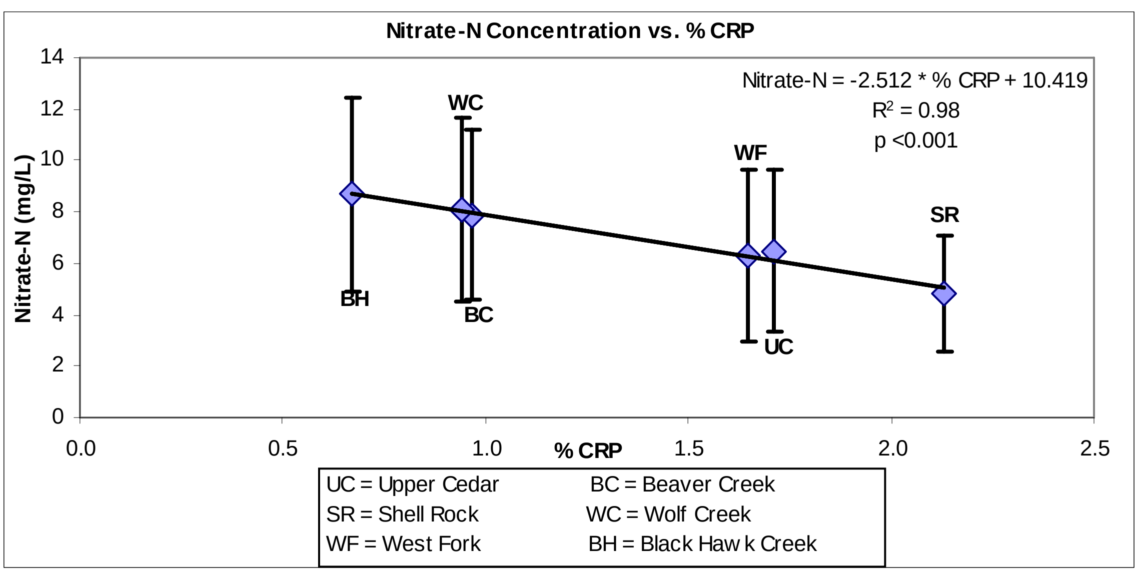

Figure 21. Relationship of percent CRP to mean nitrate-N concentrations in 5th-order Cedar River tributaries.

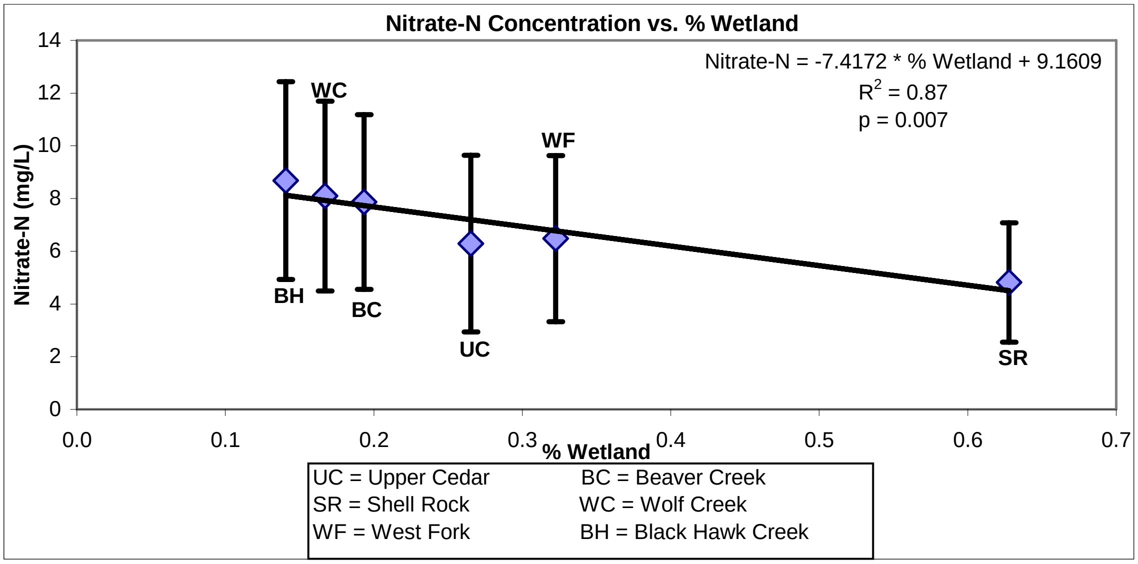

Figure 22. Relationship of percent wetland to mean nitrate-N concentrations in 5th-order Cedar River tributaries.

6.3 Reasonable Assurances

The wasteload allocations in this TMDL are set at existing levels, requiring no reductions at this time. However, extensive nonpoint reductions are required to meet the standards set by this TMDL. To decrease nonpoint nitrate contributions to the Cedar River watershed, various projects can be funded through Clean Water Act Section 319 grants. These funds are for projects that help with the installation of best management practices (BMPs) to address nutrient delivery to the Cedar River. Previous projects have found that carefully placed BMPs in Iowa can have a positive influence on water quality on a watershed scale (Fields et al., 2005; Schilling et al., 2006).

The Natural Resources Conservation Service offers service, advice, and support for many projects aimed at maintaining and improving the environment. One of the largest is the Conservation Reserve Program (CRP). Funding for the CRP program is provided by the Farm Service Agency. CRP land is designed to replace farming practices on environmentally sensitive acres with native or seeded grasses, wildlife plantings, trees, riparian, buffers, and filter strips. Participating landowners receive an annual payment throughout the term of the multi-year contract.

7 Monitoring

The Cedar River TMDL report represents ‘Phase 1’ in the development of a 2-phase iterative project to decrease nitrate concentrations in the impaired segment of the Cedar River. The effectiveness of this TMDL will continue to progress as more data are gathered and more resources are used to evaluate it, improving our understanding of nitrate in the water column and land surface. The main objective is to lead to stakeholder driven solutions and more effective management practices in the watershed. Continued monitoring will determine what management practices result in higher load reductions and the attainment of water quality standards. These monitoring activities are continuing components of the monitoring programs in the state of Iowa and will:

- assess the future beneficial use status
- determine if water quality is improving, getting worse, or staying the same
- evaluate the effectiveness of implemented best management practices

The first phase of the Cedar River TMDL has set specific and quantifiable targets for nitrate concentration reductions in the river, and has allocated allowable loads to all sources. Phase 2 will consist of implementing the follow-up monitoring plan, evaluating collected data, and readjusting the allocations and management practices if needed. The monitoring plan will also demonstrate whether nonpoint source reductions and TMDL goals are being achieved.

Water quality monitoring will continue in the Cedar River at the USGS stream gaging stations by the Iowa DNR Ambient monitoring program, the USGS, and the Cedar Rapids water treatment plant. This monitoring will continue indefinitely as long as funding is available. Also, many current and future 319 projects will undoubtedly have a nitrate nitrogen monitoring aspect to them. Data from these monitoring projects will indicate the overall trend of water quality in the larger streams and sub-basins in the Cedar River watershed, and help determine if the Cedar River is meeting TMDL goals.

Unfortunately, the scale (greater than 5^{th} order streams) of most ambient monitoring and this TMDL is larger than the scale of most water quality improvement projects, including 319, CRP, and CREP projects. If additional monitoring funds were made available, a more rigorous monitoring strategy of the Cedar River could be developed that includes a smaller scale investigation of nitrate levels and inputs at 3^{rd}-order streams. A rigorous monitoring strategy would incorporate multi-year, intense even-interval water quality sampling of many smaller sub-basins in the watershed. In addition to the water quality sampling, discharge monitoring data could also be equated with concentrations to give loads from the smaller watersheds. The smaller scale monitoring would be better fitted to the smaller, field scale water quality projects that are implemented in the watershed.

8 Public Participation

Pubic meetings have been held on numerous occasions during the past four years of the Cedar River TMDL process. Public informational meetings were first held in Cedar Rapids, Charles City, and Waterloo on June 7 and 8, 2001. Additional meetings were held in 2005. Public meetings were held in Cedar Rapids, Charles City, and Waterloo on May 15 and 17, 2006 to present and discuss the draft TMDL. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL report.

9 References

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Appendix A.

Time of Travel and Lagrangian Sampling on the Cedar River

Douglas J. Schnoebelen

Water-quality models and solute transport models require time of travel and flow data and are only as accurate as the data that are input. In order to better assess water-quality conditions and provide information on the transport of compounds on the Cedar River, accurate time of travel are needed. All surface water models require accurate data on travel times. The most accurate method of determining travel times in a stream at low-flow is by dye tracing (Kilpatrick and Wilson, 1989; Jobson, 2000). Knowing travel times from dye tracing it is then possible to extrapolate travel times to other flow conditions within the stream (Jobson, 2000). This allows investigators to more accurately predict travel times over a range of flow conditions. The USGS digital model DAFLOW (Jobson, 1989; USGS, 2002) can be used in conjunction with dye-tracing data for predictions of streamflow and transport velocity. The dye tracing provides accurate time of travel data that can be used in the DAFLOW model over a range of flow conditions. A dye tracing study was conducted by the U.S. Geological Survey on the Cedar River from Waterloo, Iowa to Cedar Rapids, Iowa in the fall of 2003. This dye tracing study was then used in the calibration and verification of the DAFLOW model.

In addition, dye tracing and time of travel data can provide accurate travel times for a Lagrangain sample set. A Lagrangian sample set is when water samples are collected from the same mass of water as it moves downstream. A Lagrangian sample set can help show how a constituent may move downstream (conservative or nonconservative behavior). The Water Department of the City of Cedar Rapids Iowa and the U.S. Geological Survey (USGS) funded a cooperative study to collect Lagrangian samples for nitrate on the lower reach of Cedar River from Waterloo to Cedar Rapids in October of 2003. The Lagrangian sample study was during a period of low flow (1000 ft^3/second or less). In addition, there was steady streamflow during the sampling (no rainfall within a week or during the sampling). Since there was no runoff during the sampling concentrations of nitrate plus nitrite as nitrogen (referred to as nitrate hereafter) were low (less than 2 milligrams per liter) between Waterloo and Cedar Rapids. In general, the Lagrangian sample set showed nitrate (following the same mass of water) as decreasing just slightly in concentration from Waterloo to Cedar Rapids, Iowa (a distance of approximately 76 river miles). At the Waterloo site the nitrate concentration was 1.7 milligrams per liter (mg/L) and moving to sites downstream nitrate concentrations were 1.5 mg/L at Vinton, 1.1 mg/L at Palo and 1.0 at Cedar Rapids, Iowa respectively. This is not surprising as the study was at low flow when travel times would be slow allowing for more pools in the Cedar River. More pooled water would allow more processing by algae. The lower nitrate concentrations during this time of no runoff contrast significantly with high nitrate concentrations typically found in the spring (May and June) at Cedar Rapids that are often over 10 mg/L.

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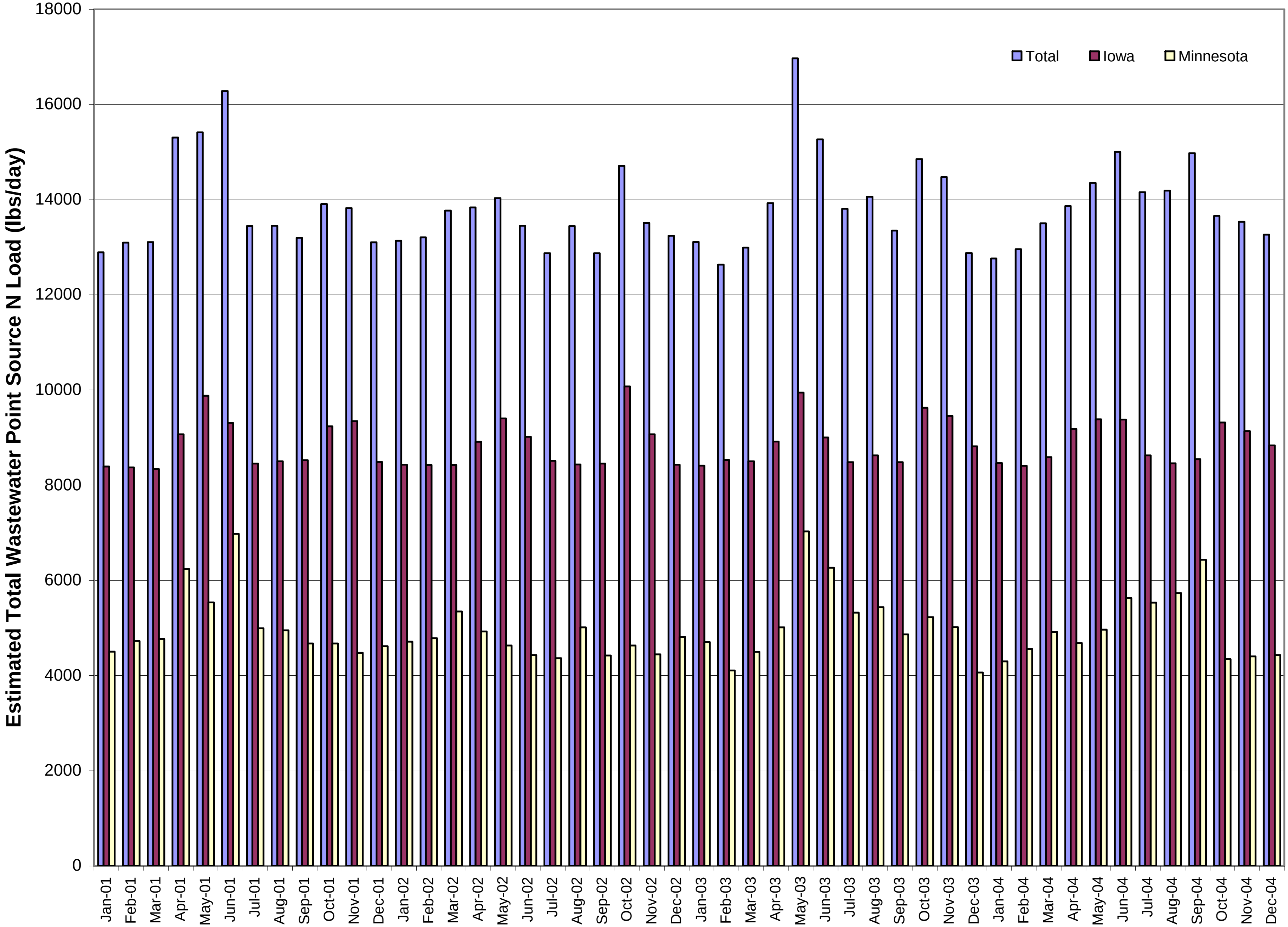
Appendix B. Monthly Point Source Loads for Iowa and Minnesota.



Appendix C. NPDES permitted and TMDL wasteload allocation by sub-basin.

Upper Cedar River				
NPDES #	Name	Current Allocation (tonsN/yr)	Controlled TMDL Allocation (tons/yr)	Continuous TMDL Allocation (lbs/day)
Iowa				
6658001	Orchard	0.4	0.4	--
0960001	Plainfield	2.2	2.2	--
6677001	Stacyville	2.3	2.3	--
3414001	Floyd	1.8	--	9.7
0932001	Janesville	4.1	--	22.4
6673001	St. Ansgar	5.1	--	27.8
1967001	Nashua	8.2	--	45.1
0915001	Denver	8.0	--	43.9
6663001	Osage	23.0	--	125.9
3405001	Charles City	35.6	--	195.0
0990001	Waverly	45.5	--	249.1
3405100	Cambrex, Inc.	1.7	1.7	--
Minnesota				
	Austin	635.7	*NA*	*NA*
	Elkton	0.7	*NA*	*NA*
	Hollandale	1.6	*NA*	*NA*
	Jim's Motor Mart	0.0	*NA*	*NA*
	Lyle	2.8	*NA*	*NA*
	Oakland S.D.	0.0	*NA*	*NA*
	Blooming Prairie	9.5	*NA*	*NA*
	Adams	3.9	*NA*	*NA*
	Waltham	1.0	*NA*	*NA*
	Osmundson Bros.	0.0	*NA*	*NA*

Appendix C. (Cont.)

NPDES #	Name	Allocation (tons/yr)	Controlled TMDL Allocation (tons/yr)	Continuous TMDL Allocation (lbs/day)
		Iowa		
1228001	Clarksville	6.2	6.2	--
4100900	DNR Pilot Knob S.P.	0.0	0.0	--
9820001	Fertile	1.7	1.7	--
9525001	Forest City	21.5	--	117.8
9500102	Golden Oval Eggs	16.7	16.7	--
9825001	Grafton	1.4	1.4	--
1253001	Greene	5.4	--	29.7
9800801	IDOT Northwood	0.5	0.5	--
9545001	Lake Mills	14.8	--	80.9
1700100	Lehigh Cement	0.1	--	0.8
9549001	Leland	1.2	1.2	--
0700115	Magellan Pipe Co.	0.0	--	0.0
9845001	Manly	6.6	6.6	--
3420001	Marble Rock	1.6	1.6	--
1750001	Mason City	89.8	--	492.0
3423001	Nora Springs	7.5	--	41.4
9855001	Northwood	10.1	--	55.4
1759001	Plymouth	2.2	2.2	--
1769001	Rock Falls	0.8	0.8	--
3430001	Rockford	4.7	4.7	--
1286001	Shellrock	6.4	--	35.0
9585001	Thompson	2.9	2.9	--
1700901	Willow Pointe	0.3	--	1.6
4100112	Winnebago Industries	6.9	6.9	--
59312	Tyden #1 Family Farm Feed	0.0	0.0	--
		Minnesota		
	Albert Lea	246.8	*NA*	*NA*
	Glenville	3.5	*NA*	*NA*
	Emmons	2.1	*NA*	*NA*
	Magellan Pipe Co.	0.0	*NA*	*NA*
	MDNR S.P.	0.3	*NA*	*NA*
	Twin Lakes	0.8	*NA*	*NA*

Appendix C. (Cont.)

West Fork Cedar				
NPDES #	Name	Allocation (tons/yr)	Controlled TMDL Allocation (tons/yr)	Continuous TMDL Allocation (lbs/day)
1203001	Allison	5.5	--	30.4
1716901	Clear Lake S.D.	1.5	--	8.0
3500901	DNR Beeds Lake S.P.	0.8	--	4.3
1240001	Dumont	3.3	--	18.3
3500201	Gold Key Dining & Lounge	0.2	--	0.9
3500202	Gold Key Motel	0.1	--	0.5
3544001	Hampton	16.2	--	89.0
3554001	Latimer-Coulter	4.1	4.0	--
1773001	Rockwell	5.2	5.2	--
3570001	Sheffield	4.6	--	25.1
1778001	Swaledale	0.8	0.8	--
3500900	Terrace Hill S.D.	0.4	0.4	--
1781001	Thornton	2.1	2.1	--

Beaver Creek				
NPDES #	Name	Allocation (tons/yr)	Controlled TMDL Allocation (tons/yr)	Continuous TMDL Allocation (lbs/day)
4201001	Ackley	8.9	--	48.8
1207001	Aplington	5.2	--	28.5
1271001	New Hartford	3.2	--	17.8
1281001	Parkersburg	9.9	9.9	--
3890001	Wellsburg	3.5	--	19.3

Black Hawk Creek				
NPDES #	Name	Allocation (tons/yr)	Controlled TMDL Allocation (tons/yr)	Continuous TMDL Allocation (lbs/day)
3800600	Dietrick MHP	0.6	0.6	--
3815001	Dike	4.7	--	25.5
3833001	Grundy Center	2.2	--	12.0
3839001	Holland	1.2	1.2	--
0737002	Hudson	10.4	--	57.2
3870001	Reinbeck	8.6	--	47.3
61302	Sunnybrook Farm Feedlot	0.0	--	0.0

Wolf Creek				
NPDES #	Name	Allocation (tons/yr)	Controlled TMDL Allocation (tons/yr)	Continuous TMDL Allocation (lbs/day)
3803001	Beaman	1.0	1.0	--
3809001	Conrad	5.2	--	28.5
8640001	Gladbrook	5.0	--	27.4
8600900	Hickory Hills Park	0.0	0.0	--
0743001	La Porte	11.2	--	61.4
8681001	Traer	7.9	--	43.0

Appendix C. (Cont.)

Middle Cedar River				
NPDES #	Name	Allocation (tons/yr)	Controlled TMDL Allocation (tons/yr)	Continuous TMDL Allocation (lbs/day)
0603001	Atkins	4.8	--	26.4
0600901	Benton Care Facility	0.0	--	0.0
0600201	Benton Commerce Village	0.5	--	3.0
1011001	Brandon	1.5	--	8.4
709001	Cedar Falls	125.2	--	686.0
0709600	Cedar Falls MHV 1	0.3	0.3	--
0709600	Cedar Falls MHV 2	0.7	0.7	--
3405001	Center Point North	6.8	--	37.1
5718002	Center Point South	3.1	--	17.1
0600601	Country Aire	0.1	--	0.8
0712901	Dewar S.D.	0.9	0.9	--
0721001	Elk Run Heights	6.4	--	35.1
0723001	Evansdale	22.3	--	122.2
0625001	Garrison	1.8	1.8	--
0733001	Gilbertville	3.8	--	20.7
5700104	IP&L Duane Arnold	0.5	--	2.6
1044002	Jesup South	1.3	--	7.3
1044001	Jesup Southeast	9.6	--	52.5
0650001	Mt. Auburn	0.0	0.0	--
0653001	Newhall	4.4	--	23.9
5765001	Palo	3.0	--	16.6
0670001	Shellsburg	4.6	--	25.3
0600600	Timber Ridge MHP	0.7	--	3.8
0680001	Urbana	5.0	--	27.5
0688001	Vinton	20.3	--	111.0
5792001	Walker	3.6	3.6	--
0700904	Washburn Area STP	3.0	3.0	--
0790001	Waterloo	505.2	--	2768.0