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A Comparison of Land Use and Nonpoint Source Pollution in the Cedar River Tributaries in Iowa

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A COMPARISON OF LAND USE AND NONPOINT SOURCE POLLUTION IN THE CEDAR RIVER TRIBUTARIES IN IOWA

An Abstract of a Thesis
Submitted
in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Chad Levi Fields
University of Northern Iowa
December 2004

ABSTRACT

A comparative water analysis on major Cedar River tributaries was conducted to determine nutrient and sediment concentration, nutrient loads, and watershed land use during the spring and summer of 2002. The Cedar River watershed is located on a primarily agricultural land, and has a drainage area of 20,242 km^2. The watershed extends from southern Minnesota to southeastern Iowa, where it joins the Iowa River which subsequently flows into the Mississippi River. Past studies have concluded that the Cedar River contributes much of the nutrients entering the Mississippi River and the Gulf of Mexico. These nutrients then contribute to the zone of hypoxia in the Gulf.

From April 28, 2002 until September 28, 2002, weekly samples were taken from six of the eight major tributaries that contribute flow to the Cedar River. Discharge data were obtained from continuously monitoring U.S. Geological Survey stations. Measured water quality parameters were those found in highly agricultural watersheds, including nitrate-N, total dissolved phosphorus (TDP) and suspended sediments in the water column, and sediment phosphorus in the bedload. Watershed land use data were obtained from 2002 Landsat satellite photography.

The results of this study indicate that of the six tributaries studied, Black Hawk Creek had the highest average nitrate-N (8.2 mg/L), sediment P (355.1 μg/g), and suspended sediment (438.1 mg/L) concentrations. Black Hawk Creek also had the highest percentage of row crop agriculture (82%). Beaver Creek had the highest average total dissolved P concentrations (136.5 μg/L). This study concluded that the most impaired water body entering the Cedar River during this investigation was Black Hawk

Creek. Regression analysis between water quality variables and land use indicates that water quality is dependant on certain watershed characteristics. The most statistically significant relationship was the negative correlation between nitrate-N concentrations and watershed areas (p value = 0.0078). The other highly significant relationship was the negative correlation between suspended sediment concentration and Conservation Reserve Protection (CRP) acreage (p value = 0.0151).

Future studies of water quality and watershed land uses should take into consideration more than row crop percentages. Also, suspended sediment load should be quantitatively investigated.

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This study by: Chad Fields

Entitled: A COMPARISON OF LAND USE AND NONPOINT SOURCE
POLLUTION IN THE CEDAR RIVER TRIBUTARIES IN IOWA

has been approved as meeting the thesis requirement for the

Degree of Master of Science in Environmental Science.

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INTRODUCTION

Background

The story of human influence on water quality dates back to the dawn of history. Egyptians and Samarians alike used their respective rivers as sources of drinking water, water for their crops, and cleaning. The first serious students of hydrology were the Greek philosophers. Aristotle proposed the conversion of air into water deep inside the mountains as a source for streams and springs. Romans first employed flow measurement techniques that used cross-sectional areas of streams in 97 A.D. In the 17th century a French scientist named Perrault made the first recorded measurements of rainfall and surface water flow. He compared the measured rainfall amount to surface runoff to reveal that the two were related. Today, USGS stream gaging stations continuously monitor stream height and discharge in almost all of America's major streams and rivers.

For a long time humans did not consider the implications their actions had on the natural environment. However, as human population and technology increased it became more obvious that large population centers and intensive agricultural practices on the land impaired water quality. Pollutants do not leave the environment with the flow of the stream; they are instead carried downstream and eventually have an impact. One of the most conspicuous examples of this is the so-called "zone of hypoxia" in the Gulf of Mexico, which is popularly known in the press as the "Dead Zone". The zone of hypoxia is an area in which there are low levels of oxygen dissolved in the water (<2 mg/L) at deeper levels due to increased algae on the water surface. Loss of dead phytoplankton to the bottom water initiates benthic respiration, which results in oxygen depletion in the water column. The high level of algae in the water is the result of excess nutrients, such as phosphorus and nitrogen, for the algae to feed on. It has been speculated that this zone is caused primarily by agricultural practices in the Upper Mississippi River basin, including the Cedar River (Goolsby et al., 1999). The Cedar River has been documented as having high levels of nutrients and sediment (Becher et al., 2000, Tavener and Iqbal, 2003). The land use in the watershed is highly agricultural.

Recently there has been a field of environmental research dedicated to the quantitative and qualitative relationship of watershed land use and effects on water quality. This project was designed to measure and compare nonpoint source pollution and land uses within the tributaries of the Cedar River watershed. This was done as an effort to better understand nutrient and sediment levels and their relationships to land use practices in the Cedar River tributaries.

Nitrogen

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 can be explained by the nitrogen cycle (Fig. 1).

Nitrogen (N) in surface water comes in both dissolved and particulate forms, and may exist in both inorganic and organic compounds. Organic N compounds in surface water can be in both dissolved and particulate forms. Inorganic N is found exclusively in solution 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 nitrate. This is due to the highly soluble and mobile nature of the compound, which travels through the water quite easily.

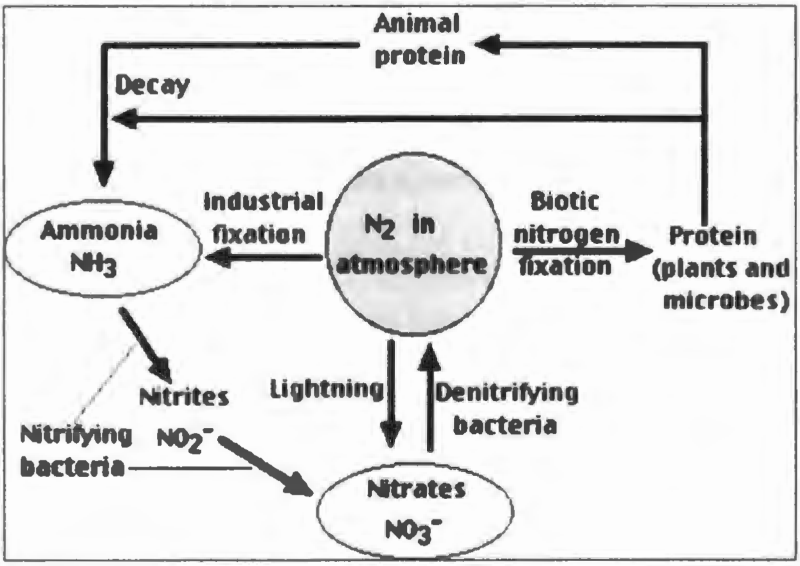

Fig. 1. The nitrogen cycle (Kimball, 2004).

Nitrate nitrogen (nitrate-N) is highly soluble and commonly found in surface waters throughout midwestern America, including Iowa (Hallberg and Keeney, 1993; Puckett, 1994; Goolsby et al., 1999). Nitrate in surface water has many sources, including municipal sewage, atmospheric deposition, biological N fixation, soil organic N, and/or nitrogen fertilizers. In Iowa, the primary nonpoint source for surface water nitrate is agriculture, specifically from the widespread use of anhydrous ammonia, application of livestock manure, legumes, 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. Baseflow and tile drainage are the main sources of nitrate to Iowa's streams (Hallberg, 1987, 1989).

Once in the water column, nitrate acts as a nutrient for bacteria and other organisms. High nitrate levels contribute to algal blooms, stream eutrophication and other concerns, including methemoglobinemia in children. Because of this the Environmental Protection Agency (EPA) set a maximum contamination level of 10 mg/L for nitrate-nitrogen in drinking water.

Phosphorus

Phosphorus (P), another important nutrient, is believed to be the primary cause of eutrophication in mainland surface water bodies. Like nitrogen, it can enter water bodies through application as a fertilizer. Unlike nitrogen, phosphorus does not have a gaseous form and therefore cannot volatilize into the atmosphere. Phosphorus is found both in the water column and sequestered in the bottom sediments of a stream or lake. Sequestered P in bottom sediments is not restricted from biological use. Certain environmental conditions can release P into the water and severely restrict further biological activities in the lake (Aguilera-Gomez et al., 1999).

Phosphorus in surface water bodies is either in the dissolved phase or the particulate phase (adsorbed onto soil, rock, or organic matter, see Fig. 2). Dissolved phosphorus is found in organic wastes excreted by animals and from the transformation of inorganic P into the soluble orthophosphate form. Particulate phosphorus may enter

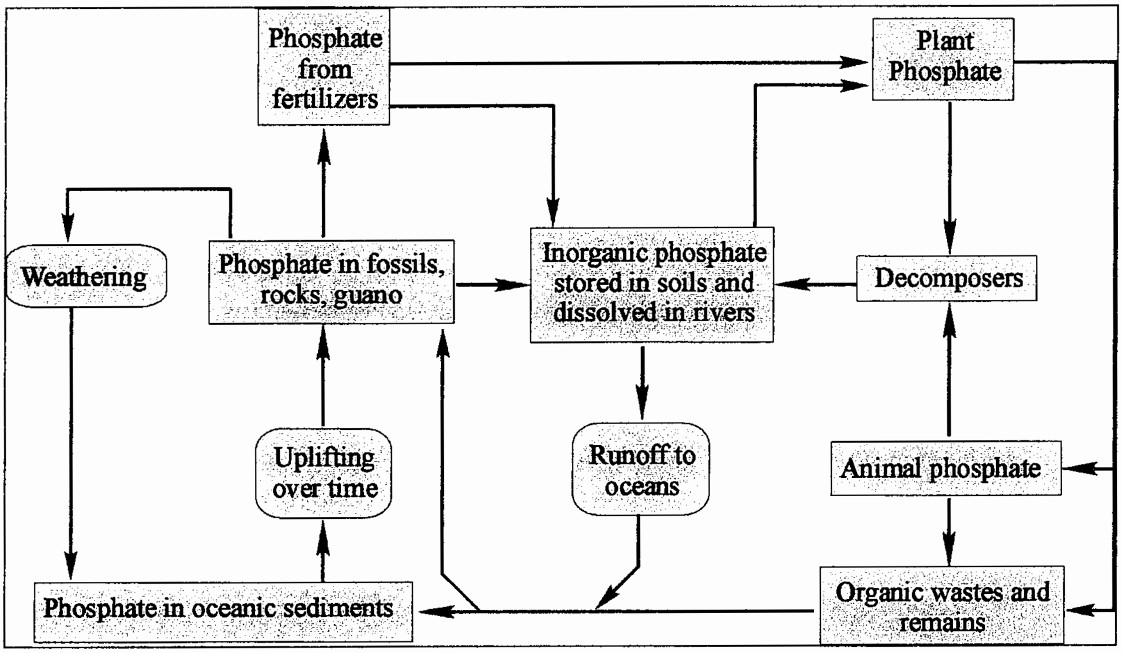

Fig. 2. The phosphorus cycle (Lenntech Phosphorus Cycle, 2004).

streams during the erosion of weathered rocks, soil, or organic wastes during precipitation or snowmelt events. Dead plants and algae also provide a particulate source of phosphorus to waterbodies. The organic and inorganic particulate and soluble forms of phosphorus undergo continuous transformations. The dissolved phosphorus (usually as orthophosphate) is assimilated by phytoplankton and altered to organic phosphorus. The phytoplankton are then ingested by detritivores (consumers of dead organic matter or detritus) or zooplankton (microscopic animals). Over half of the organic phosphorus taken up by zooplankton is excreted as inorganic P. Continuing the cycle, the inorganic P is rapidly assimilated by phytoplankton (Smith, 1990; Holtan et al., 1988).

In an aerobic surface water body most phosphorus is found in the particulate phase adsorbed onto sediment particles. This is especially true when the predominant sediment particles are silt and clay in size, as phosphate preferentially adsorbs on to smaller particles.

Suspended Sediment

Sediment, both suspended in the water column and on the bottom of the stream channel, is the major non-point source pollutant by volume in Midwestern streams (Iowa Department of Natural Resources, 1997). Sediment transportation in streams is a function of surface runoff, streambed erosion and stream bank erosion. Row crop agriculture and pasture are the primary land-use practices that contribute to sediment flux in streams nationwide, accounting for 38 and 25% of the total sediment loss, respectively (Welsch, 1991). Stream sedimentation in Iowa is compounded by the highly agricultural landscape. An estimated 70% of the Iowa land surface is either under row crops or pasture (Burkart et al., 1994). Surface runoff is the dominant sediment flux process for these two agricultural practices.

Once in the stream channel there are two major modes of sediment transport, bedload and suspended load. Stream velocity largely influences both methods of transportation. If stream velocity is not high enough for the sediment grain to overcome gravitational settling it is transported in the bedload of the stream. Bedload consists of grains moving close to the streambed by rolling, sliding, or saltating (hopping). Suspension of a sediment grain occurs when the magnitude of the vertical component of the turbulent velocity is greater than that of the settling speed of the grain (Roberts et al., 2003). Suspended sediment particle transport is highly dependent on size. The smaller the grain size, the less velocity needed to suspend it. Smaller, colloid size particles can stay suspended even in stagnant waters and move at almost the same rate as the water velocity. Most particles move in a variety of bedload and suspended transportation methods before final deposition (Fig. 3).

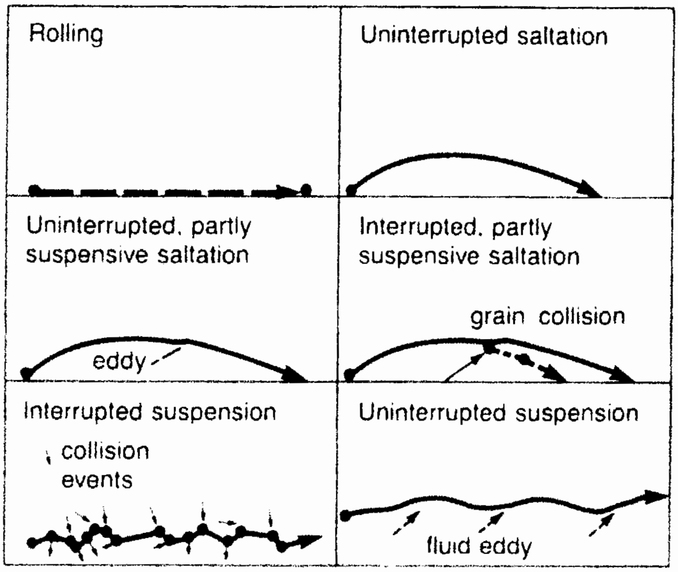

Fig. 3. Types of Sediment transport (Boggs, 1987)

After a flood event the suspended sediment and the sediment carried by the bedload are eventually deposited. Sediment deposition can occur in any area where there is a decrease in surface water velocity, such as a dam, pond, lake, ocean, or a pool formed within the stream channel. The deposited sediments remain trapped in the stream channel until another flooding event raises the velocity to a high enough level to transport the sediment. A precisely quantitative method for estimating the movement of bedload in a stream is not yet available. However, there are a number of methods and tools for sampling suspended sediment in the water column.

Besides erosion of valuable topsoil, sediment particles are also the main component of turbidity. Turbidity is the measurement of the diffraction of light by particles in the water. Higher turbidity values indicate that less light is getting through to initiate photosynthesis in aquatic vegetation. Murky water limits the amount of fish and other aquatic species that can live in the stream.

Watershed Delineation

A watershed is a unit of land that collects precipitation in channels that flow downhill to a common outlet at which the water enters another body of water such as a stream, river, wetland, lake, or ocean (Black, 1996). High areas of elevation, known as drainage divides, separate individual watersheds. Classification of watersheds is based on the highest order stream within the drainage network. First order streams are the lowest order, having no tributaries draining into them, second order streams have at least two first order tributaries, and so on (Fig. 4).

The volume of water discharging from a stream is determined by the size of the watershed, its land-use practices, and the climate. In addition to surface runoff, groundwater flow, or baseflow, is an important component in the makeup of discharge. A key function of a watershed is that it provides a place where the environmental chemicals are processed through their interactions with the flora and fauna, and then transported to the common outlet. The movement of water through a watershed often attenuates any chemicals that may have been added by surface runoff. This is

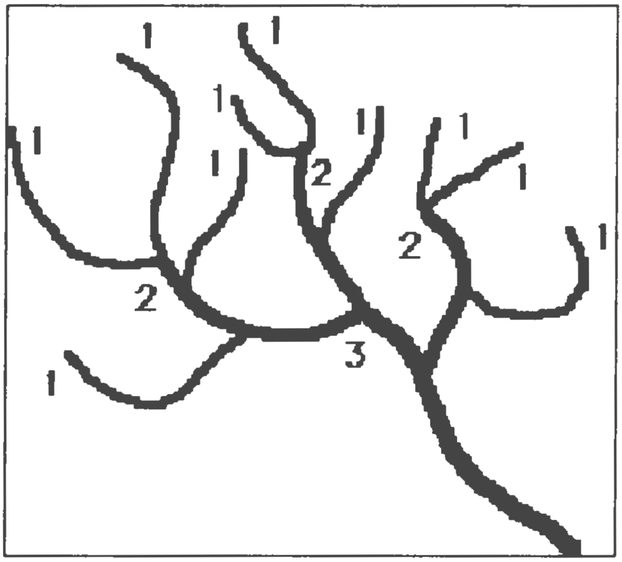

Fig. 4. Classification of stream order in a watershed.

particularly important in areas where agricultural lands produce high amounts of nutrients in the runoff water. Another function is the flushing of the soil and the aquifer materials, which in turn mobilizes chemicals and the chemical compounds present both in ground water and on the land surface. The second function is the key factor in the sediment load and associated nutrients that are transported from the watershed to the next hydrologic unit.

The land use, size, and the relief of the watershed area are key factors in determining the amount of nutrients leaving the watershed. Increased pressure on agricultural producers has increased demands on the watershed areas for more water as well as more fertile soil. In an attempt to increase the soil fertility, chemical fertilizers, animal manure, and wastewater effluent are routinely applied to the fields.

Unfortunately, fertilizers applied to the land do not remain stagnant; instead they end up being transported to the ground water or the rivers within the watershed.

All watersheds in Iowa have been delineated using the Iowa Geological Survey's Hydrologic Unit Code (HUC) watershed areas. These delineations are done by using Geographic Information System (GIS), currently known digitized topography, and various stream channel data. HUCs are designed by the USGS as a way of delineating and coding different watersheds throughout the United States, and are based on a numeric ordering method. The more digits in the code, the smaller the watershed areas.

PREVIOUS STUDIES

Nutrient Studies in the Mississippi River Basin and Gulf of Mexico

Scientific investigations to study the cause behind the large algal blooms and the resultant hypoxia in the Gulf of Mexico increased dramatically after the Midwestern flood of 1993 expanded the area of anoxic water in the Gulf. The first large scale study of nutrient inflows into the Gulf of Mexico began under the U.S. Environmental Protection Agency. The program was named the Gulf of Mexico Program and was designed as a comprehensive strategy to conserve and protect the natural marine resources in the Gulf (Dunn, 1996). The study measured total nitrogen and total phosphorus along with stream discharge to quantify the total load of nutrients entering the Gulf of Mexico from 1972 to 1993. Trends were computed for nutrient inflows from 37 streams discharging into the Gulf from the conterminous United States. These streams varied in drainage size from a low of 72 mi^2 for the Anclote River, to 1,125,300 mi^2 for the Mississippi River drainage basin. It was determined that more than 85% of the nutrient loading into the Gulf of Mexico came from the Mississippi and the Atchafalaya Rivers. About 70% of the mean annual nutrient loads from the Atchafalaya River are introduced from the Mississippi River through the Old River Outflow Channel. This study signified the importance of the Mississippi River to the nutrient loading into the Gulf of Mexico.

During the 37-year study, statistically significant long term increases in flow-adjusted residual concentrations of total nitrogen were detected at 19 stations. Decreases were detected at 7 stations, and 11 stations had no significant trends. Total Phosphorus had an increasing trend at 7 stations, and had a decreasing trend at 11 stations. No significant trends were detected in 19 stations.

Goolsby and others (2001) provided a long-term historical look at specific forms of nitrogen input into the Gulf of Mexico. This study put historical streamflow and concentration data into regression models to estimate the flux of nitrogen (N) to the Gulf of Mexico and to determine major contributors of nitrogen within the Mississippi Basin. From 1980-1996 the mean annual total N flux to the Gulf of Mexico was 1,568,000 t/yr (Goolsby and Battaglin, 2001). The majority of nitrogen entering the gulf (61%) was in the nitrate form, with the other leading forms being organic N (37%) and ammonium N (2%). It is estimated that the flux of nitrate N to the Gulf has approximately tripled during the last 30 years, with most of the increase between 1970 and 1983. Mean annual flux of nitrogen into the Gulf has remained static during the last thirty years, with fluctuations being the result of precipitation changes and not due to a concentration increase. During wet years N flux can go up by 50% or more due to flushing of nitrate N that has accumulated in the soils of the unsaturated zones in the watershed (Goolsby and Battaglin, 2001).

Nutrient Studies in Iowa

Becher and others (2000) released a study on nutrient loading into the Mississippi River from eastern Iowa watersheds during 1996 and 1997. The rivers in the study included the Wapsipinicon River, the Cedar River, the Iowa River and the Skunk River. In this study twelve surface monitoring sites were selected following the NAWQA sampling design protocol (Hirsch et al., 1988). These twelve sites were then classified as either *indicator* or *integrator* sites. Indicator sites were smaller watersheds (320 to 1,080 km^2) that had homogenous land use and topography. Integrator sites represented larger watersheds (6,050 to 32,400 km^2) that were affected by combinations of land use, point sources, and topography. Monthly sampling and statistical analysis revealed that integrator sites typically had lower nitrate and phosphorus dissolved in the water column. The study indicated that larger watersheds tended to negate some of the effects of larger row crop areas. Throughout the study, nitrates in both indicator and integrator sites had concentrations above the 10 mg/L as nitrate-N drinking water maximum contamination level (MCL) set by the EPA. Total phosphorus levels were also generally higher than the EPA's recommended level of 0.1 mg/L. Becher and others concluded that although only 4.5% of the total Mississippi watershed is included in the eastern Iowa (including the Cedar, Wapsipinicon and Iowa Rivers), the contribution of nutrients into the Mississippi is around 45%, making the region the largest contributor of nutrients to the Mississippi River.

Schilling and Libra (2000) found a strong linear correlation ($R^2 = 0.94$) between the nitrate concentrations in water and the row crop intensity in the watershed, particularly in small (<1,000 km^2) watersheds. In larger watersheds (>1,000 km^2), the relationship still existed, although not as significant as in the smaller ones ($R^2 = 0.65$). The study also suggested that nitrate concentration in the water was directly influenced by the watershed size. For example, the slope of nitrate concentration versus the row crop percentage decreased with increasing watershed size. This project was done using certain selected watersheds in Iowa, and was not watershed specific or landform specific in its implementation.

A study done by Tomer and Burkart (2003) looked at Nitrate N fluxes from tile-drained watersheds in Central Iowa. The study indicated that in tile-drained watersheds, Nitrate-N concentrations were not usually diluted by flooding, unlike most natural watersheds in which precipitation has a diluting effect on the nitrate-N concentration, especially in urban, point-source influenced streams. Measured nitrate-N concentrations generally exceeded the 10 mg/L nitrate-N standard set by the EPA. Smaller discharge usually indicated a smaller concentration.

Tavener and Iqbal (2003) developed a hydrologic budget of the Cedar River to determine the total nitrogen and phosphorus loads leaving the Cedar River watershed in Iowa. This was done by using mean concentrations of nitrogen and phosphorus determined from a study by Becher and others (2000) during the 1996-1997 water years. The concentration was multiplied by the sum of the tributary discharge and the calculated Cedar River baseflow. This gave an estimation of the total nitrogen and phosphorus discharged from the Cedar River during July, August and September of 2000. The approximate total nitrogen lost during the three month study period was 2.99×10^6 kg. Total phosphorus discharged was estimated to be 2.39×10^5 kg (Tavener and Iqbal, 2003).

Suspended Sediment

In recent years there has been increasing recognition of the need to include sediment control strategies in watershed areas that undergo heavy erosion. In addition to the harmful effects of erosion on the topsoil, part of the sediments transported to the stream channel may eventually turn into suspended sediment. Suspended sediment impairs aquatic ecosystems by reducing light penetration through the water column, clogging aquatic vegetation and impairing water quality (Waters, 1995). Suspended sediment is also significant for its function in the transport of nutrients, heavy metals and contaminants downstream.

Although sediment has been recognized as the number one non-point source pollutant by volume in Iowa streams, there have been very few studies that include suspended sediment in Iowa watersheds. This includes the Cedar River, and the entire Mississippi River basin. Accurately measuring suspended sediment transport is complicated due to short periods of intense loading, followed by longer periods where sediment transport is limited. In temperate, agriculturally dominated watersheds, most sediment transport occurs during the early spring months of high rainfall and little vegetation. In times of flooding, sediment loads can increase as much as an order of magnitude from the average value.

Continuously measuring suspended sediment concentration in a water body can be very costly and time consuming. The highly erratic nature of the transport of suspended sediment and of water discharge, especially in smaller streams, compounds this problem. Because of the difficulty in continuously measuring suspended sediment concentrations, there have been numerous estimation procedures and algorithms designed to accurately depict the amount of sediment in the water column. They are mostly done by drawing a linear, log, or other kinds of relationship with the discharge that is usually measured more vigorously than suspended sediment concentration.

Phillips and others (1998) did a comparative study to find out the most accurate method of estimating suspended sediment load by using infrequent (weekly-monthly) sampling periods on the Ouse River (3,315 km^2) and the Upper Swale River (499.2 km^2) in England. They included 22 different load estimation procedures on the weekly and monthly data and compared that to the 15-minute interval continuous sediment concentration and discharge data. The study found that watershed size had a great deal of impact on the accuracy of the data. The Ouse River watershed, at 3315 km^2, had much more accurate estimations in all procedures than the much smaller Upper Swale River. Also, sampling frequency had a large impact on the accuracy and precision of load estimation procedures. The smaller the time between samples, the higher the accuracy and precision of the data.

STUDY AREA

The area studied in this research included six major tributaries of the Cedar River. The sampling sites were: Beaver Creek in New Hartford, West Fork Cedar River in Finchford, Shell Rock River in Shell Rock, Little Cedar River in Janesville, Wolf Creek north of Dysart, and Black Hawk Creek in Hudson (Fig. 5). The Cedar River extends from the headwaters in southern Minnesota to Conesville IA, where it joins the Iowa River which subsequently flows into the Mississippi River. The total drainage area of the Cedar River is 20,242 km^2, 87% of which is located in Iowa (Iowa Department of Environmental quality, 1976). There are eight major tributaries to the Cedar River, along with many smaller, first order streams throughout (Squillance et al., 1996).

Landform Regions

The major landform regions that the main tributaries flow across 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 (Fig. 6). The Cedar River also flows over the Southern Iowa Drift plain before joining the Iowa River. The Des Moines Lobe is the youngest landform region in Iowa, formed by glaciation in the Late Wisconsian period 12,000-15,000 years ago. 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 very limited because most water either evaporated or moved through subsurface drainage routes. These types of terrains are often poorly suited for row-crop agriculture due to high water levels that drown the plant roots. However, over the past 150 years man-made drainage basins have been

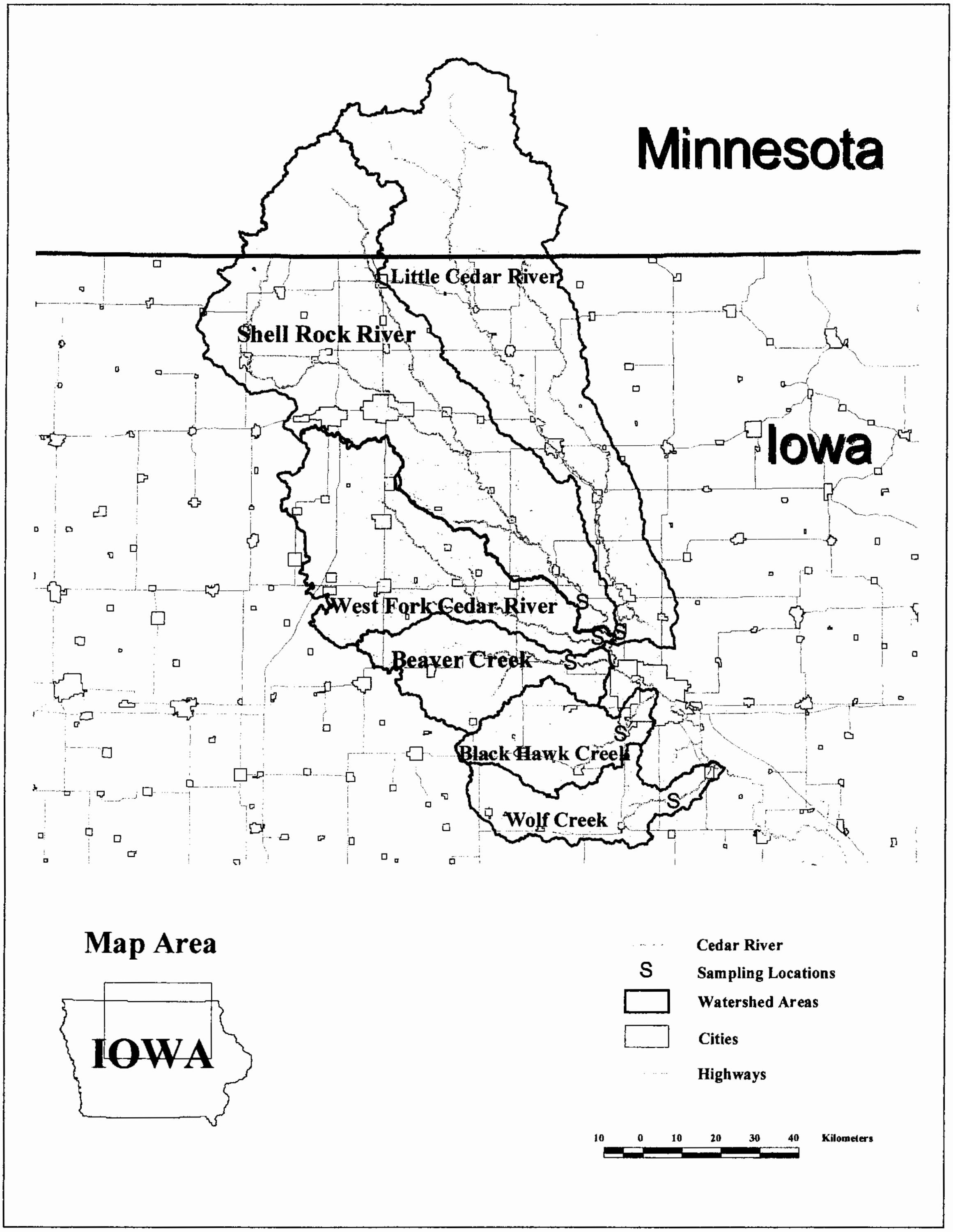

Fig. 5. Cedar River tributaries and sampling sites used in this study.

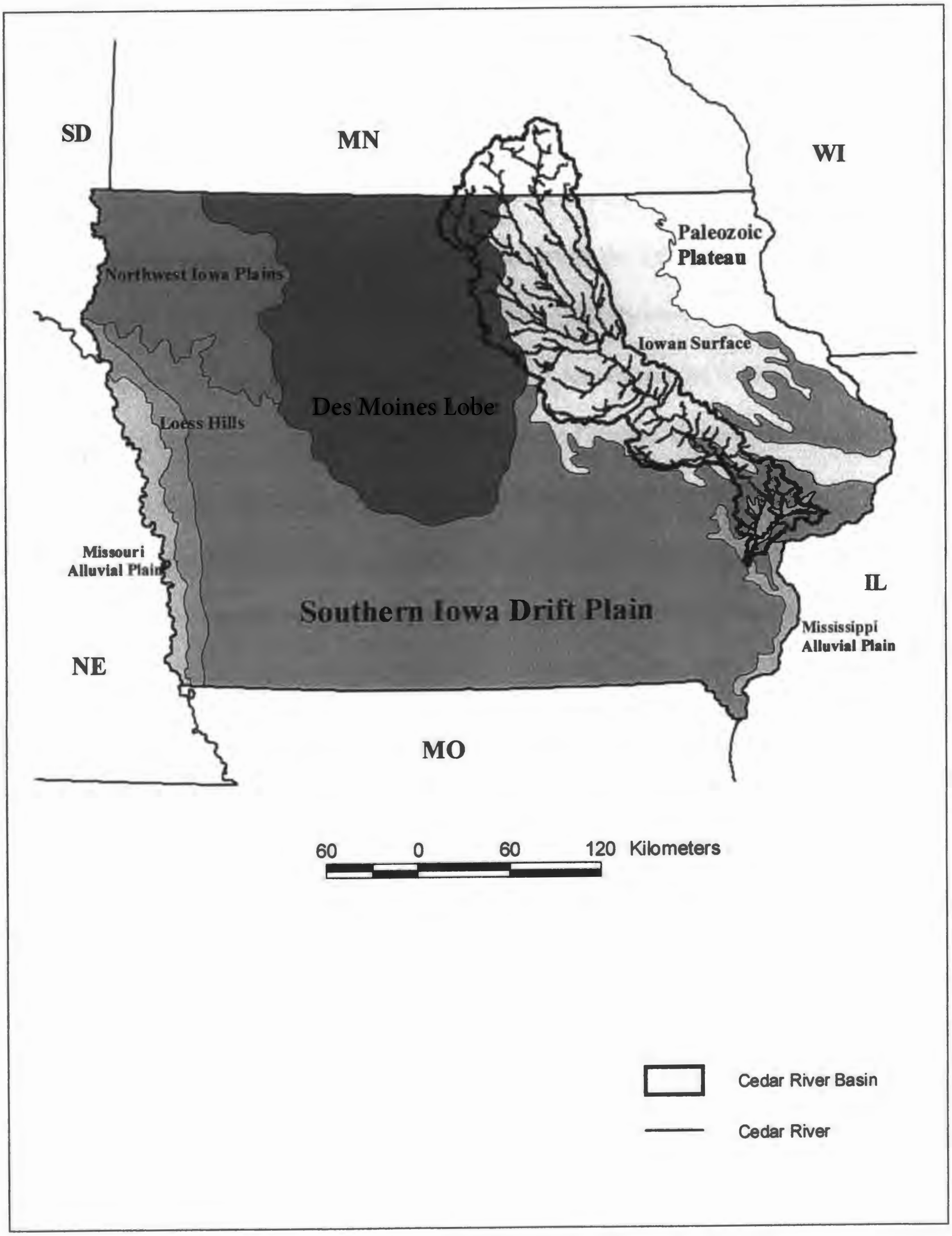

Fig. 6. Location of the Cedar River watershed and major landform regions of Iowa.

put in place, 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. Row crop agriculture in the Des Moines Lobe has dramatically increased over the past hundred years. In 1900, row crop agriculture in the Des Moines lobe was estimated to be 41%, which has increased to 72% in 1992 (Brown and Jackson, 1999).

Much of the central 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, undergoing 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 has been blown off the surface by strong winds. Topography in the Iowan Surface tends to be gently rolling, with highly meandering low-gradient streams. Rowcrop agriculture dominates 60% of the Iowan Surface (Brown and Jackson, 1999; Prior, 1991).

Predominant land use in the Cedar River watershed is agricultural (81%); the two major crops are corn and soybeans. Along with rowcrop agriculture, livestock operations are scattered throughout the watershed, which include beef, dairy cattle, hogs and sheep establishments. There are four major urban establishments located along the Cedar River; Albert Lea in Minnesota, and Mason City, Cedar Falls, Waterloo, and Cedar

Rapids in Iowa. There are also many other small towns scattered throughout the watershed. Most municipal water providers in the watershed use ground water as their primary source. Some cities, like Cedar Falls and Waterloo, use the Silurian-Devonian aquifer. Many use shallow wells drilled into the alluvial aquifer found along the river channel.

Surface and Groundwater Hydrology

The Cedar River joins the Iowa River in Conesville, where the yearly average discharge is recorded as 136 m^3/s. This discharge is larger than the Iowa River average of 82 m^3/s. It should be noted that discharges of both rivers vary considerably over time. During flood events overland flow is the main constituent of discharge and during dry events baseflow is the primary component of flow. On an annual basis, it is estimated that 96% of the flow is baseflow, and the remaining 4% is surface runoff (Squillace and Endberg, 1988).

The alluvial aquifer system in the Cedar River watershed is the most widespread and the most easily accessed of all groundwater aquifers within the watershed. It supplies the most water in the area, exceeding the next productive aquifer by 2.5 times (Olcott, 1992). Most of this aquifer is formed along the Cedar River Valley and is composed of ancestral channels of the Cedar River. The channels consist of highly permeable gravel, sand and silt deposited during the constant meandering of the stream channel. These sediments are originally derived from either the bedrock under the channel, or are deposited from glacial processes during the past ice ages.

Also close to the land's surface is the Pleistocene aquifer, which consists of glacial till. The permeability of this aquifer varies greatly from region to region, ranging from low-permeability in clay-rich areas to high-permeability areas of sandy sediment.

The Silurian-Devonian aquifer lies directly beneath the alluvial aquifers. Most of the Silurian-Devonian formation consists of limestone and dolomite with interbedded shale and evaporite beds. The thickness of the Silurian-Devonian aquifer ranges between 92 and 122 meters. Water movement in the aquifer is primarily through secondary openings, caused by fracturing and dissolution of the calcium-carbonate by water. Permeability in the Silurian-Devonian aquifer varies greatly depending upon the amount of fracturing and secondary dissolution.

The Cambrian-Ordovician aquifer contains many layers separated by leaky confining beds. The topmost layer of the Cambrian-Ordovician aquifer is the Maquoketa confining unit, which is a lithologically diverse dolomitic shale (Eaton and Bradbury, 1998). This low-conductivity unit has areas of fractures and holes that allow infiltration from the aquifers above and below it. The most important water-yielding layer in the Cambrian-Ordovician system is the Jordan aquifer. The Jordan aquifer is not made up of one specific formation, but of many hydrologically connected groups, including the Jordan Sandstone, the St. Peter Sandstone, and the dolomitic St. Lawrence Formation (Olcott, 1992). The high quality of water and the high conductivity in the Jordan Aquifer make it well suited for long-term human consumption.

The two aquifers below the Cambrian-Ordovician system are the Dresbach aquifer and the crystalline rock aquifer. Because of high salinity, these two aquifers are not for human use in Iowa.

Climate

Iowa climate 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 (Squillence et al., 1996). Precipitation in the watershed ranges from 91 cm/yr in the southwesteren region to 81 cm/yr in the northeastern region, with some 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).

MATERIALS AND METHODS

Sampling Sites

Weekly samples were taken from six major tributaries of the Cedar River from April 28, 2002 to September 28, 2002. These tributaries are 3rd order streams that serve as the major sources of water to the Cedar River. Although there are other streams in the watershed that are of lesser orders, their contribution to the total flow of the Cedar River is less significant than the tributaries investigated.

All six tributaries were tested for four variables: nitrate-N (NO_3), total dissolved phosphorus (TDP), total suspended solids (TSS) in the water, and total phosphorus (TP) in the bottom sediments of the stream channel. Samples were taken weekly at sites close to United States Geological Survey (USGS) discharge monitoring stations (see Table 1). The goal was to correlate nutrient concentrations in the water column with stream discharge and then estimate the annual nutrient loads.

Table 1

GPS Coordinates of sampling locations (UTM Zone 15)

Tributary Name	Location	Easting	Northing
Wolf Creek	Hwy 21 N Dysart	557832	4677962
Black Hawk Creek	Hudson	544142	4695128
Beaver Creek	New Hartford	531299	4713415
West Fork	Finchford	538238	4719717
Shell Rock River	Shell Rock	534357	4728805
Little Cedar	Janesville	543883	4720864

Sampling Procedure

The DH-48 depth-integrating sampler is designed to accurately capture a representative sample of sediment and other water quality variables in the stream column without disturbing the natural flow (Fig. 7). The sampler is made of streamlined aluminum casting and can sample the water column to within 3 ½ inches of the streambed. The unit is attached to standard one-meter long wading rods so it can be safely lowered from a bridge during high-flow periods, or used by a standing person during low flow. During the sampling process the nozzle is pointed directly towards the stream current. As water enters the bottle, a special valve releases air from the bottle into the stream. A neoprene seal connects the bottle with the aluminum chassis, eliminating any leaks. The general design of the sampler is to cause the least amount of disturbance to the stream flow while taking a representative sample of the water column (FISP, 1996).

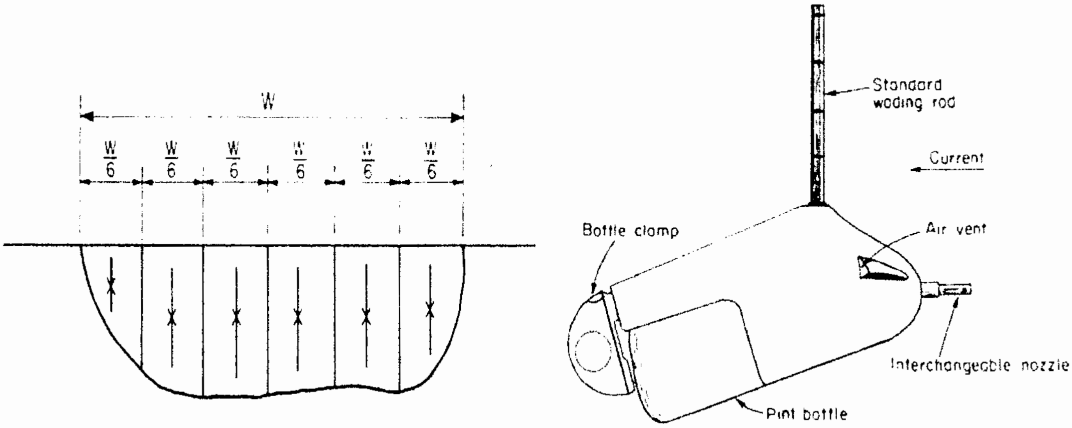

Fig. 7. Stream channel sampling method (left) and DH-48 depth-integrating sampler (right) (FISP, 1996).

The bottles used in the DH-48 sampler held one pint of water and were made of HDPE plastic. Prior to sampling, the bottles were acid washed and rinsed with deionized water. At each location the DH-48 sampler was inserted at five evenly spaced intervals in the water column perpendicular to the stream channel. During low-flow conditions, sampling was done in-stream, and during high-flow conditions the sampler was lowered from the upstream side of a bridge. The DH-48 sampler was then moved down and up the water column at a uniform rate, paying close attention as to not fill the sampling bottle completely. If the bottle becomes full, sediment concentration increases as water exits the air vent and more water enters the nozzle. If bottle was accidentally filled, the water was removed and the sampling process was started again. This procedure was done on five equidistant transects in the stream.

The reason for five different transects instead of a single grab sample is that many water quality variables, most importantly sediment, are not homogeneously mixed throughout the water column. Instead, they are concentrated at areas of high depth and flow and diffused in shallow, low-flow areas. Taking one grab sample thus biases the data. After all five sampling bottles were filled they were composited together into a single acid washed gallon container. A portion of the composite (usually 100 mL, depending on the concentration of sediment) was filtered on site with a hand-pump and 45 μm glass filtration membrane and put inside a smaller plastic container. All samples were then labeled with stream location, date and time, and taken back to the lab and frozen for preservation. Samples were later thawed for lab analysis.

Along with water quality samples, grab samples of the bottom sediments were taken at consistent locations with a sampling dredge. All sediment samples were placed in plastic bags, labeled and refrigerated for lab analysis.

Lab Analysis

A Dionex (DX-120) Ion Chromatograph was used for nitrate analysis on filtered water samples. Under room temperature, all water samples were manually injected into the ion exchange column. The samples were scanned under suppressed conductivity (in µS) to obtain peaks for all nitrate detections (Fig. 8). These peaks in conductivity were linearly correlated with standard NO_3^- concentration values using a linear regression model (y=mx+b). Dionex uses the program Peaknet® for measuring and recording changes in conductivity along with fitting a calibration curve to the standards. The limit of detection for nitrate on a Dionex DX-120 system is 0.1 mg/L (Clescerl, 1998). A carbonate-bicarbonate eluent was used during the whole procedure.

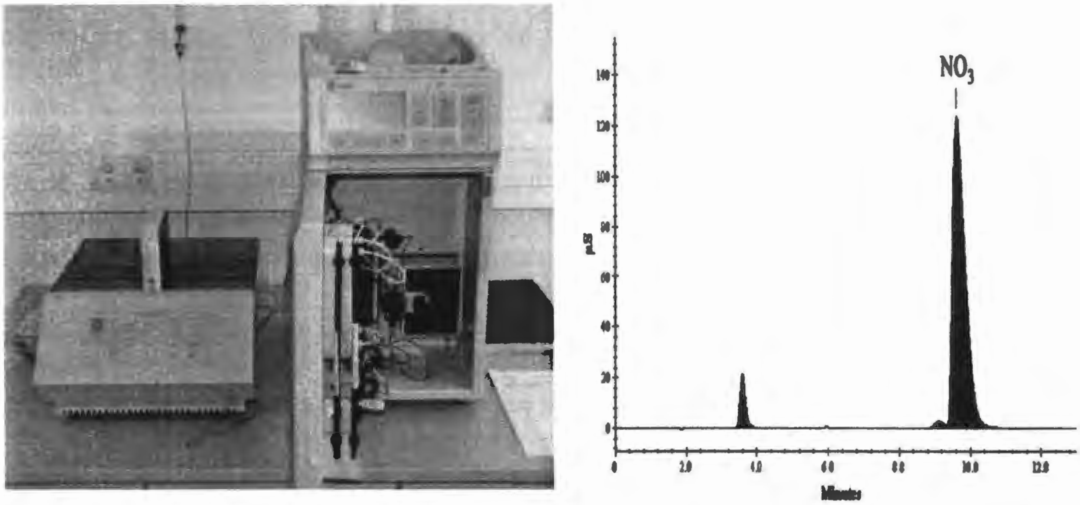

Fig. 8. A Dionex (DX-120) Ion Chromatograph (left) and Peaknet® readings (right).

For measuring total phosphorus in the bottom sediments, a portion of each grab sample was placed into an aluminum cup and desiccated until it became completely dry. After desiccation, one gram of the sediment sample was separated and carefully ground with a standard mortar and pestle and placed in a 125 ml Erlenmeyer flask with 50ml of deionized water, 1ml of digestion H_2SO_4, and 0.4 grams of potassium persulfate ($K_2S_2O_8$). This mixture was slurried together, labeled, covered with aluminum foil, and autoclaved for 30 minutes. After cooling, the slurry was poured out of the flask into plastic tubes, which were then centrifuged for 10-11 minutes or until a noticeable separation existed between the sediment and the water column. Using a pipette, as much water as possible was removed from the centrifuge tube and placed in a 100ml volumetric flask. The pH of the water went back to neutral (7) after addition of sodium hydroxide (NaOH) to the solution. The flask was filled to the 100 ml mark with deionized water.

In a separate 250 ml flask, the molybdenum reagent was mixed. This required 37.5 ml of ammonium molybdnate, 125 ml of reagent H_2SO_4, 12.5 ml of potassium antymonyl tartate, 1.06 grams of ascorbic acid, and 75ml of deionized water. Then, 5 ml out of the sediment water were mixed with 10 ml of the reagent in a 50mL volumetric flask and filled to the mark with deionized water. In the next 10-30 minutes, the substance was poured into a cuvette to measure the absorbance with a colorimeter set at a wavelength of 880 nm. The higher the absorbance the higher the amount of phosphorus present in the sample. The readings were then compared with a linear calibration curve to obtain the concentrations of Total P in µg of mass per gm of sediments. Using the ascorbic acid assay, the detection limit for TP in sediment is 5 µg/g (Clescerl, 1998).

The analytical procedure for total dissolved phosphorus (TDP) was much the same as for sediment P. The procedure included taking 50ml of the filtered water sample, adding the H_2SO_4, autoclaving, adding the NaOH and the phenylethylene, and then mixing 40 ml of the sampled water with 10 ml of the reagent. The higher amount of sample water used was due to the fact that the concentration of TDP in the water column is much less than the concentration of phosphorus in the sediment. Also, a different standard calibration curve was used for the measurement of total dissolved phosphorus in the water. The limit of detection for TDP using the ascorbic acid method is 5 μg/L (Clescerl, 1998).

Total suspended solids were measured by first determining the total volume of water and sediment in each sample. Subsequently, the water and sediment were placed in a container of known weight, and put in a drying oven at 105°C. After the water had completely dried up, the container volume and the dried sediment were measured to finally calculate, in mg/l, the total suspended solids per unit volume of water in the sample (WMO, 1994).

Load Calculation

Along with concentrations, the accurate stream discharge data are also needed to calculate the loads of TDP and NO_3 that were transported from the watershed area to the streams during the period of study. For this reason, the water quality sampling locations near the USGS gauging stations were selected. The USGS stations usually measure flow every 15-minutes, and are checked for accuracy by in-situ measurements every few weeks (Fig. 9).

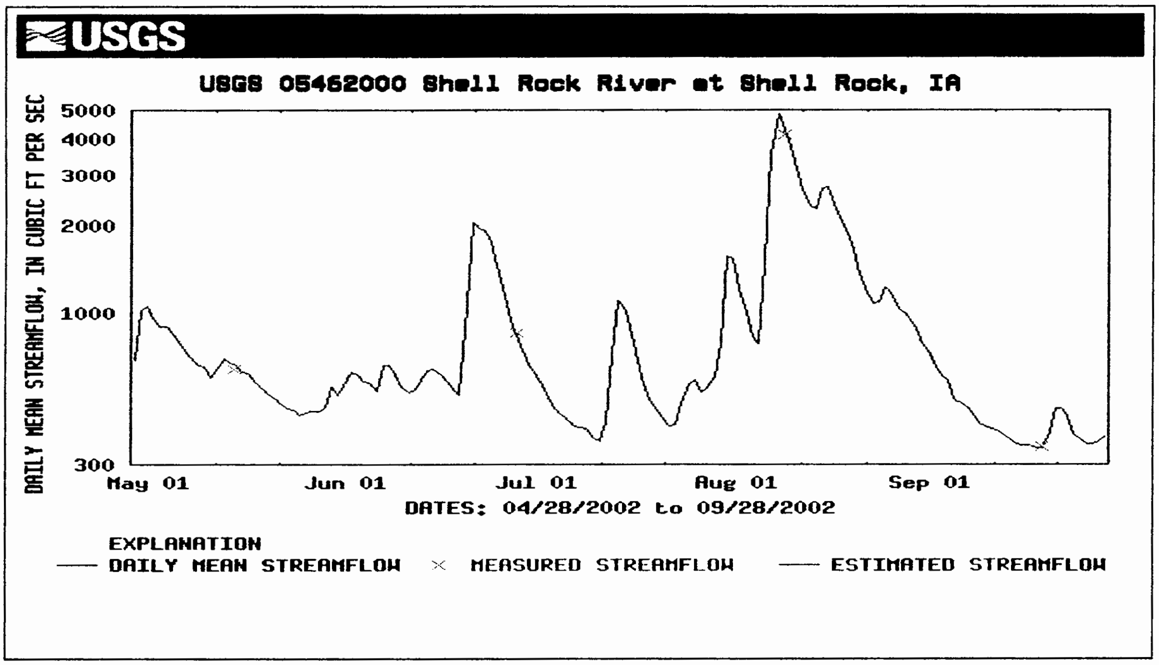

Fig. 9. USGS hydrograph for the Shell Rock River used to determine flow and estimate loads during the study period.

The general idea of a pollutant load is the mass of the pollutant that passes through a cross-sectional area over a period of time. The end result is a basic unit mass, in kilograms, Tones, etc. The ideal step to study loads is to determine flux, or pollutant transfer rates. Flux is the instantaneous composite of the streamflow and the pollutant concentration (Fig. 10).

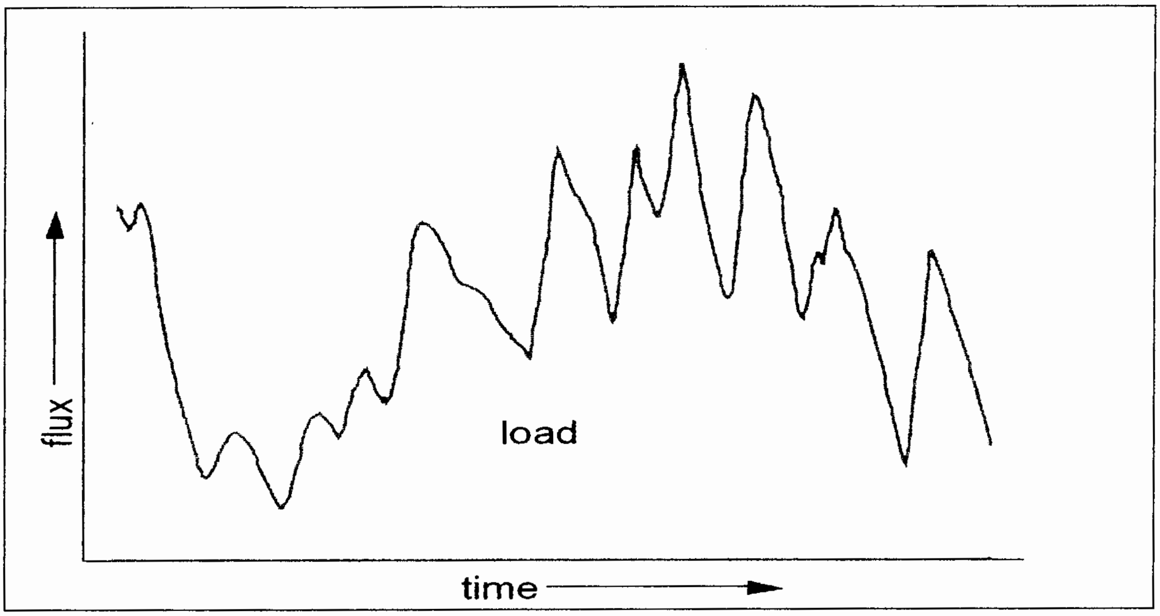

Fig. 10. A hypothetical graph of flux over time, shaded area represents total load.

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:

$$L = \text{flux}(t)dt$$

Where flux is the instantaneous mass of pollutants that pass through a cross sectional area and dt is total time passed. A true single measurement of flux is not possible because there are currently no methods of taking instantaneous measurements of discharge and concentration together. It can only be done 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 is the concentration of the nutrient in question, q is the discharge, and t_i is the passage of time given in the ith 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; some models take the average between the two sampling periods and combining them with measured discharge, other models fit a linear regression of the concentration curve to a hydrograph. The method is, however, not an exact duplicate of the flux or the load, but is a rough estimation, giving a general idea of the pollutant transfer over a certain period of time.

Finally, pollutant levels were compared with land use practices in the watershed. Watershed delineation for all six tributaries involved using Hydrologic Unit Area Codes (HUCS) provided by the Iowa Geological Survey. HUC images are statewide watershed coverages for streams and lakes in Iowa. They are delineated by the land topography and the mapped stream channels, and represent the best estimation of the runoff inputs into the stream channel.

Landuse in the six watershed areas was delineated by using 2002 Landsat satellite images. Landsat images are 30 m^2 resolution depictions of the land cover over the entire state. Landsat coverage were used to subdivide the surface of Iowa into eight regions: urban/roads, CRP land, wetland, grazing land, forest, row crop (corn, soybean and other), barren land (e.g. exposed sand, rock, etc.), and water. Measured water quality variables were then compared with land uses in the watershed to see if there were any significant correlations.

RESULTS AND DISCUSSION

Discharge

Discharge measurements, taken from continuously monitoring USGS stations, indicated great variability in the streamflow of the tributaries. During most of the study period the highest observed flow was in the Shell Rock River, which discharged a total of $3.33x10^8$ m^3 of water during the 5-month project (Fig. 11-16). The Little Cedar River had the second highest discharge with $2.90x10^8$ m^3 during the study period, followed by the West Fork Cedar River $2.01x10^8$ m^3, Beaver Creek at $6.64x10^7$ m^3, Black Hawk Creek at $4.64x10^7$ m^3 and Wolf Creek at $3.04x10^7$ m^3. There is an order of magnitude difference between the discharge of Shell Rock River and Wolf Creek.

Nitrate

During the study, nitrate concentrations in the six tributaries varied greatly, both temporally and spatially. Peaks in nitrate values tended to follow peaks in discharge in all of the tributaries (Fig. 11-16). This is especially obvious in the Shell Rock and Little Cedar Rivers, which also have the greatest discharge and lowest nitrate-N values measured in the study. The highest measured nitrate values occurred during the early spring and the summer months (May-June), with a steady decline in the late summer and early fall. This signifies a rise in nitrate values during the period of peak agricultural fertilization. Most row crop agriculture in Iowa undergoes either synthetic or manure fertilization in the late spring and early summer months, which adds excess nitrogen and phosphorus to the soil column. With the exception of the Shell Rock River, during the project period nitrate-N levels rose to above the 10 mg/L EPA drinking water standard in all of the tributaries.

Figure 17 shows the median and mean nitrate-N values measured during the study. During the five month project, Black Hawk Creek had the highest average nitrate values at 8.2 mg/L. Beaver Creek had the second highest values at 8.0 mg/L. The lowest mean values were recorded in the Shell Rock River, at 4.1 mg/L, followed by the Little Cedar River at 4.8 mg/L.

Figure 18 shows the nitrate loads that passed though the streams during the study period. Nitrate loading during the study was calculated by taking the daily discharge and multiplying it by either the known nitrate values from sampled days, or the average value between two measured dates. During the study the Shell Rock River had the greatest nitrate load at 1,720 metric tons; the primary reason being the higher discharge in Shell Rock River. Even with its low concentrations, the high discharge in the Shell Rock River increased the nitrogen flux. The least amount of nitrate load came from the Wolf Creek at 260 metric tons. This is also due to the discharge, as the concentrations in the Wolf Creek are in the lower range compared to the other tributaries.

The high levels of nitrate-N in the Cedar River tributaries indicate the strong influence of row crop agriculture and fertilization in all of the watershed areas. The smaller watersheds in the study (Beaver Creek, Black Hawk Creek) also tended to have more nitrate-N than larger watersheds (e.g., Little Cedar and Shell Rock River). This could be due to a number of factors, including homogeneity in land use, geology, and existence of point sources in the smaller watersheds. For larger watersheds, the residence times for nutrients are longer, which could cause nitrogen to be used as food by algae and bacteria in the water column.

No previous studies estimating nitrogen loading from the tributaries to the Cedar River have been done. However, Becher et al., (2000), and Tavener and Iqbal (2003) have estimated total nitrogen loads from the downstream mouth of the Cedar River, located at Conesville, IA. Using Becher's average value of 5 mg/L at the Conesville station, Tavener and Iqbal estimated the monthly loss of total nitrogen from July through September, 2000 at 1,550 metric tons per month. Nitrate-N is by far the main constituent of total nitrogen (80-90%). Using the same three months as used by Tavener and Iqbal, nitrate-N loading into the Cedar River is estimated to be 842.4 metric tons. This is equivalent to 54% of the total nitrogen measured at the downstream station.

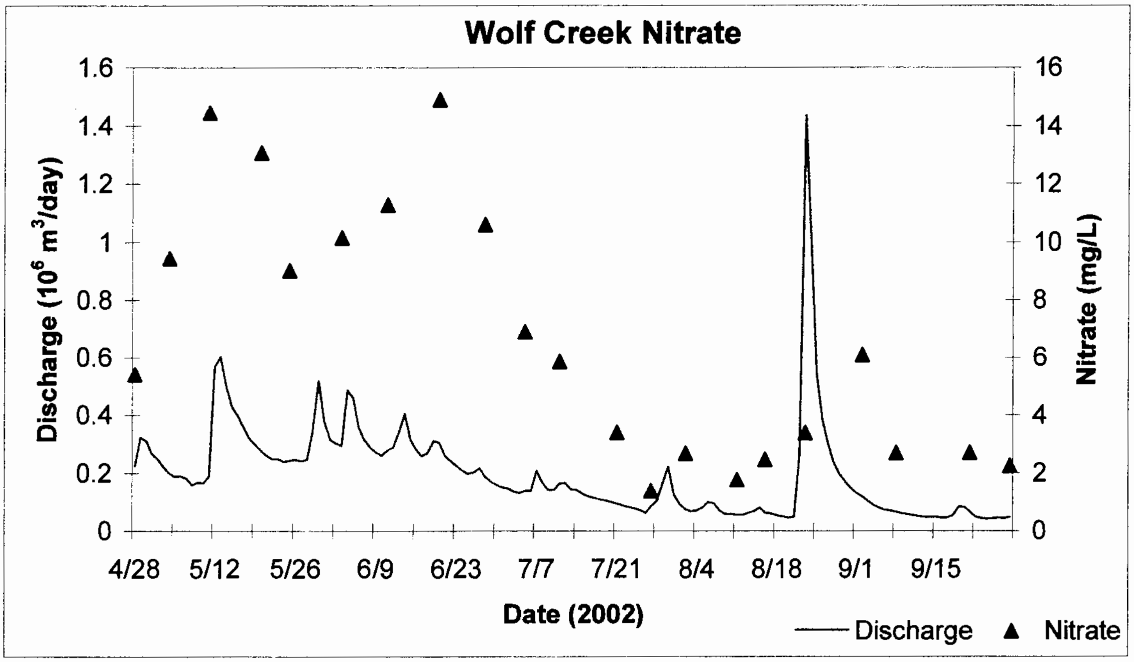

Fig. 11. Hydrograph and nitrate-N concentrations at Wolf Creek.

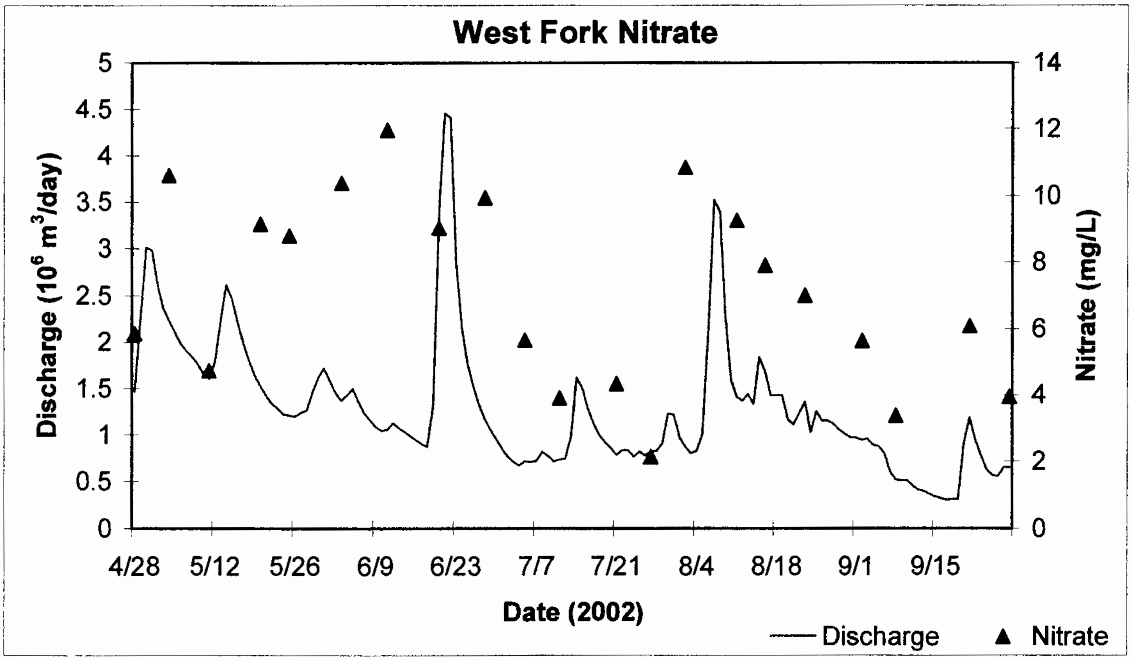

Fig. 12. Hydrograph and nitrate-N concentrations at West Fork.

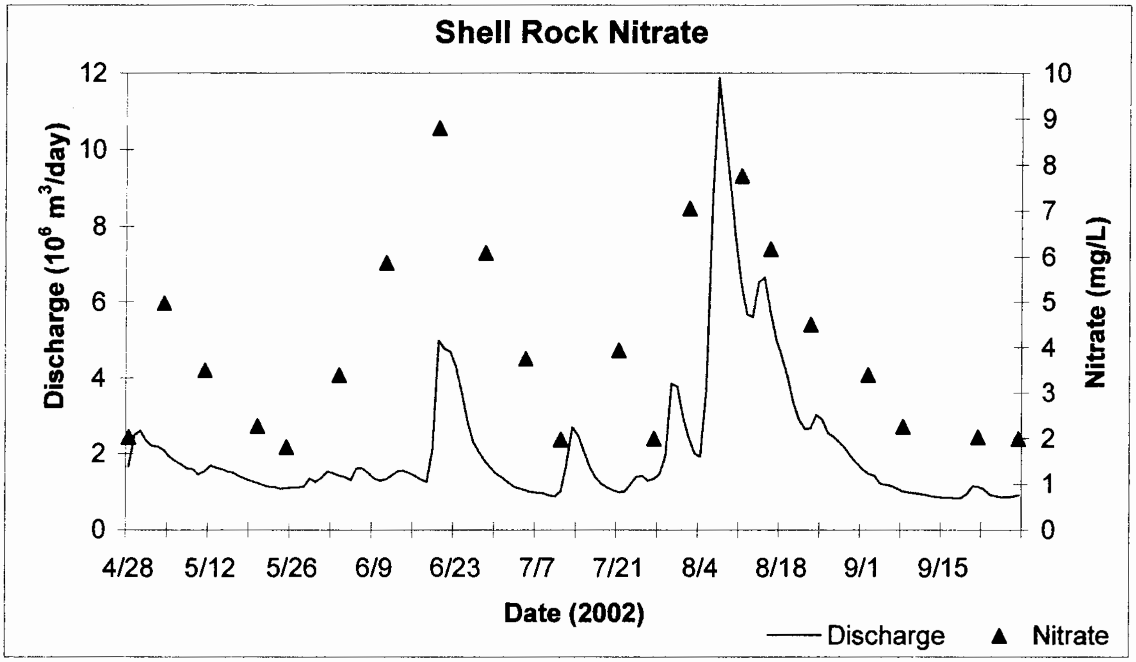

Fig. 13. Hydrograph and nitrate-N concentrations at Shell Rock River.

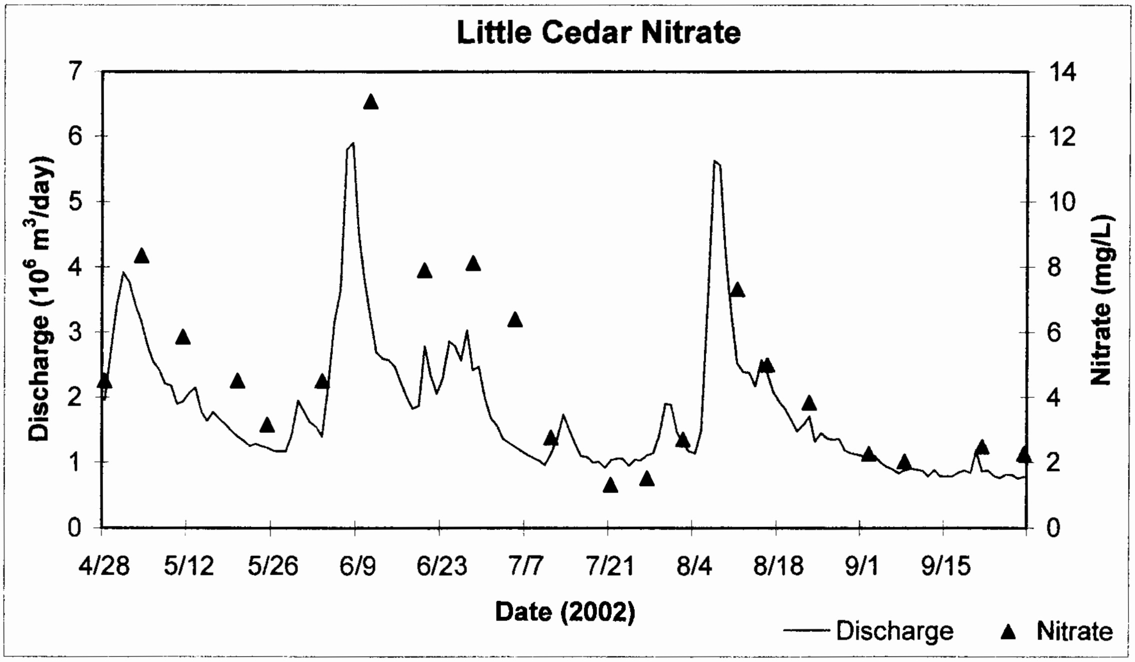

Fig. 14. Hydrograph and nitrate-N concentrations at the Little Cedar River.

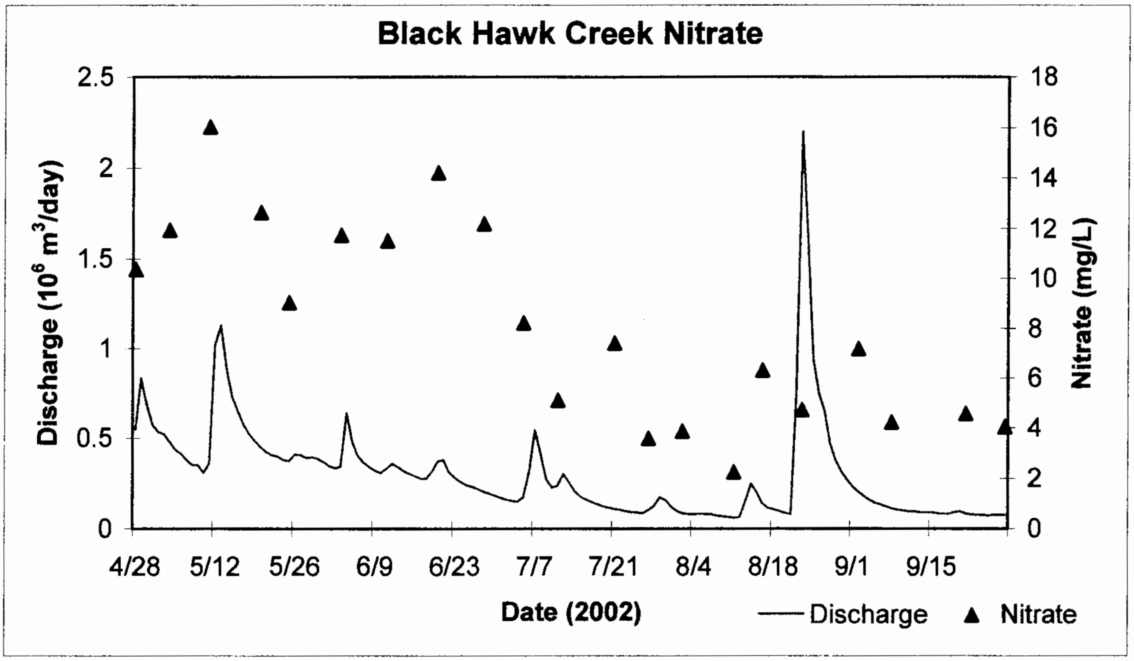

Fig. 15. Hydrograph and nitrate-N concentrations at Black Hawk Creek.

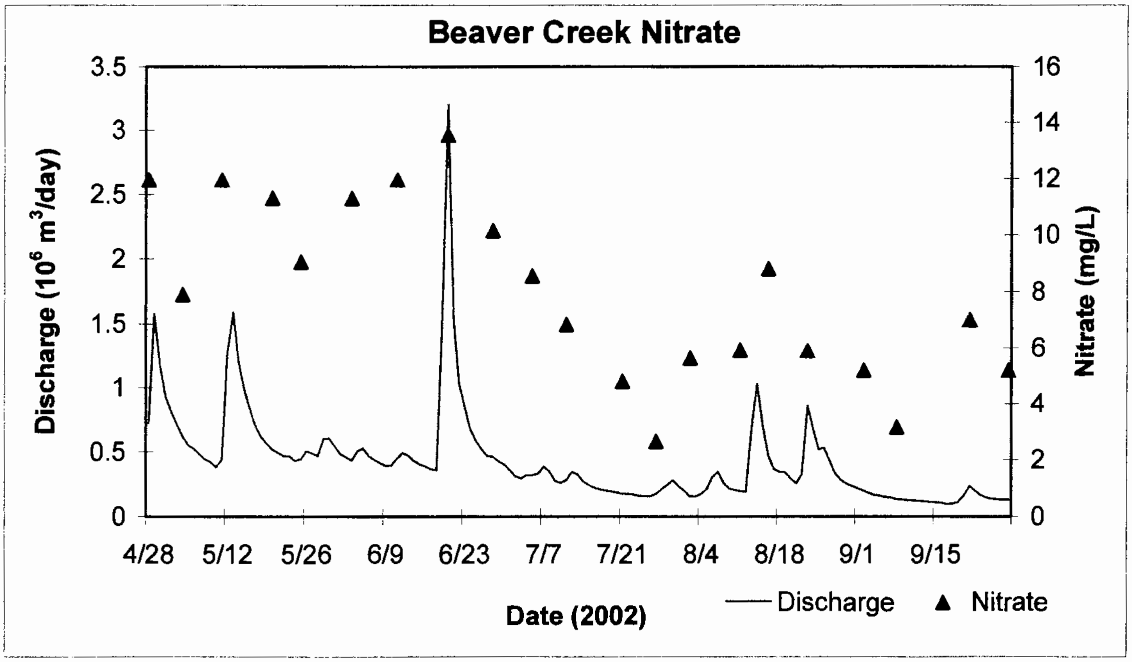

Fig. 16. Hydrograph and nitrate-N concentrations at Beaver Creek.

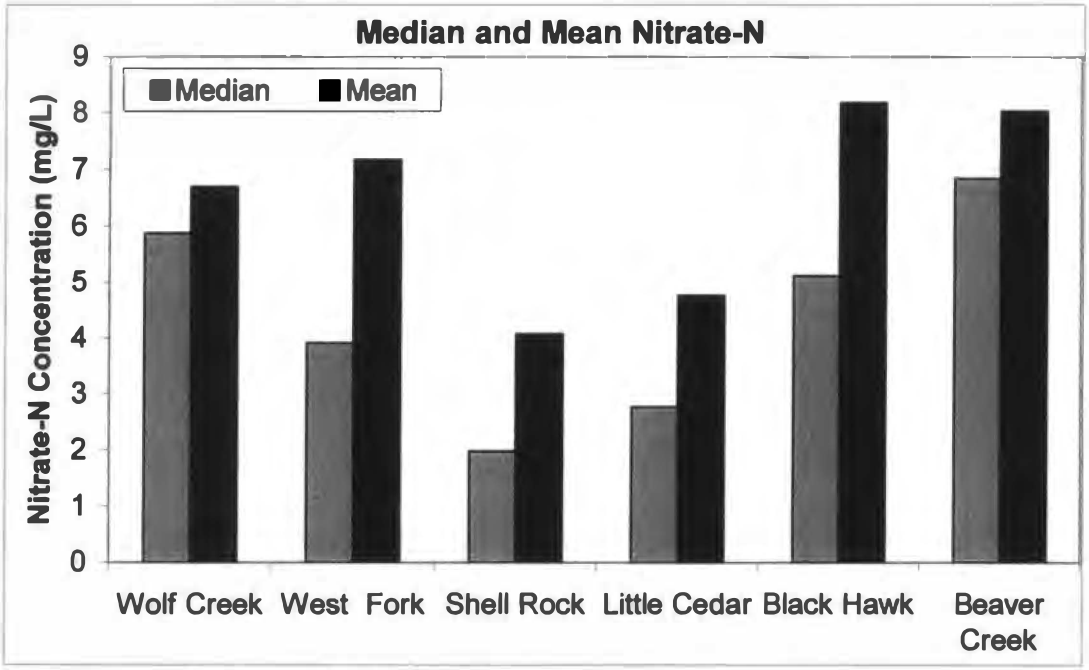

Fig. 17. Median and mean nitrate-N concentrations during the study period.

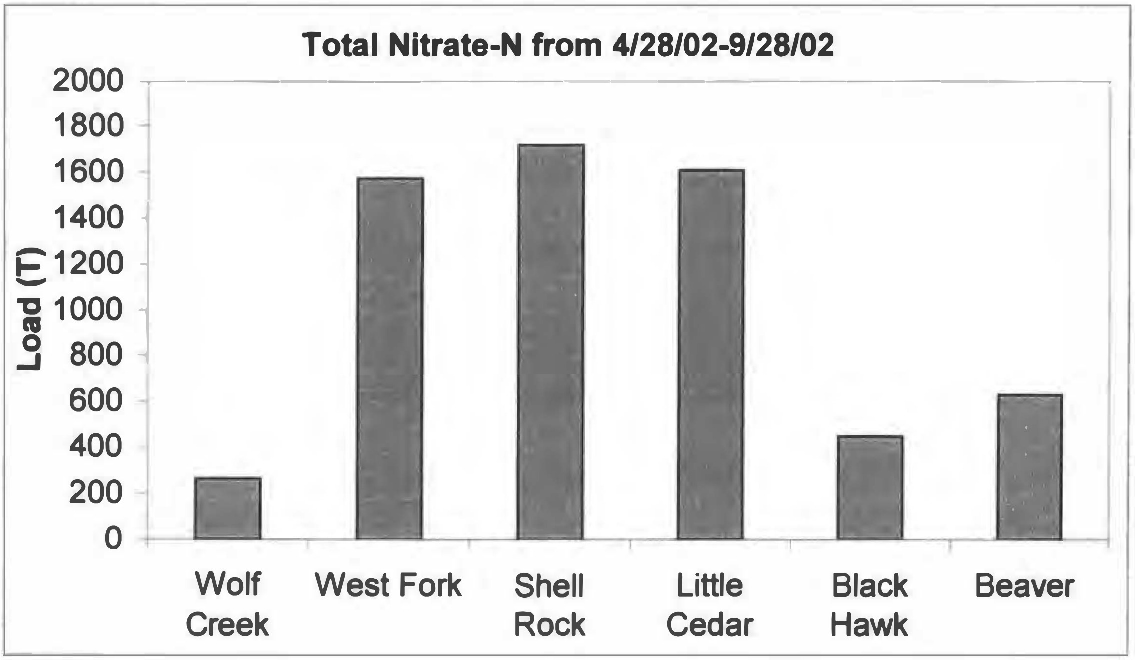

Fig. 18. Nitrate-N load calculated during the project period.

Total Dissolved Phosphorus

Streams that had higher nitrate-N concentrations also tended to have higher total dissolved phosphorus (TDP) concentrations. Unlike nitrate-N, TDP concentrations did not closely follow the trends in stream discharge (Fig.19-24). This is because P heavily adsorbs onto soil particles. A slight seasonal variation seems to be evident as most tributaries had higher values during the late summer and early fall months, notably Wolf Creek and Shell Rock River. However, Beaver Creek had most of its higher concentrations during the spring and the summer months. TDP values in all of the streams were an order of magnitude lower than that of nitrate-N. This is to be expected as phosphorus is not as easily dissolved in water as nitrate-N.

Figure 25 shows the median and mean total dissolved phosphorus concentrations measured during the study. The two highest mean concentrations were found in Black Hawk Creek and Beaver Creek at 114.6 and 136.5 μg/L, respectively. They are followed by the Little Cedar River (109.5 μg/L), West Fork Cedar (103.7 μg/L), and Wolf Creek (102.7 μg/L). The lowest concentration was found in Shell Rock River, at 93.7 μg/L. The highest independent TDP concentration was 859.6 μg/L measured in Beaver Creek on May 11, 2002. This value is over twice as high as the second largest concentration. Although it is unknown what caused this high value, it could be attributed to high fertilizer. However, nitrate-N concentrations measured on that day were not as high.

All tributaries had TDP concentrations elevated either due to row crop agriculture, effluent in the stream, or both. The EPA stream total phosphorus standard of 118 μg/L (EPA, 2000) was surpassed in over 30% of total samples taken. Beaver Creek had a higher average concentration of dissolved phosphorus than EPA total phosphorus guidelines. Most phosphorus used by aquatic plants and algae is believed to be dissolved phosphorus as phosphorus adsorbed onto sediments is difficult to extract.

Figure 26 shows total dissolved phosphorus loads transported during the study period. TDP loads were measured by taking either the average concentration between two sampling periods, or the concentration at a sampling period, and multiplying it by the total discharge for the day. Total dissolved phosphorus loads in the streams tended to closely follow nitrate-N loads and were heavily dependent on discharge. The highest load during the 5-month study was in the Shell Rock River, at 41.6 metric tons of total dissolved phosphorus passing out of the watershed. The second highest load was in the Little Cedar River at 28.6 metric tons. The lowest dissolved phosphorus load was 3.6 metric tons, measured in Wolf Creek.

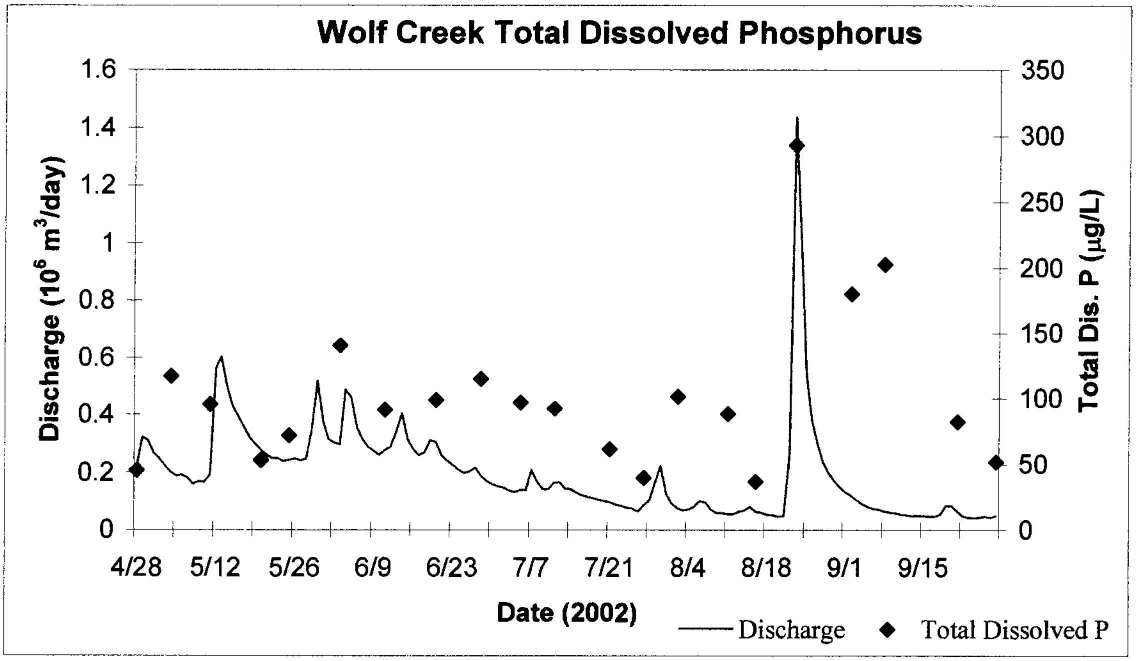

Fig. 19. Hydrograph and dissolved phosphorus concentrations at Wolf Creek.

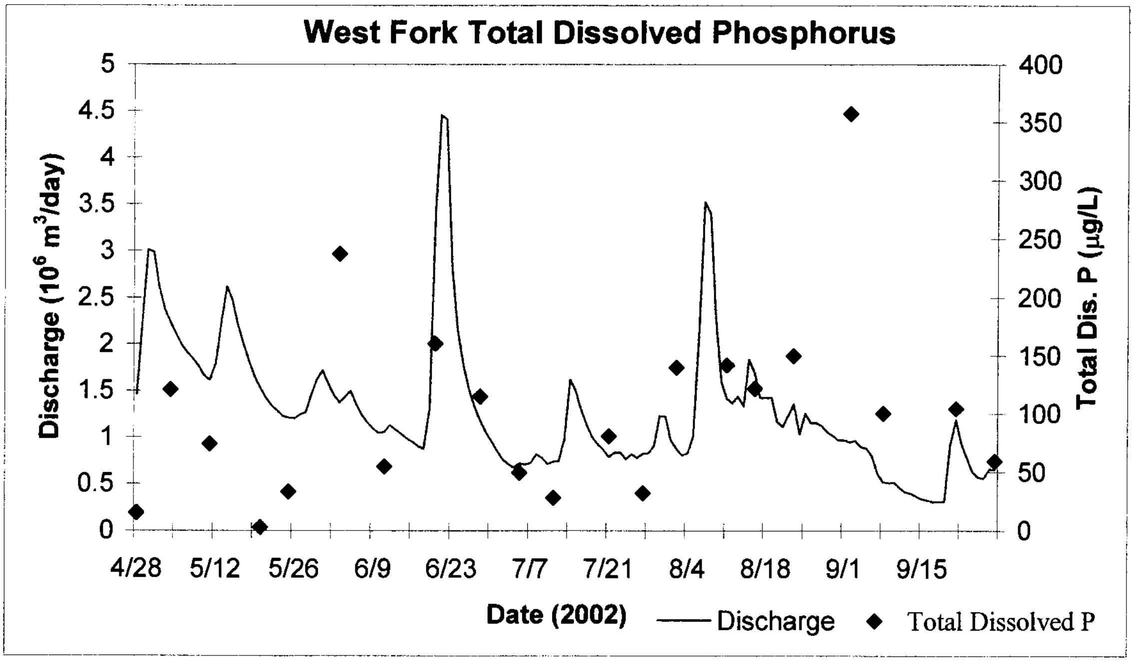

Fig. 20. Hydrograph and dissolved phosphorus concentrations at West Fork.

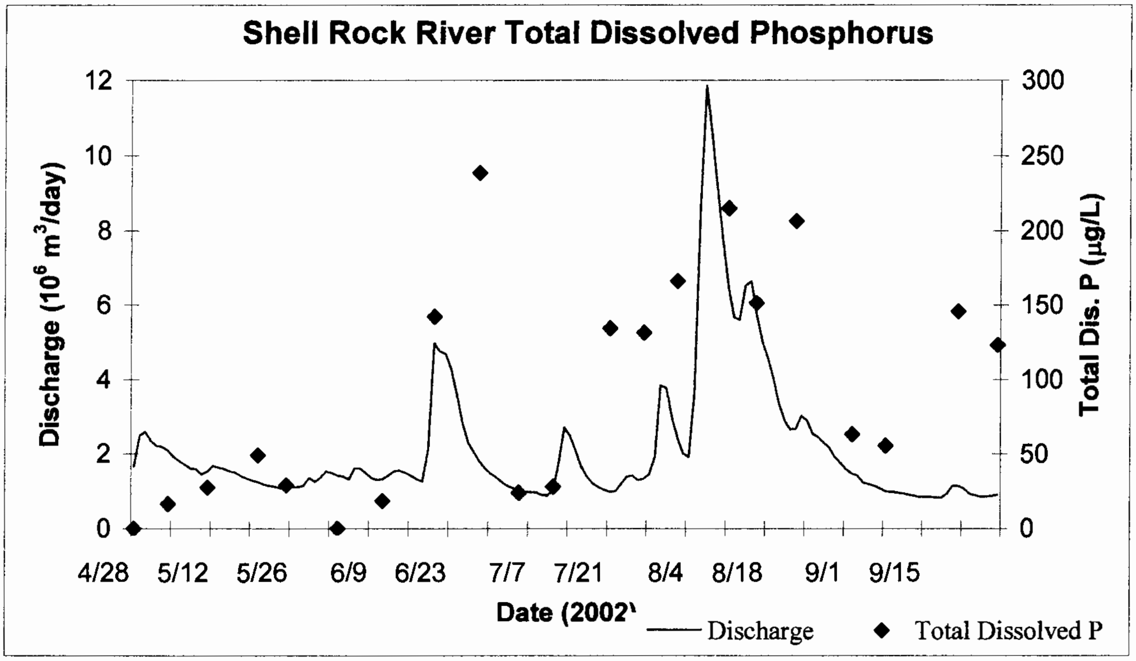

Fig. 21. Hydrograph and dissolved phosphorus concentrations at Shell Rock River.

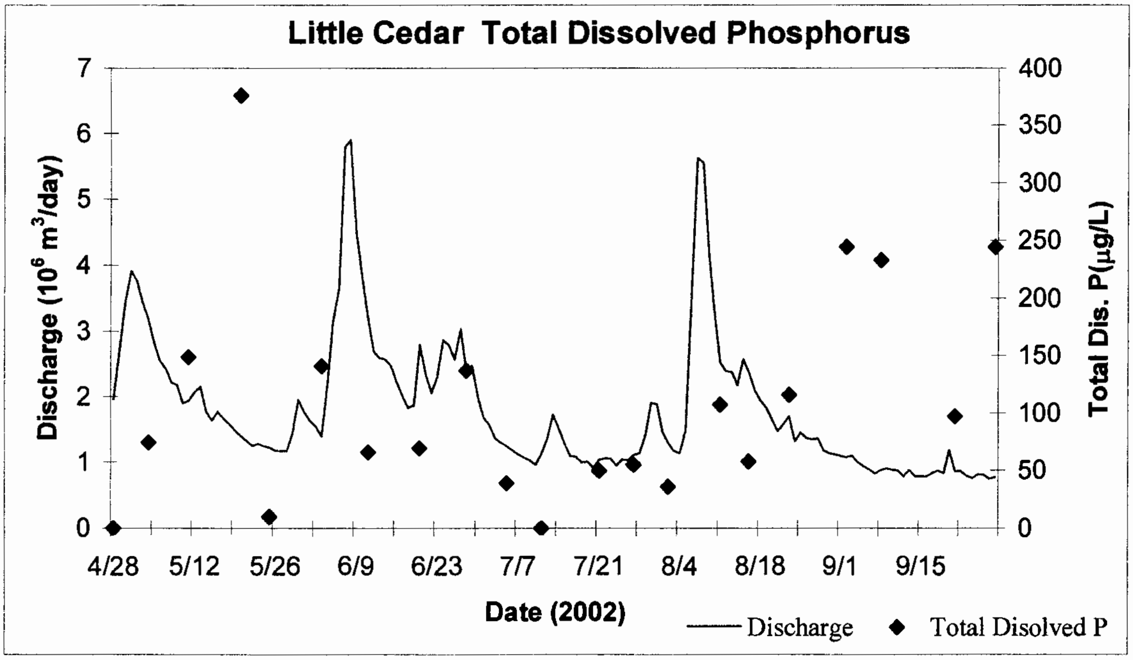

Fig. 22. Hydrograph and dissolved phosphorus concentrations at Little Cedar.

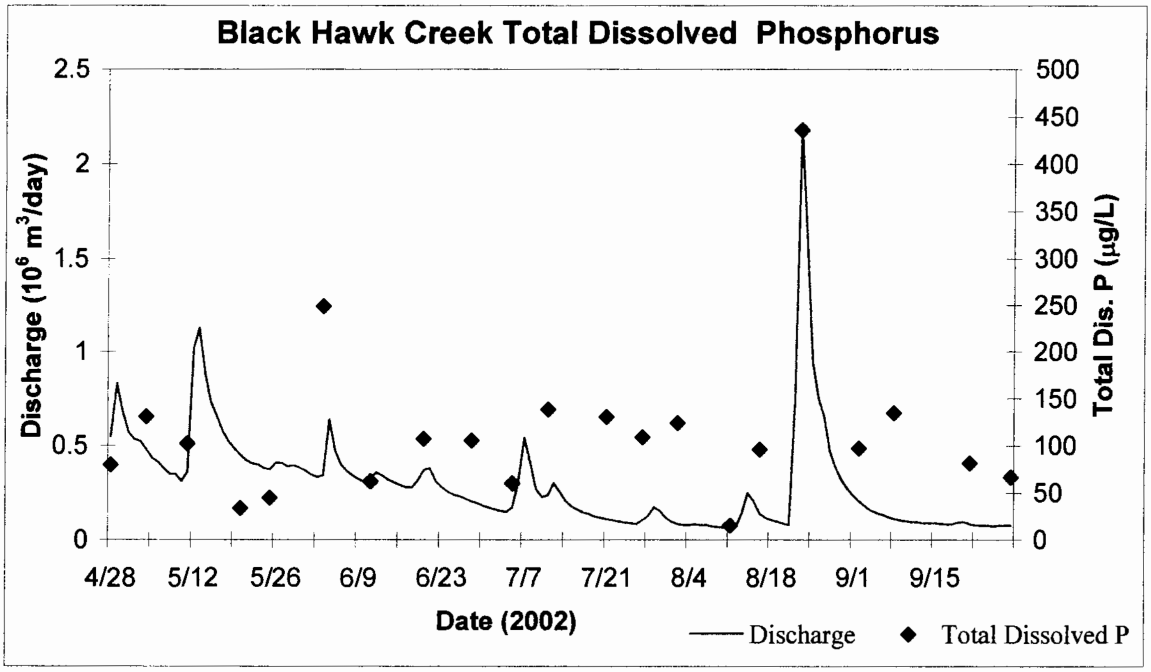

Fig. 23. Hydrograph and dissolved phosphorus concentrations at Black Hawk Creek.

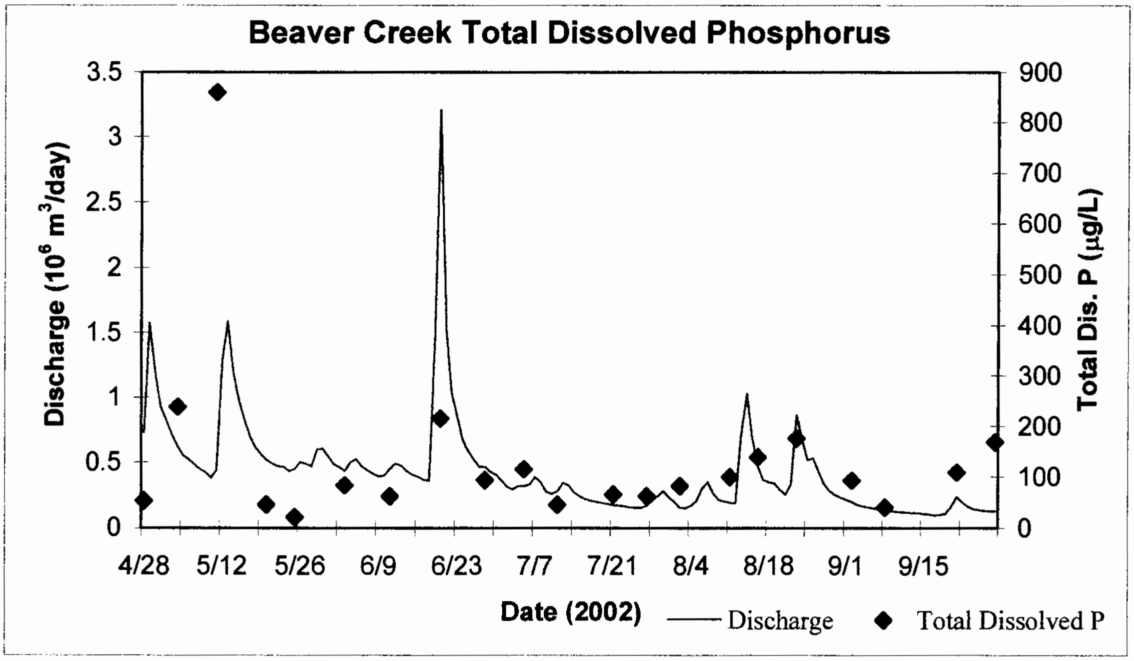

Fig. 24. Hydrograph and dissolved phosphorus concentrations at Beaver Creek.

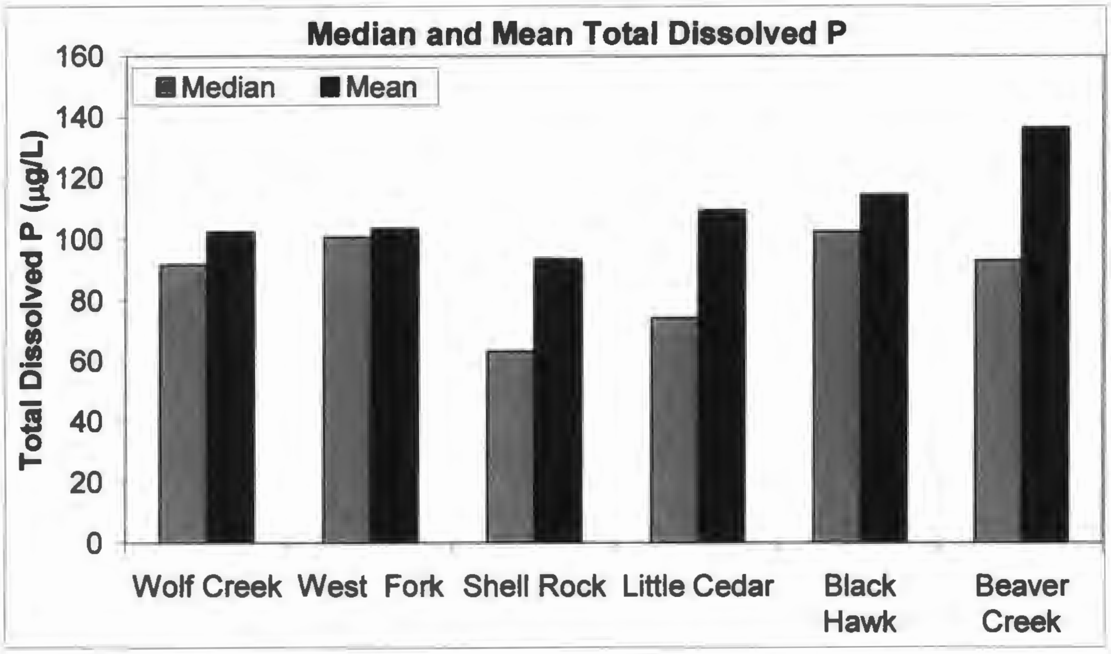

Fig. 25. Median and mean dissolved phosphorus concentrations during the study.

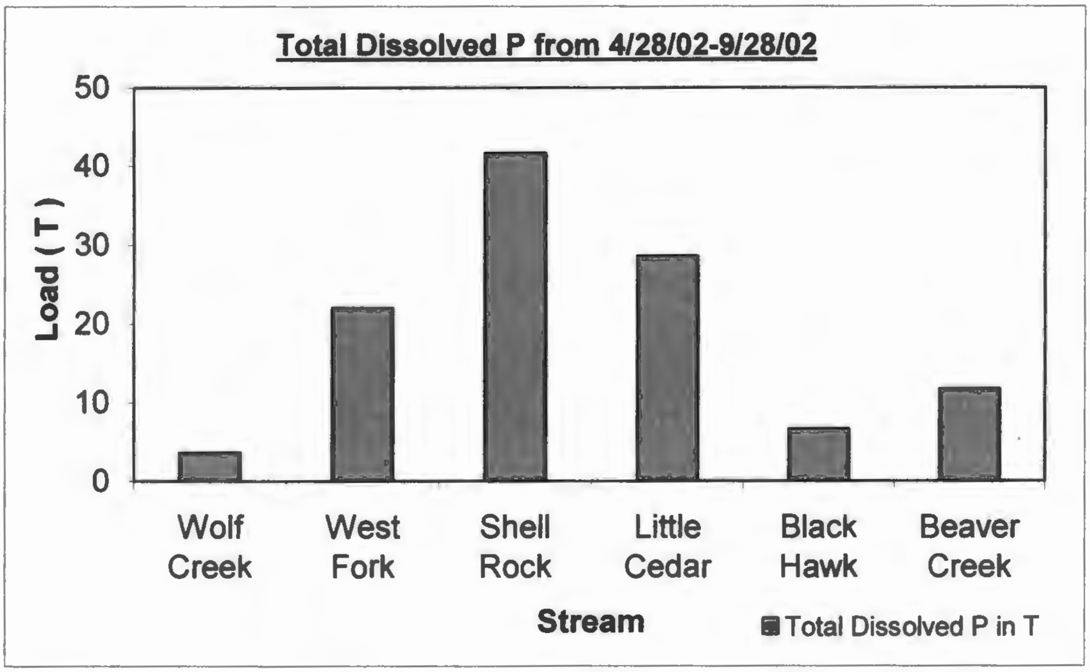

Fig. 26. Total dissolved phosphorus load during the study.

Bedload Sediment Phosphorus

Mean sediment P concentrations did not resemble TDP, or nitrate-N concentrations. Bedload sediment phosphorus tended to have much higher concentration than dissolved phosphorus in the water column. This is attributed to the strong chemical affinity of phosphorus to adsorb on to soil particles. Sediment phosphorus did not show any seasonal trend. Although sediment P in Shell Rock and Little Cedar are weakly correlated with discharge, such trends did not exist in other streams (Fig. 27-32).

Figure 33 shows median and mean values of sediment phosphorus observed during the study. The highest mean value was observed in Black Hawk Creek at 355.1 µg/g, the second highest in West Fork at 273.1 µg/g, followed by Shell Rock (263.3 µg/g), Wolf Creek (253.2µg/g), and Little Cedar (221.7 µg/g). Beaver Creek had the lowest average values measured during the study at 109.6µg/g. The highest value for observed sediment P concentration was 1,573 µg/g on September 28, 2002 at West Fork Creek, which was two times higher than any other value measured during this study.

Sediment phosphorus concentrations could be controlled by a number of factors, including phosphorus concentrations in the water, sediment grain size, and aquatic vegetation density. Also important is whether the sediment is taken from a depositional environment like a pool, or a scouring environment like a riffle or run. The sampling procedure probably has more to do with the fluctuations in concentrations than the stream's overall water quality.

Load estimation was not done on sediment P, as bed load flux estimation was not done in this study.

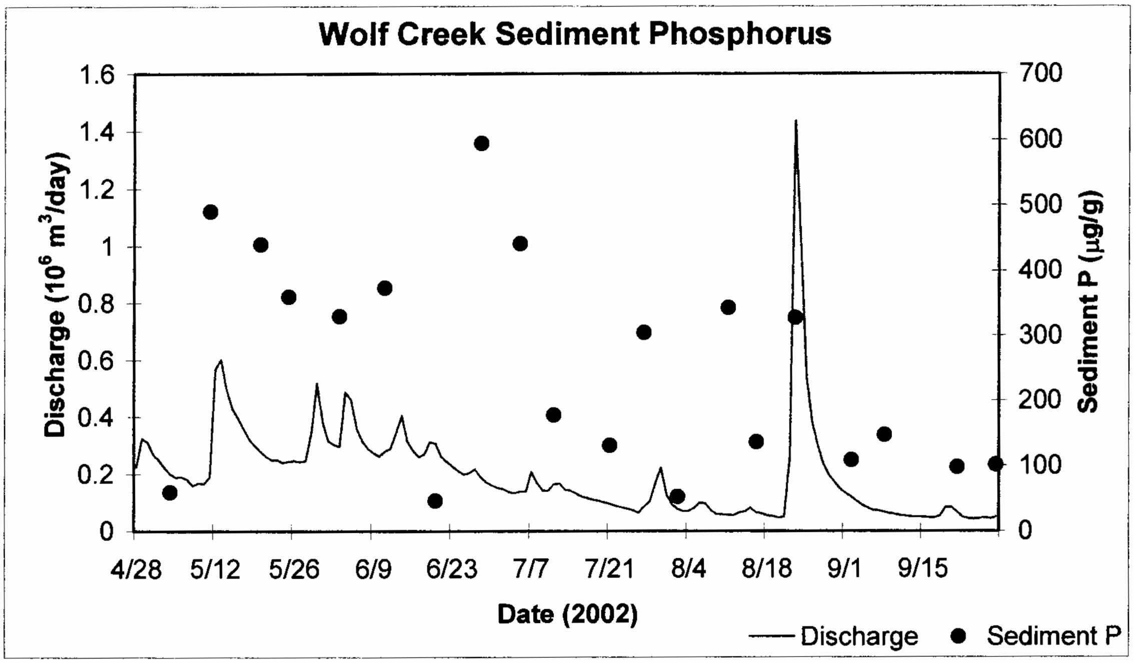

Fig. 27. Hydrograph and sediment phosphorus concentrations at Wolf Creek.

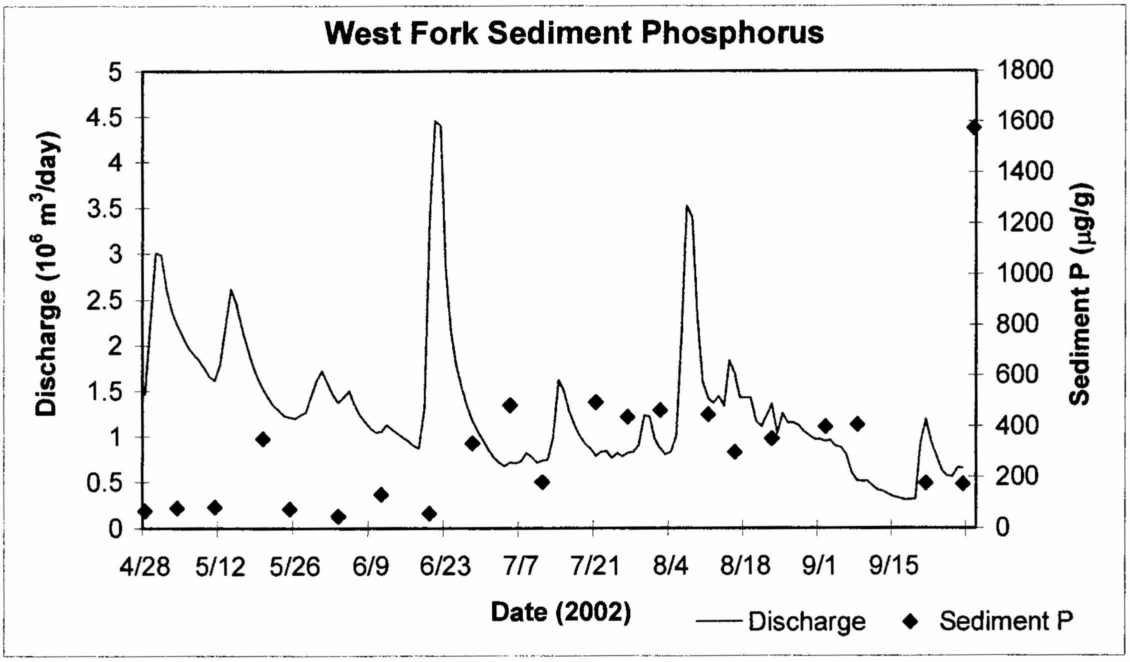

Fig. 28. Hydrograph and sediment phosphorus concentrations at West Fork.

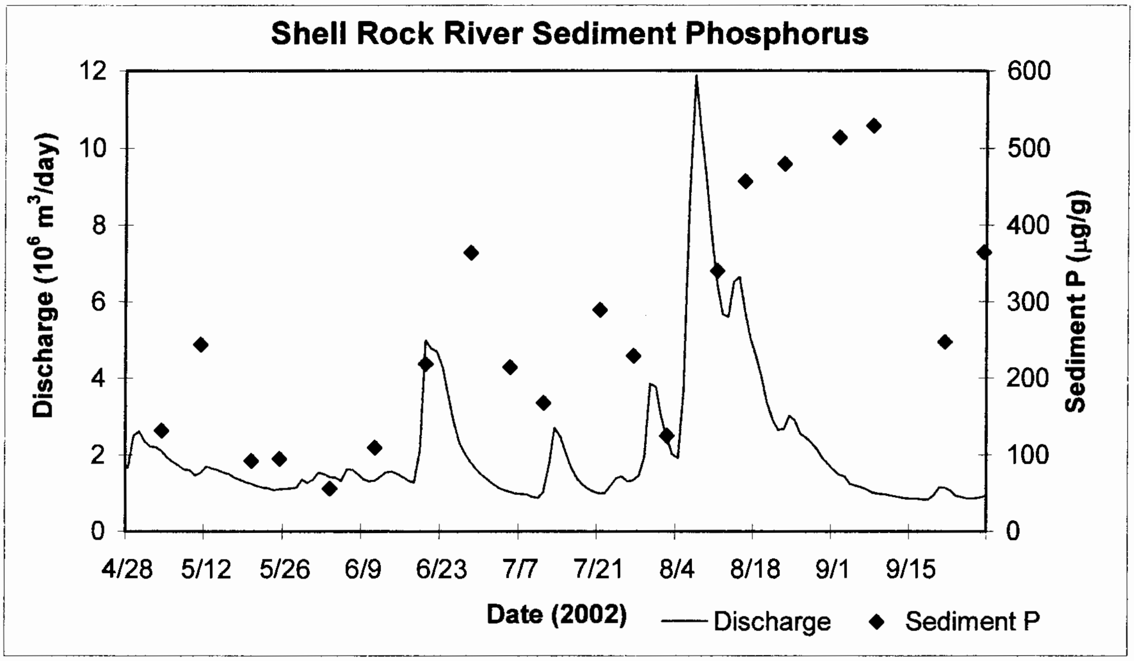

Fig. 29. Hydrograph and sediment phosphorus concentrations at Shell Rock River.

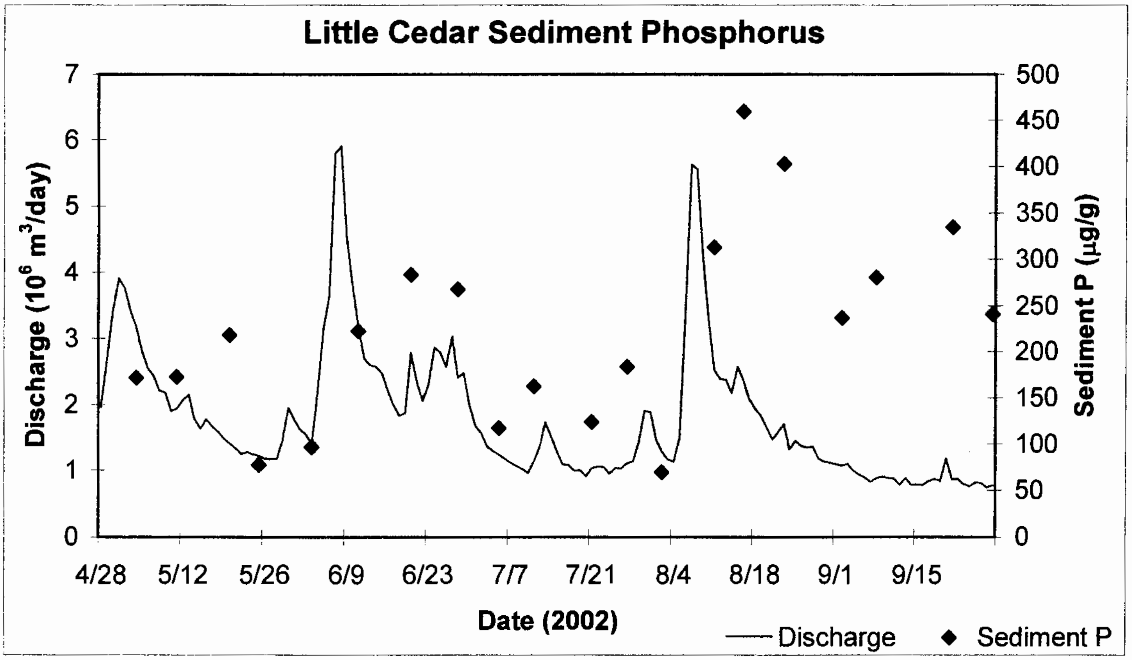

Fig. 30. Hydrograph and sediment phosphorus concentrations at Little Cedar.

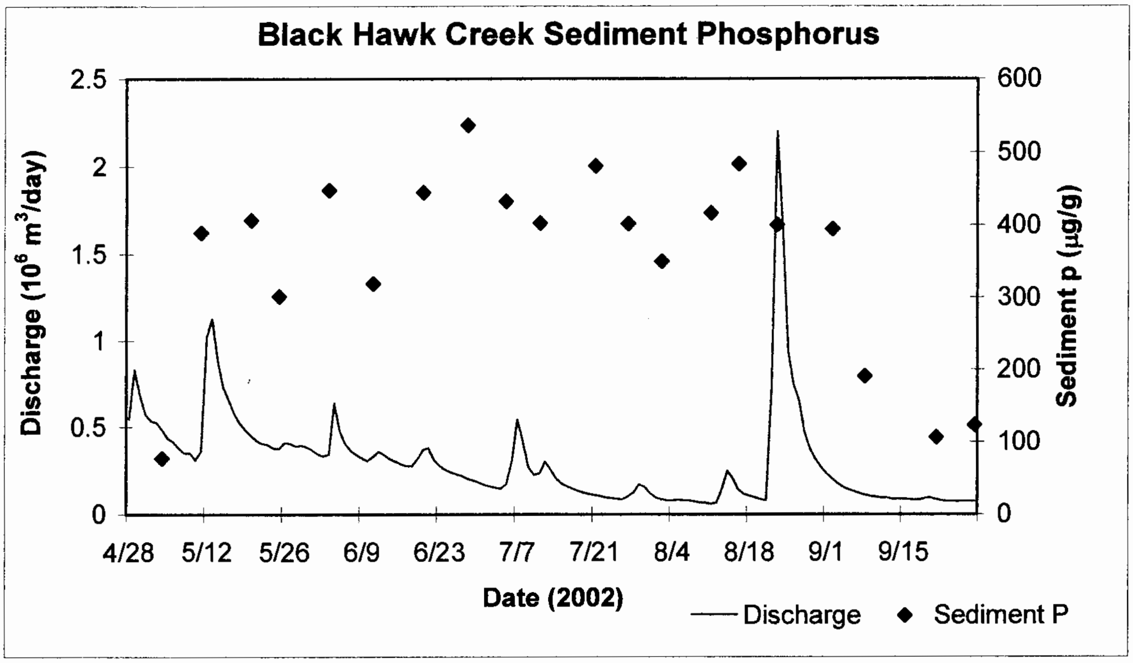

Fig. 31. Hydrograph and sediment phosphorus concentrations at Black Hawk Creek.

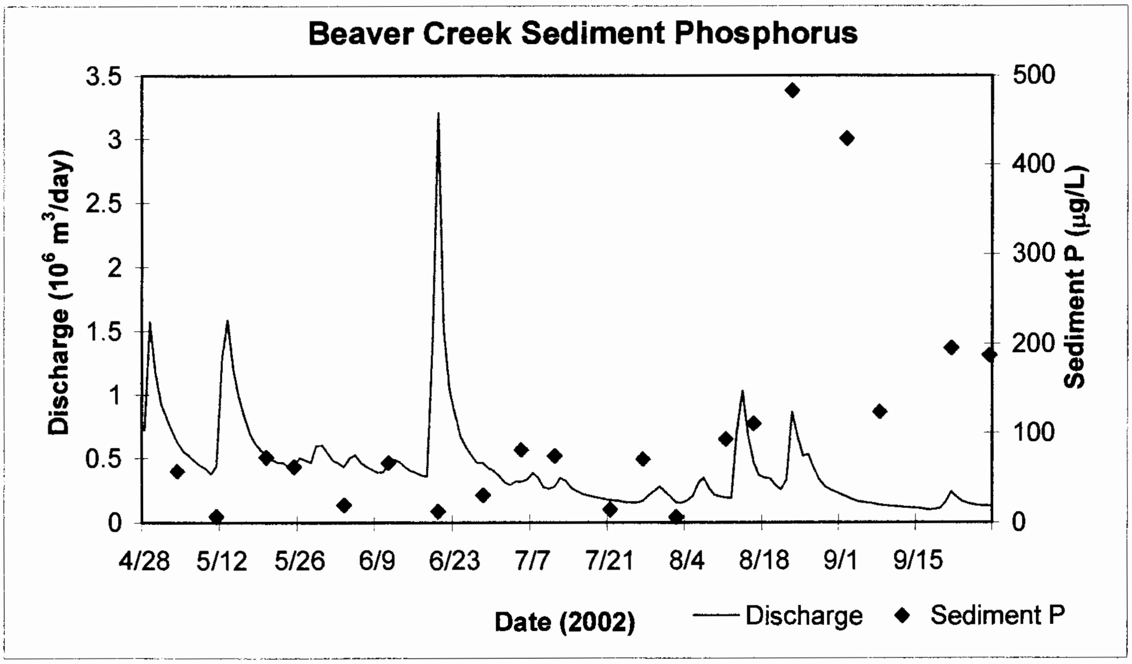

Fig. 32. Hydrograph and sediment phosphorus concentrations at Beaver Creek.

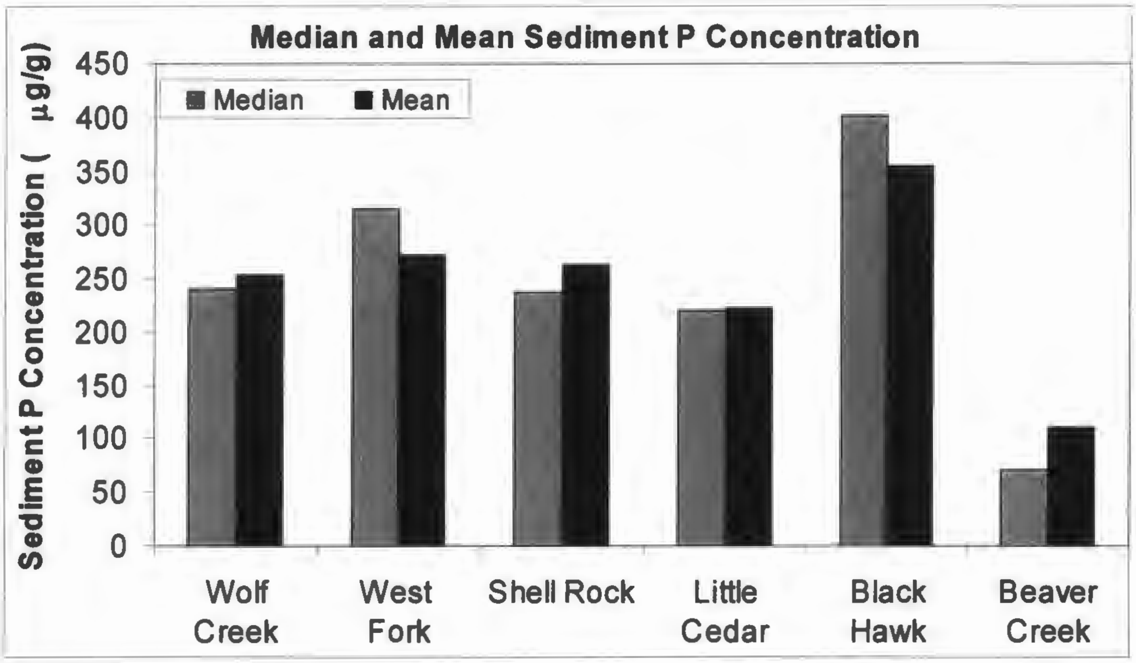

Fig. 33. Median and mean sediment phosphorus concentrations during the study.

Suspended Sediment

Suspended sediment concentrations were analyzed from 7-11-2002 until 9-28-2002. Figures 34-39 indicate the suspended sediment concentration and discharge measured during the study. Suspended sediment somewhat followed the discharge trends, with higher values occurring during high flow events. In this study, the highest concentration of suspended sediment measured in any of the tributaries was 680 mg/L on August 16, 2002 at Beaver Creek. Although this value was taken during a storm event, it was not the highest measured discharge in the stream for that year. This indicates that suspended sediment values are highly variable. In order to estimate loads of suspended sediment more accurately, sampling frequency should be much higher (~15 minutes to daily).

Figure 40 shows the median and mean suspended sediment concentrations for all of the tributaries. Suspended sediment concentrations in the tributaries were surprisingly similar given the local variations in vegetation and terrain characteristics. Mean suspended sediment concentrations were highest in Black Hawk Creek, at 438.1 mg/L, followed by West Fork (379.1 mg/L), Beaver Creek (360.5 mg/L), Shell Rock River (353.7 mg/l) and Little Cedar River (321.2 mg/L). The lowest concentration was found in Wolf Creek at 279.8 mg/L.

High suspended sediments in streams are indicative of intense agricultural activities in watersheds. Other studies in Iowa indicate that suspended sediments in less agricultural streams tend to average between 10 and 100 mg/L (Kalkhoff and Eash, 1994).

Load estimation and seasonal fluctuations of suspended sediments were not completed, as sampling was not done in short enough intervals to analyze them accurately.

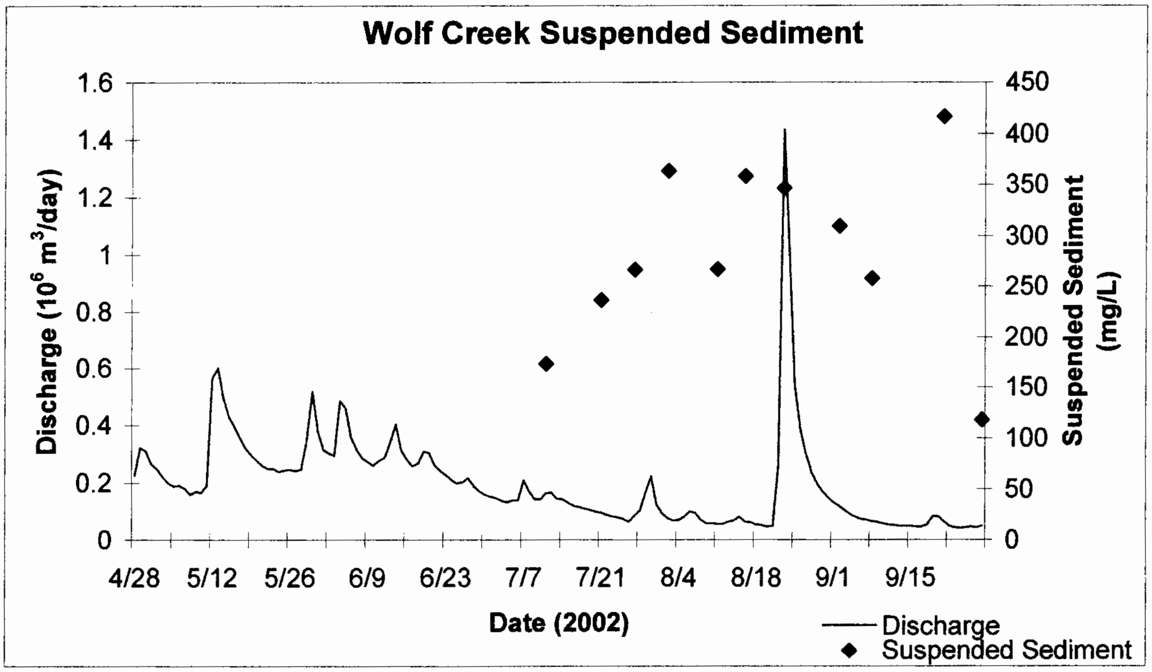

Fig. 34. Hydrograph and suspended sediment concentrations at Wolf Creek.

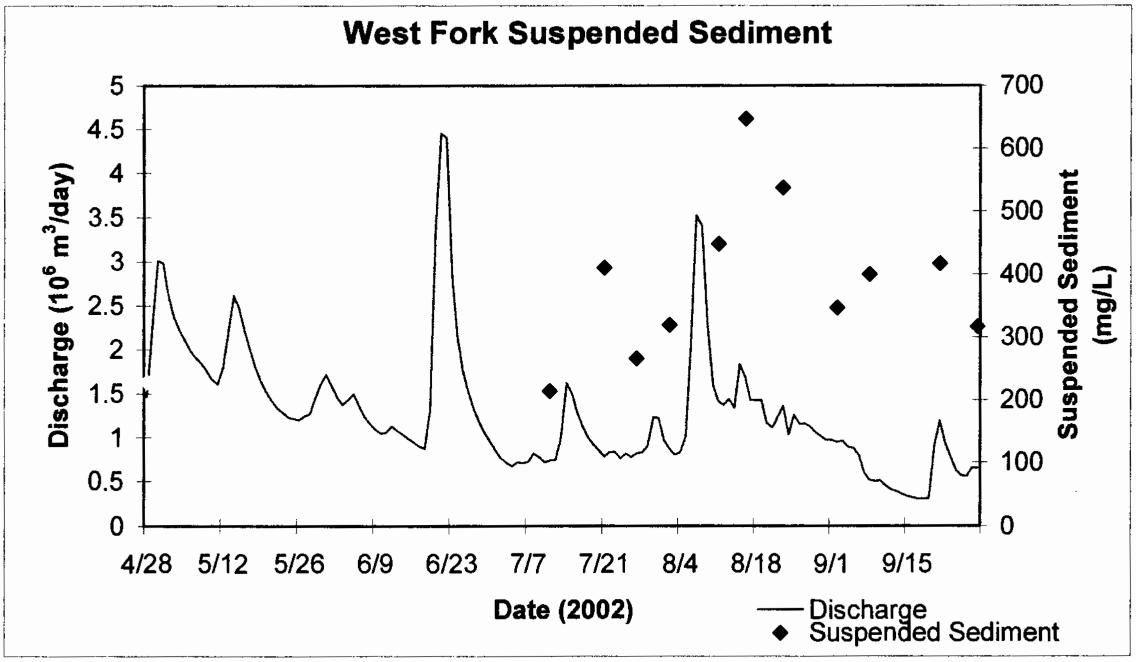

Fig. 35. Hydrograph and suspended sediment concentrations at West Fork.

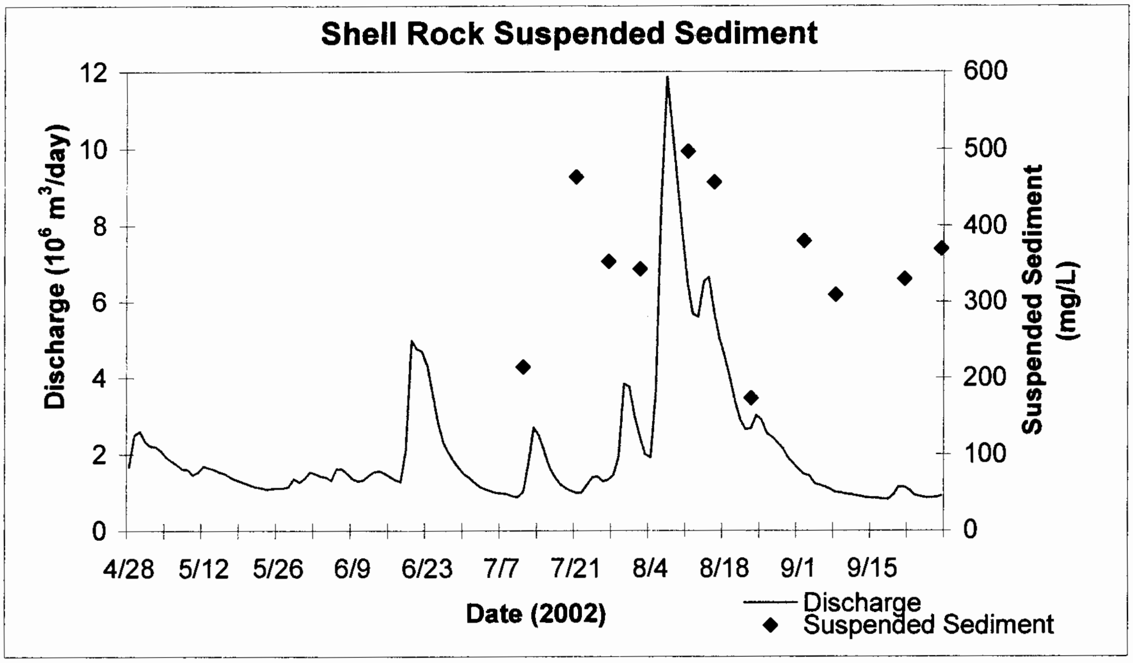

Fig. 36. Hydrograph and suspended sediment concentrations at Shell Rock River.

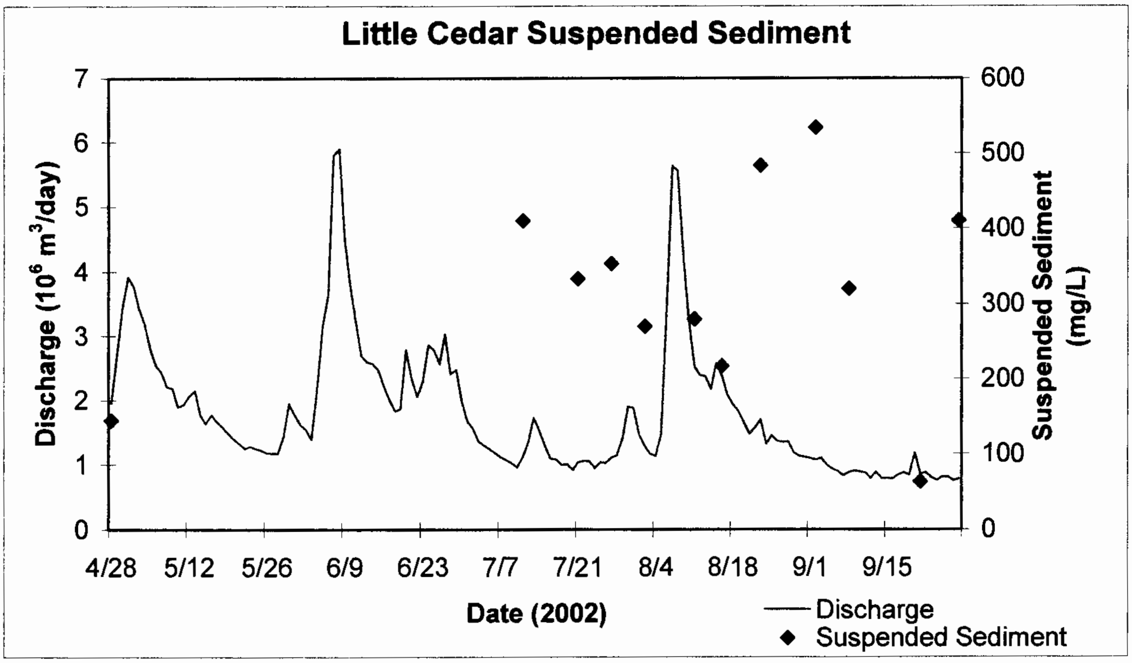

Fig. 37. Hydrograph and suspended sediment concentrations at Little Cedar.

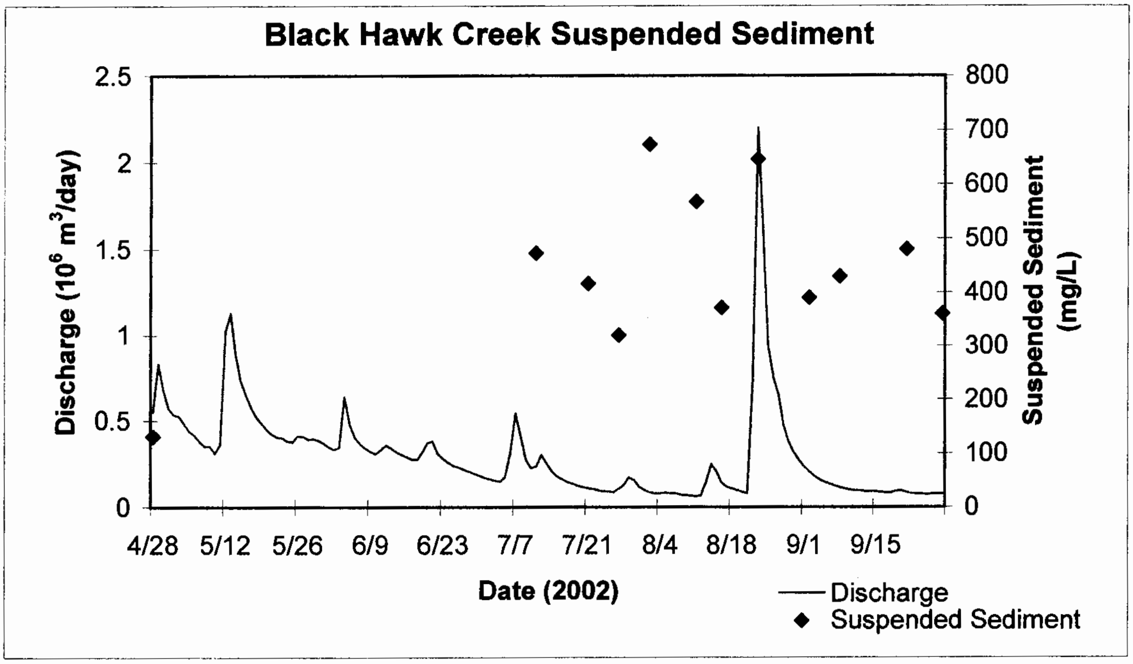

Fig. 38. Hydrograph and suspended sediment concentrations at Black Hawk Creek.

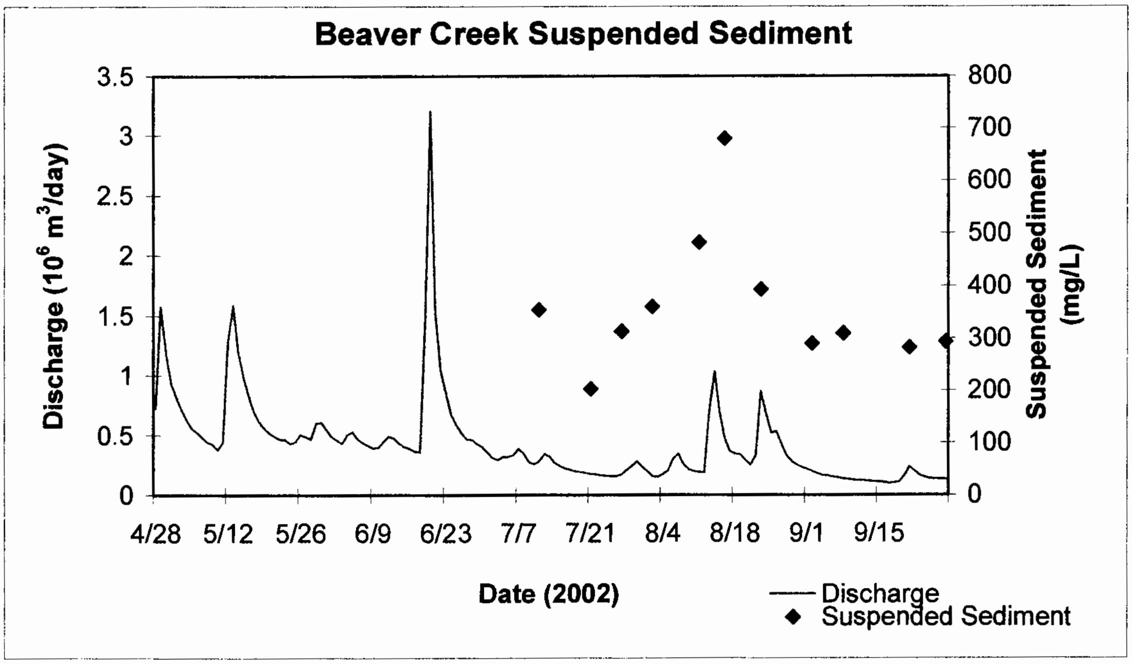

Fig. 39. Hydrograph and suspended sediment concentrations at Beaver Creek.

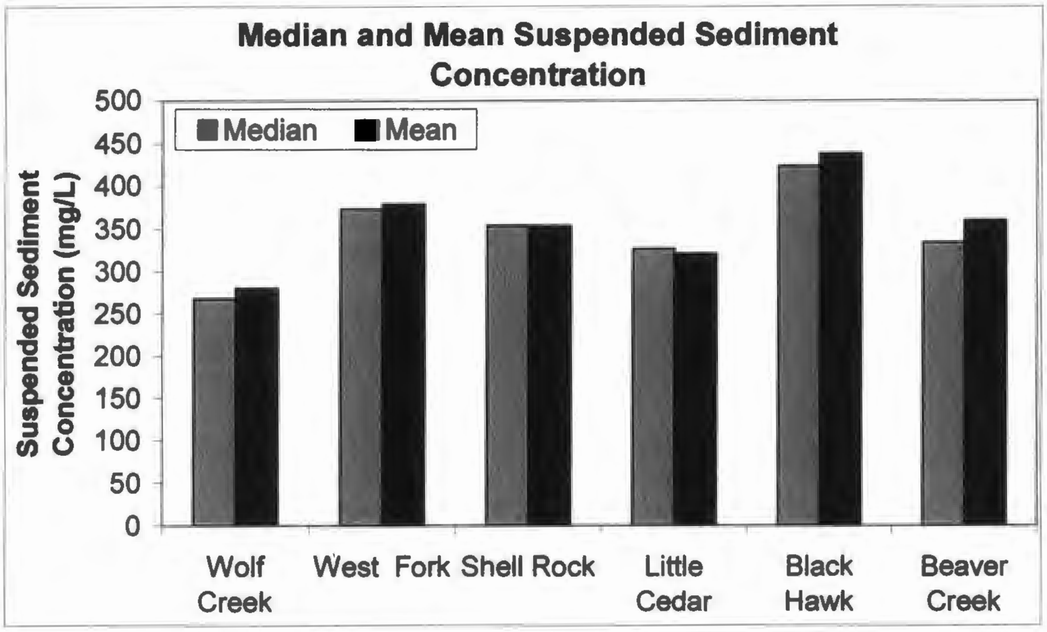

Fig. 40. Mean and median suspended sediment concentrations during the study.

Land Use

Thirty-meter area Landsat satellite images taken during the summer of 2002 were used to estimate land use percentages in the Shell Rock, Little Cedar, West Fork, Beaver Creek, Wolf Creek, and Black Hawk Creek watersheds (Fig. 41-46). Land cover in all of the tributaries was dominated by agriculture, as is typical in most of Iowa. The two major types of land cover in all watersheds were row crop cover and grazing/alfalfa. When added together these two land uses accounted for 82-92 percent of total acreage in the watersheds. Other measured variables include water, conservation reserve protection (CRP) land, wetland, forest, roads, barren land, and other (unclassified and cloud cover).

Black Hawk Creek had the highest amount of row crop acres in the study area, at 80.6%. The second highest row crop acreage belonged to West Fork Cedar at 77.1%, followed by the Shell Rock River (74.3%), the Little Cedar River (71.4%), Beaver Creek (70.9%) and Wolf Creek (37.6%).

After row crop acreage, the next highest percentage of land was typically grazing/hay operations. Wolf Creek had the highest amount of pastured and hayed land, at 45.7% of the total watershed area. The other watersheds did not have nearly as high a percentage in them as Wolf Creek did. The next highest was the Little Cedar River, at 16.7%, followed by Beaver Creek (16.0%), Shell Rock River (15.8%), West Fork Cedar (15.1%), and Black Hawk Creek (12.0%).

CRP acreage was much lower in percentage in all watersheds. The highest acreage was in Wolf Creek at 4.1%, and the second highest was in the Shell Rock River at 2.1%, then followed by the Little Cedar (2.0%), Beaver Creek (1.7%), West Fork (1.7%), and Black Hawk Creek (1%).

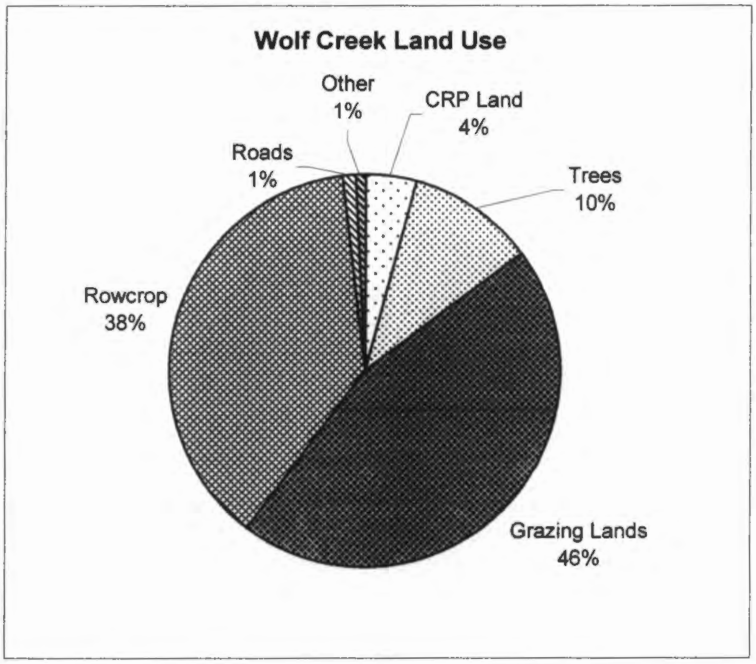

Fig. 41. 2002 land use in the Wolf Creek watershed.

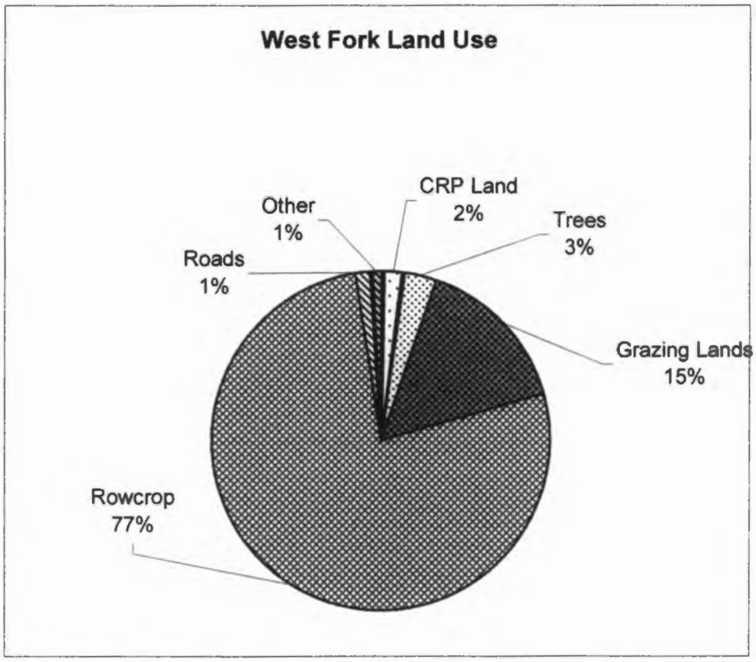

Fig. 42. 2002 land use in West Fork watershed.

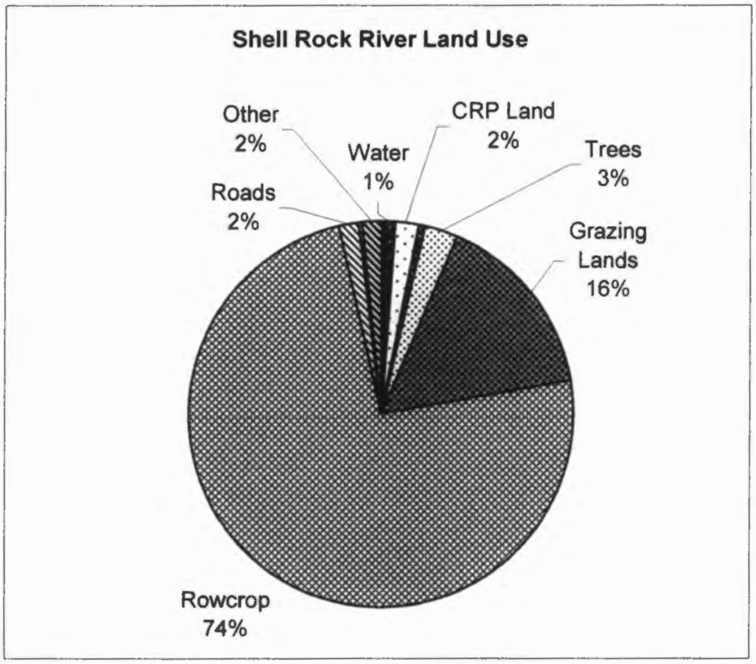

Fig. 43. 2002 land use in Shell Rock watershed.

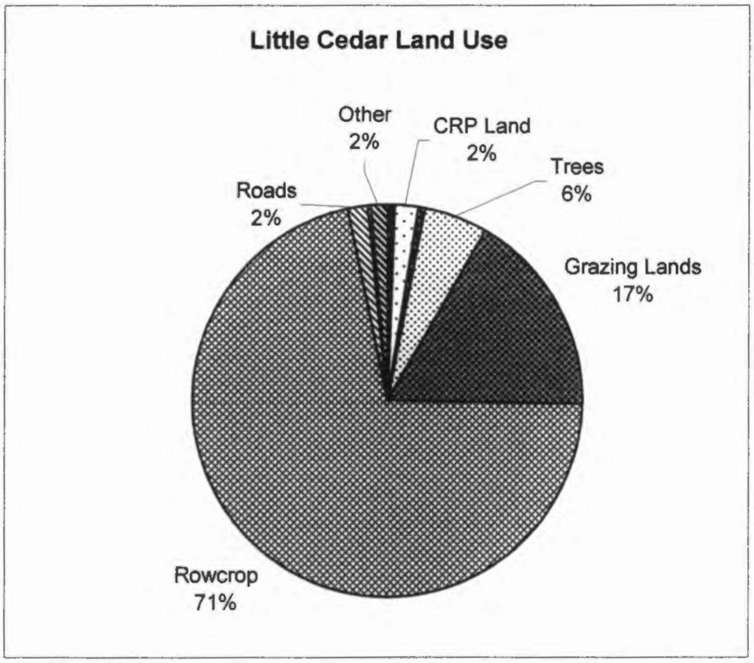

Fig. 44. 2002 land use in Little Cedar watershed.

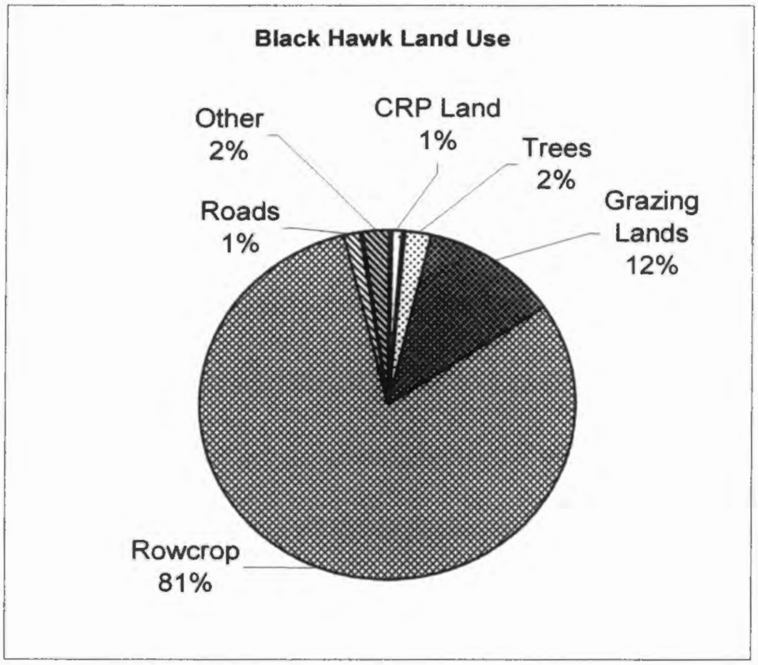

Fig. 45. 2002 land use in the Black Hawk Creek watershed.

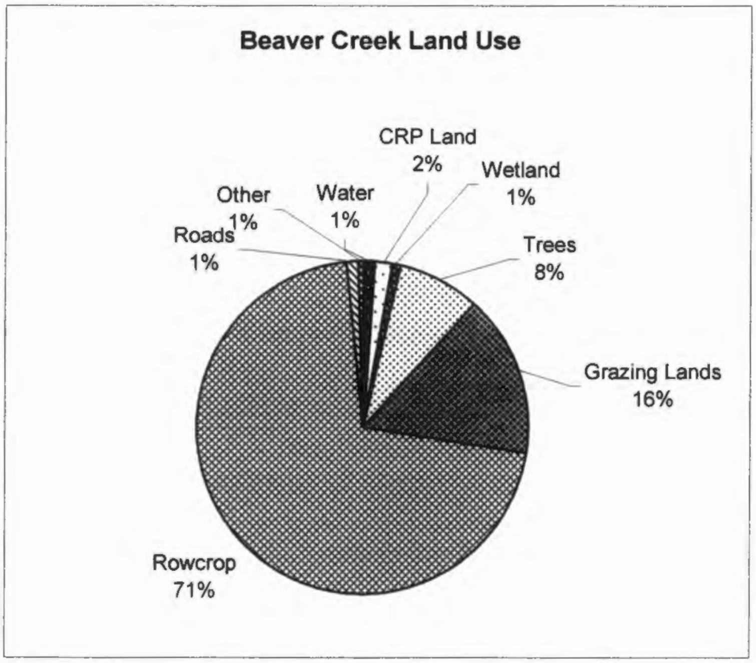

Fig. 46. 2002 land use in the Beaver Creek watershed.

Regression Analysis

Regression analysis was done on all of the tributaries. Water quality parameters for each stream were compared to each watershed's land use percentages to find any significant correlations between the measured parameters. The significance level was chosen to be 95% for this study (P-value=0.05).

Nitrate-N was found to be significantly dependent on watershed area. The regression equation is $y = -0.0006x + 8.6108$ (R^2=0.86, P value =0.0078). The slope is negative, indicating that the larger the watershed, the smaller the amount of nitrate in the stream. Another significant relationship with nitrate-N was barren land, the equation being: $y = -21.314x + 8.5061$ (R^2=0.68, P value =0.0447). The slope of this regression analysis is also negative, indicating that the higher the percentage of barren land, the lower the nitrate-N values in the stream. The significance of this relationship is lower than that of the watershed area.

The inverse relationship of nitrate-N values and watershed area could be attributed to a couple of factors. The first factor is that larger watersheds have longer travel times between the initial input of the nitrate-N and the measurement taken at the mouth of the stream. During this time period aquatic species could use the nitrate-N as a food source, thus lowering the initial amount. The other factor could be that the baseflow component in the watershed becomes more important as the watershed gets larger. The deeper sources of groundwater into the streams are less influenced by surface activities, and hence derive less nitrate-N. The inverse relationship of barren land to nitrate-N concentrations could be attributed to more development in the area and less row crop agriculture in the watersheds, thus reducing the need for fertilization and nitrogen input to the land.

Total dissolved phosphorus had no significant relationships to land use cover at the 95% confidence level. If the confidence level is dropped to 92%, however, a relationship is noted between percent barren land and dissolved phosphorus concentrations. The equation is: $y = -170.61x + 126.27$ ($R^2=0.58$, P value =0.0776). The slope is negative, indicating that the higher percentage of barren land decreases the dissolved phosphorus. Barren land in a watershed area could reduce the need for fertilization and thus the phosphorus runoff into the stream.

Suspended sediment concentrations had significant relationships with three variables. The most significant relationship was with the percentage of Conservation Reserve Program. The equation is: $y = -45.43x + 449.86$ ($R^2=0.81$, P value =0.0151). The slope is again negative, indicating a decrease in the suspended sediments with an increase in acres in the CRP program. Suspended Sediment was also found to have a significant relationship with percent row crop acres in a watershed. The equation is: $y = 2.82x + 161.86$ ($R^2=0.68$, P value =0.0440). The slope of the regression on row crop percentage is positive, indicating an increase in suspended sediment concentrations with more row crop percentages. The least significant relationship between the land use types and the suspended sediment concentrations is with percent forest. The equation is: $y = -13.732x + 424.66$ ($R^2=0.67$, P value =0.0478). The slope in this equation is also negative, indicating that an increase in forested lands yields lower suspended sediment concentrations.

The inverse correlation between CRP acreage and suspended sediment is likely due to the CRP acres acting as buffer strips against sediment transport. CRP programs have long been touted as a way to reduce sediment load to the stream channel. Conversely, row crop acres and suspended sediment had a positive correlation. This indicates that row crop agriculture increases sediment transport to the streams. Inverse relationship of forested acres with suspended sediment is indicative that trees and shrubs hold sediment on the ground.

Sediment phosphorus was determined to be significant with only one land use variable; percent wetlands in the watershed. The equation for this is: $y = -249.29x + 332.61$ ($R^2=0.69$, P value =0.0413). The negative slope indicates that the larger the area of wetlands in the watershed, the lower the total sediment phosphorus in the stream.

The inverse relationship between wetlands and sediment phosphorus is attributed to the wetlands acting as a phosphorus sink, thus reducing their levels in the stream sediment.

CONCLUSIONS

Nitrate-N, total dissolved phosphorus, sediment phosphorus, and suspended sediment were measured in Wolf Creek, West Fork River, Shell Rock River, Little Cedar River, Beaver Creek, and Black Hawk Creek. All tributaries are the major contributors of nutrients to the Cedar River. Black Hawk Creek is the most impaired tributary of the Cedar River, with the highest amounts of nitrate-N, phosphate P, and suspended sediments (Table 2). Black Hawk Creek also had the second highest total dissolved phosphorus measured during the study. Beaver Creek was found mildly impaired, having very high values in all parameters except sediment-P. Shell Rock River and Little Cedar River seemed to have the least impact from nonpoint source pollution. These two tributaries are on the lower end of nutrient and sediment pollution.

Table 2

Tributary ranking from worst (1) to best (6) of the water quality parameters measured in this study

Tributary Name	Nitrate-N	TDP	Sediment-P	Sus. Sediment
Wolf Creek	4	5	4	6
West Fork	3	4	2	2
Shell Rock	6	6	3	4
Little Cedar	5	3	5	5
Black Hawk	1	2	1	1
Beaver Creek	2	1	6	3

The water quality parameters measured are common in agricultural areas, and reflect the different levels of impairments commonly found in highly row-cropped watersheds. The results indicate that both nitrate-N and phosphorus are high in all tributaries and do not meet the EPA standards. It should be noted, however, that this study was done during the spring and summer months, when the levels of nutrients and sediments tend to be higher compared to the fall and winter months.

Regression analysis indicated that there were statistically significant relationships between nonpoint pollution parameters and land use in the watersheds. The most statistically significant was the negative relationship between nitrate-N concentration and watershed area (P value =0.0078). Also highly significant (P value =0.0151) was the negative relationship between CRP acres and suspended sediment measured in the watershed. These results indicate that more than percent row crop acres have an influence on water quality.

The load of nutrients entering the watershed is consistent with the previous studies in the area, including the work by Becher et al. (2000), and Tavener and Iqbal (2003). Additional studies on the Cedar River and its tributaries are needed to better understand the movement of nutrients and suspended sediments in these severely impacted agricultural streams. In particular, load estimation on bedload sediment, sediment P, and suspended sediments would greatly add to our understanding of nonpoint source pollution.

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APPENDIX A

CEDAR RIVER TRIBUTARY DISCHARGE AND WATER QUALITY VARIABLES

Wolf Creek

Date 2002	Discharge m^3/day	NO^3-N mg/L	Mean NO^3-N mg/L	TDP μg/L	Mean TDP μg/L	Sediment P μg/g	Sus. Sed. mg/L
4/28	225084.95	5.42		45.38			243.33
4/29	322947.97		7.45		81.87		
4/30	310715.09		7.45		81.87		
5/1	266676.73		7.45		81.87		
5/2	249550.71		7.45		81.87		
5/3	222638.37		7.45		81.87		
5/4	200619.19	9.48		116.78		59.25	
5/5	188386.32		11.97		106.07		
5/6	190832.89		11.97		106.07		
5/7	181046.59		11.97		106.07		
5/8	159027.41		11.97		106.07		
5/9	168813.71		11.97		106.07		
5/10	166367.14		11.97		106.07		
5/11	190832.89	14.45		95.36		490.92	
5/12	567605.53		13.77		74.21		
5/13	601857.58		13.77		74.21		
5/14	496654.84		13.77		74.21		
5/15	428150.72		13.77		74.21		
5/16	396345.24		13.77		74.21		
5/17	357200.03		13.77		74.21		
5/18	320501.40		13.77		74.21		
5/19	298482.22		13.77		74.21		
5/20	278909.61	13.09		53.07		440.08	
5/21	261783.58		11.06		62.30		
5/22	249550.71		11.06		62.30		
5/23	249550.71		11.06		62.30		
5/24	239764.40		11.06		62.30		
5/25	244657.55	9.03		71.53		360.08	
5/26	247104.13		9.60		106.17		
5/27	242210.98		9.60		106.17		
5/28	247104.13		9.60		106.17		
5/29	347413.73		9.60		106.17		
5/30	518674.02		9.60		106.17		
5/31	379219.21		9.60		106.17		
6/1	315608.25		9.60		106.17		
6/2	303375.37		9.60		106.17		
6/3	296035.64	10.16		140.77		330.08	
6/4	486868.53		10.73		116.04		
6/5	459956.20		10.73		116.04		

6/6	357200.03		10.73		116.04		
6/7	315608.25		10.73		116.04		
6/8	288695.91		10.73		116.04		
6/9	274016.46		10.73		116.04		
6/10	261783.58		10.73		116.04		
6/11	278909.61	11.29		91.27		374.25	
6/12	288695.91		13.10		94.89		
6/13	342520.58		13.10		94.89		
6/14	403684.97		13.10		94.89		
6/15	315608.25		13.10		94.89		
6/16	281356.19		13.10		94.89		
6/17	259337.01		13.10		94.89		
6/18	269123.31		13.10		94.89		
6/19	310715.09		13.10		94.89		
6/20	305821.94	14.90		98.50		45.92	
6/21	261783.58		12.76		106.70		
6/22	242210.98		12.76		106.70		
6/23	227531.53		12.76		106.70		
6/24	210405.50		12.76		106.70		
6/25	198172.62		12.76		106.70		
6/26	203065.77		12.76		106.70		
6/27	217745.22		12.76		106.70		
6/28	188386.32	10.61		114.91		594.25	
6/29	171260.29		8.76		105.82		
6/30	159027.41		8.76		105.82		
7/1	151687.68		8.76		105.82		
7/2	146794.53		8.76		105.82		
7/3	137008.23		8.76		105.82		
7/4	132115.08		8.76		105.82		
7/5	139454.81	6.91		96.73		441.75	
7/6	139454.81		6.39		94.32		
7/7	207958.92		6.39		94.32		
7/8	168813.71		6.39		94.32		
7/9	141901.38		6.39		94.32		
7/10	141901.38		6.39		94.32		
7/11	163920.56	5.87		91.91		177.58	173.50
7/12	166367.14		4.64		76.53		
7/13	144347.96		4.64		76.53		
7/14	141901.38		4.64		76.53		
7/15	129668.50		4.64		76.53		
7/16	119882.20		4.64		76.53		
7/17	114989.05		4.64		76.53		
7/18	110095.90		4.64		76.53		
7/19	105202.75		4.64		76.53		
7/20	100309.60		4.64		76.53		
7/21	95416.45	3.40		61.15		130.92	236.67
7/22	88076.72		2.40		50.39		

7/23	83183.57		2.40		50.39		
7/24	78290.42		2.40		50.39		
7/25	73397.27		2.40		50.39		
7/26	63610.96		2.40		50.39		
7/27	85630.14	1.40		39.62		305.08	266.67
7/28	102756.17		2.05		70.41		
7/29	163920.56		2.05		70.41		
7/30	222638.37		2.05		70.41		
7/31	124775.35		2.05		70.41		
8/1	92969.87		2.05		70.41		
8/2	75843.84	2.69		101.15		52.58	363.33
8/3	68504.12		2.24		94.64		
8/4	70950.69		2.24		94.64		
8/5	80736.99		2.24		94.64		
8/6	100309.60		2.24		94.64		
8/7	95416.45		2.24		94.64		
8/8	70950.69		2.24		94.64		
8/9	58717.81		2.24		94.64		
8/10	58717.81		2.24		94.64		
8/11	56271.24	1.78		88.07		342.58	267.31
8/12	56271.24		2.13		62.34		
8/13	63610.96		2.13		62.34		
8/14	68504.12		2.13		62.34		
8/15	80736.99		2.13		62.34		
8/16	63610.96	2.48		36.60		135.92	358.00
8/17	61164.39		2.94		164.90		
8/18	53824.66		2.94		164.90		
8/19	51378.09		2.94		164.90		
8/20	46484.94		2.94		164.90		
8/21	48931.51		2.94		164.90		
8/22	261783.58		2.94		164.90		
8/23	1436139.85	3.39		293.21		327.58	346.67
8/24	1003095.97		4.74		236.20		
8/25	540693.20		4.74		236.20		
8/26	381665.79		4.74		236.20		
8/27	303375.37		4.74		236.20		
8/28	237317.83		4.74		236.20		
8/29	198172.62		4.74		236.20		
8/30	171260.29		4.74		236.20		
8/31	149241.11		4.74		236.20		
9/1	132115.08		4.74		236.20		
9/2	119882.20	6.09		180.00		108.42	310.00
9/3	105202.75		4.40		191.30		
9/4	90523.30		4.40		191.30		
9/5	80736.99		4.40		191.30		
9/6	73397.27		4.40		191.30		
9/7	70950.69		4.40		191.30		

9/8	66057.54	2.71		202.64		146.75	258.00
9/9	61164.39		2.71		142.25		
9/10	58717.81		2.71		142.25		
9/11	53824.66		2.71		142.25		
9/12	51378.09		2.71		142.25		
9/13	48931.51		2.71		142.25		
9/14	48931.51		2.71		142.25		
9/15	48931.51		2.71		142.25		
9/16	46484.94		2.71		142.25		
9/17	46484.94		2.71		142.25		
9/18	53824.66		2.71		142.25		
9/19	83183.57		2.71		142.25		
9/20	83183.57		2.71		142.25		
9/21	66057.54	2.71		81.89		98.42	416.67
9/22	48931.51		2.49		66.80		
9/23	44038.36		2.49		66.80		
9/24	41591.78		2.49		66.80		
9/25	44038.36		2.49		66.80		
9/26	46484.94		2.49		66.80		
9/27	44038.36		2.49		66.80		
9/28	48931.51	2.26		51.70		101.75	118.00

West Fork River

Date 2002	Discharge m^3/day	NO^3-N mg/L	Mean NO^3-N mg/L	TDP µg/L	Mean TDP µg/L	Sediment P µg/g	Sus. Sed. mg/L
4/28	1467945.33	5.87		15.32		67.48	
4/29	2223937.17		8.24		67.86		
4/30	3009287.92		8.24		67.86		
5/1	2984822.17		8.24		67.86		
5/2	2617835.83		8.24		67.86		
5/3	2370731.70		8.24		67.86		
5/4	2231276.90	10.61		120.36		78.42	
5/5	2111394.70		7.68		97.15		
5/6	1991512.49		7.68		97.15		
5/7	1908328.93		7.68		97.15		
5/8	1844717.96		7.68		97.15		
5/9	1761534.39		7.68		97.15		
5/10	1661224.80		7.68		97.15		
5/11	1609846.71	4.74		73.93		82.58	
5/12	1788446.72		6.94		38.51		
5/13	2211704.29		6.94		38.51		
5/14	2617835.83		6.94		38.51		
5/15	2471041.30		6.94		38.51		
5/16	2211704.29		6.94		38.51		
5/17	1996405.65		6.94		38.51		
5/18	1800679.60		6.94		38.51		
5/19	1641652.19		6.94		38.51		
5/20	1521769.99	9.14		3.08		352.58	
5/21	1423906.97		8.97		18.08		
5/22	1335830.25		8.97		18.08		
5/23	1284452.16		8.97		18.08		
5/24	1225734.35		8.97		18.08		
5/25	1211054.90	8.80		33.08		74.25	
5/26	1198822.02		9.59		135.00		
5/27	1240413.80		9.59		135.00		
5/28	1267326.13		9.59		135.00		
5/29	1453265.87		9.59		135.00		
5/30	1617186.44		9.59		135.00		
5/31	1715049.46		9.59		135.00		
6/1	1582934.38		9.59		135.00		
6/2	1458159.03		9.59		135.00		
6/3	1372528.88	10.38		236.92		45.92	
6/4	1431246.69		11.17		145.92		
6/5	1497304.23		11.17		145.92		
6/6	1352956.28		11.17		145.92		
6/7	1237967.23		11.17		145.92		
6/8	1159676.81		11.17		145.92		

6/9	1088726.12		11.17		145.92		
6/10	1044687.76		11.17		145.92		
6/11	1056920.64	11.96		54.91		130.92	
6/12	1127871.33		10.50		107.64		
6/13	1076493.24		10.50		107.64		
6/14	1034901.46		10.50		107.64		
6/15	988416.52		10.50		107.64		
6/16	949271.31		10.50		107.64		
6/17	900339.80		10.50		107.64		
6/18	870980.89		10.50		107.64		
6/19	1311364.49		10.50		107.64		
6/20	3400740.01	9.03		160.36		58.42	
6/21	4452767.49		9.48		137.63		
6/22	4403835.98		9.48		137.63		
6/23	2838027.63		9.48		137.63		
6/24	2152986.48		9.48		137.63		
6/25	1766427.54		9.48		137.63		
6/26	1519323.41		9.48		137.63		
6/27	1328490.52		9.48		137.63		
6/28	1174356.26	9.93		114.91		333.42	
6/29	1054474.06		7.80		82.18		
6/30	956611.04		7.80		82.18		
7/1	851408.29		7.80		82.18		
7/2	763331.57		7.80		82.18		
7/3	709506.91		7.80		82.18		
7/4	672808.28		7.80		82.18		
7/5	716846.63	5.67		49.45		482.58	
7/6	707060.33		4.79		38.77		
7/7	721739.79		4.79		38.77		
7/8	817156.23		4.79		38.77		
7/9	773117.87		4.79		38.77		
7/10	714400.06		4.79		38.77		
7/11	733972.66	3.91		28.09		179.25	214.00
7/12	743758.97		4.13		54.24		
7/13	983523.37		4.13		54.24		
7/14	1614739.86		4.13		54.24		
7/15	1502197.38		4.13		54.24		
7/16	1286898.74		4.13		54.24		
7/17	1122978.18		4.13		54.24		
7/18	1000649.40		4.13		54.24		
7/19	919912.41		4.13		54.24		
7/20	858748.02		4.13		54.24		
7/21	785350.75	4.35		80.38		495.92	410.00
7/22	831835.69		3.25		56.15		
7/23	834282.26		3.25		56.15		
7/24	763331.57		3.25		56.15		
7/25	817156.23		3.25		56.15		

7/26	778011.02		3.25		56.15		
7/27	819602.81	2.14		31.92		437.58	266.00
7/28	826942.53		6.49		85.77		
7/29	905232.95		6.49		85.77		
7/30	1228180.92		6.49		85.77		
7/31	1218394.62		6.49		85.77		
8/1	971290.49		6.49		85.77		
8/2	870980.89	10.84		139.62		462.58	320.00
8/3	802476.78		10.05		140.60		
8/4	826942.53		10.05		140.60		
8/5	1010435.70		10.05		140.60		
8/6	2089375.52		10.05		140.60		
8/7	3523068.79		10.05		140.60		
8/8	3400740.01		10.05		140.60		
8/9	2289994.71		10.05		140.60		
8/10	1592720.68		10.05		140.60		
8/11	1414120.67	9.26		141.62		447.58	447.98
8/12	1367635.73		8.58		131.65		
8/13	1436139.85		8.58		131.65		
8/14	1333383.67		8.58		131.65		
8/15	1830038.51		8.58		131.65		
8/16	1683243.98	7.90		121.70		299.25	646.66
8/17	1425130.26		7.45		135.75		
8/18	1425130.26		7.45		135.75		
8/19	1425130.26		7.45		135.75		
8/20	1167016.54		7.45		135.75		
8/21	1110745.30		7.45		135.75		
8/22	1233074.07		7.45		135.75		
8/23	1357849.43	7.00		149.81		350.92	536.66
8/24	1030008.30		6.32		253.58		
8/25	1255093.25		6.32		253.58		
8/26	1154783.66		6.32		253.58		
8/27	1154783.66		6.32		253.58		
8/28	1120531.60		6.32		253.58		
8/29	1056920.64		6.32		253.58		
8/30	1012882.28		6.32		253.58		
8/31	968843.92		6.32		253.58		
9/1	968843.92		6.32		253.58		
9/2	946824.74	5.64		357.36		398.42	346.66
9/3	959057.61		4.52		229.08		
9/4	893000.07		4.52		229.08		
9/5	878320.62		4.52		229.08		
9/6	800030.20		4.52		229.08		
9/7	604304.16		4.52		229.08		
9/8	516227.44	3.39		100.75		407.58	400.00
9/9	506441.14		4.74		102.65		
9/10	511334.29		4.74		102.65		

9/11	452616.48		4.74		102.65		
9/12	408578.12		4.74		102.65		
9/13	393898.66		4.74		102.65		
9/14	364539.76		4.74		102.65		
9/15	335180.85		4.74		102.65		
9/16	320501.40		4.74		102.65		
9/17	303375.37		4.74		102.65		
9/18	308268.52		4.74		102.65		
9/19	310715.09		4.74		102.65		
9/20	919912.41		4.74		102.65		
9/21	1186589.14	6.09		104.50		174.25	416.66
9/22	939485.01		5.03		81.87		
9/23	775564.45		5.03		81.87		
9/24	628769.92		5.03		81.87		
9/25	565158.95		5.03		81.87		
9/26	555372.65		5.03		81.87		
9/27	653235.67		5.03		81.87		
9/28	648342.52	3.96		59.24		170.08	316.66

Shell Rock River

Date	Discharge	NO^3-N	Mean NO^3-N	TDP	Mean TDP	Sediment P	Sus. Sed.
2002	m^3/day	mg/L	mg/L	µg/L	µg/L	µg/g	mg/L
4/28	1673457.67	2.03		0.00			
4/29	2493060.48		3.50		8.39		
4/30	2593370.08		3.50		8.39		
5/1	2341372.80		3.50		8.39		
5/2	2211704.29		3.50		8.39		
5/3	2192131.69		3.50		8.39		
5/4	2096715.24	4.97		16.79		130.92	
5/5	1925454.95		4.24		22.14		
5/6	1820252.21		4.24		22.14		
5/7	1727282.34		4.24		22.14		
5/8	1617186.44		4.24		22.14		
5/9	1600060.41		4.24		22.14		
5/10	1460605.60		4.24		22.14		
5/11	1536449.44	3.50		27.50		244.25	
5/12	1693030.28		2.88		38.35		
5/13	1641652.19		2.88		38.35		
5/14	1602506.98		2.88		38.35		
5/15	1534002.87		2.88		38.35		
5/16	1502197.38		2.88		38.35		
5/17	1406780.94		2.88		38.35		
5/18	1345616.55		2.88		38.35		
5/19	1289345.31		2.88		38.35		
5/20	1240413.80	2.26		49.20		91.75	
5/21	1184142.56		2.04		39.22		
5/22	1140104.20		2.04		39.22		
5/23	1127871.33		2.04		39.22		
5/24	1078939.82		2.04		39.22		
5/25	1105852.15	1.81		29.23		95.08	
5/26	1113191.87		2.60		14.61		
5/27	1115638.45		2.60		14.61		
5/28	1147443.93		2.60		14.61		
5/29	1355402.85		2.60		14.61		
5/30	1264879.56		2.60		14.61		
5/31	1365189.15		2.60		14.61		
6/1	1534002.87		2.60		14.61		
6/2	1494857.66		2.60		14.61		
6/3	1421460.39	3.39		0.50		55.92	
6/4	1399441.21		4.63		9.27		
6/5	1318704.22		4.63		9.27		
6/6	1617186.44		4.63		9.27		
6/7	1614739.86		4.63		9.27		
6/8	1494857.66		4.63		9.27		

6/9	1360296.00		4.63		9.27		
6/10	1301578.19		4.63		9.27		
6/11	1328490.52	5.87		18.54		109.25	
6/12	1431246.69		7.34		80.67		
6/13	1541342.59		7.34		80.67		
6/14	1560915.20		7.34		80.67		
6/15	1499750.81		7.34		80.67		
6/16	1419013.82		7.34		80.67		
6/17	1323597.37		7.34		80.67		
6/18	1272219.28		7.34		80.67		
6/19	2128520.72		7.34		80.67		
6/20	4988567.54	8.80		142.18		218.42	
6/21	4770822.31		7.45		190.67		
6/22	4697425.05		7.45		190.67		
6/23	4281507.20		7.45		190.67		
6/24	3572000.30		7.45		190.67		
6/25	2838027.63		7.45		190.67		
6/26	2302227.59		7.45		190.67		
6/27	2040444.00		7.45		190.67		
6/28	1808019.33	6.09		238.54		364.25	
6/29	1624526.16		4.92		131.27		
6/30	1475285.05		4.92		131.27		
7/1	1372528.88		4.92		131.27		
7/2	1245306.95		4.92		131.27		
7/3	1137657.63		4.92		131.27		
7/4	1083832.97		4.92		131.27		
7/5	1034901.46	3.75		24.00		214.25	
7/6	990863.10		2.87		26.05		
7/7	976183.64		2.87		26.05		
7/8	966397.34		2.87		26.05		
7/9	902786.38		2.87		26.05		
7/10	880767.20		2.87		26.05		
7/11	1022668.58	1.98		28.09		167.58	214.25
7/12	1746854.94		2.96		81.15		
7/13	2691233.10		2.96		81.15		
7/14	2471041.30		2.96		81.15		
7/15	2060016.61		2.96		81.15		
7/16	1663671.37		2.96		81.15		
7/17	1389654.91		2.96		81.15		
7/18	1215948.05		2.96		81.15		
7/19	1113191.87		2.96		81.15		
7/20	1044687.76		2.96		81.15		
7/21	990863.10	3.94		134.23		289.25	463.33
7/22	1000649.40		2.97		132.85		
7/23	1196375.44		2.97		132.85		
7/24	1389654.91		2.97		132.85		
7/25	1423906.97		2.97		132.85		

7/26	1301578.19		2.97		132.85		
7/27	1335830.25	1.99		131.49		229.25	353.33
7/28	1455712.45		4.53		149.00		
7/29	1945027.56		4.53		149.00		
7/30	3841123.61		4.53		149.00		
7/31	3767726.34		4.53		149.00		
8/1	2984822.17		4.53		149.00		
8/2	2441682.39	7.06		166.54		124.25	343.33
8/3	2013531.67		7.41		190.75		
8/4	1923008.38		7.41		190.75		
8/5	3645397.56		7.41		190.75		
8/6	8636411.68		7.41		190.75		
8/7	11865891.40		7.41		190.75		
8/8	10520274.85		7.41		190.75		
8/9	9150192.54		7.41		190.75		
8/10	7731178.72		7.41		190.75		
8/11	6458959.44	7.76		215.00		340.92	496.66
8/12	5676055.27		6.97		182.75		
8/13	5602658.00		6.97		182.75		
8/14	6532356.71		6.97		182.75		
8/15	6654685.48		6.97		182.75		
8/16	5749452.53	6.17		151.49		456.75	456.66
8/17	5039945.62		5.34		178.46		
8/18	4575096.27		5.34		178.46		
8/19	4012383.89		5.34		178.46		
8/20	3351808.50		5.34		178.46		
8/21	2886959.14		5.34		178.46		
8/22	2642301.59		5.34		178.46		
8/23	2666767.34	4.51		206.41		479.25	173.33
8/24	3009287.92		3.95		134.71		
8/25	2886959.14		3.95		134.71		
8/26	2544438.57		3.95		134.71		
8/27	2446575.55		3.95		134.71		
8/28	2304674.16		3.95		134.71		
8/29	2150539.90		3.95		134.71		
8/30	1920561.80		3.95		134.71		
8/31	1759087.82		3.95		134.71		
9/1	1600060.41		3.95		134.71		
9/2	1480178.21	3.39		63.01		513.42	380.00
9/3	1433693.27		2.83		59.24		
9/4	1233074.07		2.83		59.24		
9/5	1191482.29		2.83		59.24		
9/6	1152337.08		2.83		59.24		
9/7	1091172.69		2.83		59.24		
9/8	1007989.12	2.26		55.47		528.42	310.00
9/9	988416.52		2.15		100.74		
9/10	966397.34		2.15		100.74		

9/11	944378.16		2.15		100.74		
9/12	917465.83		2.15		100.74		
9/13	885660.35		2.15		100.74		
9/14	861194.59		2.15		100.74		
9/15	851408.29		2.15		100.74		
9/16	848961.71		2.15		100.74		
9/17	831835.69		2.15		100.74		
9/18	834282.26		2.15		100.74		
9/19	939485.01		2.15		100.74		
9/20	1142550.78		2.15		100.74		
9/21	1137657.63	2.03		146.03		247.58	330.00
9/22	1069153.51		2.01		134.70		
9/23	929698.71		2.01		134.70		
9/24	893000.07		2.01		134.70		
9/25	861194.59		2.01		134.70		
9/26	863641.17		2.01		134.70		
9/27	875874.05		2.01		134.70		
9/28	910126.10	1.99		123.40		365.08	370.00

Little Cedar River

Date 2002	Discharge m^3/day	NO^3-N mg/L	Mean NO^3-N mg/L	TDP µg/L	Mean TDP µg/L	Sediment P µg/g	Sus. Sed. mg/L
4/28	1959707.01	4.51		0.00			
4/29	2666767.34		6.43		36.97		
4/30	3425205.76		6.43		36.97		
5/1	3914520.87		6.43		36.97		
5/2	3767726.34		6.43		36.97		
5/3	3425205.76		6.43		36.97		
5/4	3180548.21	8.35		73.93		171.75	
5/5	2813561.88		7.11		111.43		
5/6	2544438.57		7.11		111.43		
5/7	2429449.52		7.11		111.43		
5/8	2211704.29		7.11		111.43		
5/9	2177452.24		7.11		111.43		
5/10	1900989.20		7.11		111.43		
5/11	1937687.83	5.87		148.93		172.58	
5/12	2067356.34		5.19		262.57		
5/13	2148093.33		5.19		262.57		
5/14	1778660.42		5.19		262.57		
5/15	1636759.04		5.19		262.57		
5/16	1773767.27		5.19		262.57		
5/17	1671011.10		5.19		262.57		
5/18	1582934.38		5.19		262.57		
5/19	1489964.51		5.19		262.57		
5/20	1404334.36	4.51		376.15		218.42	
5/21	1330937.10		3.84		193.10		
5/22	1250200.10		3.84		193.10		
5/23	1282005.59		3.84		193.10		
5/24	1247753.53		3.84		193.10		
5/25	1223287.77	3.16		10.00		77.58	
5/26	1176802.84		3.84		75.35		
5/27	1171909.69		3.84		75.35		
5/28	1171909.69		3.84		75.35		
5/29	1436139.85		3.84		75.35		
5/30	1949920.71		3.84		75.35		
5/31	1773767.27		3.84		75.35		
6/1	1624526.16		3.84		75.35		
6/2	1543789.17		3.84		75.35		
6/3	1399441.21	4.51		140.77		96.75	
6/4	2175005.66		8.80		103.26		
6/5	3156082.45		8.80		103.26		
6/6	3645397.56		8.80		103.26		
6/7	5798384.04		8.80		103.26		
6/8	5896247.06		8.80		103.26		
6/9	4501699.00		8.80		103.26		

6/10	3792192.10		8.80		103.26		
6/11	3205013.96	13.09		65.82		222.58	
6/12	2691233.10		10.49		67.64		
6/13	2593370.08		10.49		67.64		
6/14	2568904.32		10.49		67.64		
6/15	2471041.30		10.49		67.64		
6/16	2219044.02		10.49		67.64		
6/17	2006191.95		10.49		67.64		
6/18	1832485.08		10.49		67.64		
6/19	1869183.72		10.49		67.64		
6/20	2789096.12	7.90		69.45		283.42	
6/21	2334033.07		8.02		103.09		
6/22	2060016.61		8.02		103.09		
6/23	2294887.86		8.02		103.09		
6/24	2862493.39		8.02		103.09		
6/25	2789096.12		8.02		103.09		
6/26	2568904.32		8.02		103.09		
6/27	3033753.68		8.02		103.09		
6/28	2409876.91	8.13		136.73		267.58	
6/29	2471041.30		7.27		87.64		
6/30	1989065.92		7.27		87.64		
7/1	1675904.25		7.27		87.64		
7/2	1563361.77		7.27		87.64		
7/3	1360296.00		7.27		87.64		
7/4	1296685.04		7.27		87.64		
7/5	1240413.80	6.40		38.55		117.58	
7/6	1179249.41		4.58		19.28		
7/7	1115638.45		4.58		19.28		
7/8	1069153.51		4.58		19.28		
7/9	1022668.58		4.58		19.28		
7/10	959057.61		4.58		19.28		
7/11	1125424.75	2.76		0.00		162.58	410.00
7/12	1357849.43		2.03		24.81		
7/13	1729728.91		2.03		24.81		
7/14	1514430.26		2.03		24.81		
7/15	1286898.74		2.03		24.81		
7/16	1091172.69		2.03		24.81		
7/17	1081386.39		2.03		24.81		
7/18	995756.25		2.03		24.81		
7/19	1005542.55		2.03		24.81		
7/20	915019.25		2.03		24.81		
7/21	1034901.46	1.30		49.62		124.25	333.33
7/22	1056920.64		1.41		52.31		
7/23	1052027.48		1.41		52.31		
7/24	946824.74		1.41		52.31		
7/25	1037348.03		1.41		52.31		
7/26	1027561.73		1.41		52.31		

7/27	1108298.72	1.52		55.00		183.42	353.33
7/28	1137657.63		2.12		45.28		
7/29	1419013.82		2.12		45.28		
7/30	1903435.77		2.12		45.28		
7/31	1883863.17		2.12		45.28		
8/1	1463052.18		2.12		45.28		
8/2	1286898.74	2.71		35.77		69.25	270.00
8/3	1164569.96		5.02		71.54		
8/4	1135211.05		5.02		71.54		
8/5	1482624.78		5.02		71.54		
8/6	3425205.76		5.02		71.54		
8/7	5627123.75		5.02		71.54		
8/8	5553726.49		5.02		71.54		
8/9	4205663.36		5.02		71.54		
8/10	3253945.48		5.02		71.54		
8/11	2519972.81	7.32		107.31		312.58	280.00
8/12	2385411.16		6.16		82.59		
8/13	2373178.28		6.16		82.59		
8/14	2172559.08		6.16		82.59		
8/15	2568904.32		6.16		82.59		
8/16	2373178.28	4.99		57.87		459.25	216.66
8/17	2086928.94		4.42		86.86		
8/18	1937687.83		4.42		86.86		
8/19	1830038.51		4.42		86.86		
8/20	1651438.49		4.42		86.86		
8/21	1475285.05		4.42		86.86		
8/22	1575594.65		4.42		86.86		
8/23	1700370.00	3.84		115.84		402.58	483.33
8/24	1318704.22		3.05		180.02		
8/25	1450819.30		3.05		180.02		
8/26	1367635.73		3.05		180.02		
8/27	1348063.13		3.05		180.02		
8/28	1357849.43		3.05		180.02		
8/29	1181695.99		3.05		180.02		
8/30	1135211.05		3.05		180.02		
8/31	1115638.45		3.05		180.02		
9/1	1093619.27		3.05		180.02		
9/2	1074046.66	2.26		244.15		236.75	533.33
9/3	1098512.42		2.15		238.52		
9/4	995756.25		2.15		238.52		
9/5	937038.43		2.15		238.52		
9/6	890553.50		2.15		238.52		
9/7	826942.53		2.15		238.52		
9/8	878320.62	2.03		232.83		280.08	320.00
9/9	902786.38		2.26		164.91		
9/10	885660.35		2.26		164.91		
9/11	873427.47		2.26		164.91		

9/12	782904.17		2.26		164.91		
9/13	880767.20		2.26		164.91		
9/14	782904.17		2.26		164.91		
9/15	782904.17		2.26		164.91		
9/16	778011.02		2.26		164.91		
9/17	836728.84		2.26		164.91		
9/18	870980.89		2.26		164.91		
9/19	836728.84		2.26		164.91		
9/20	1179249.41		2.26		164.91		
9/21	858748.02	2.48		96.98		334.25	63.00
9/22	870980.89		2.37		170.57		
9/23	790243.90		2.37		170.57		
9/24	753545.27		2.37		170.57		
9/25	809816.51		2.37		170.57		
9/26	804923.35		2.37		170.57		
9/27	746205.54		2.37		170.57		
9/28	773117.87	2.26		244.15		240.92	410.00

Black Hawk Creek

Date 2002	Discharge m^3/day	NO^3-N mg/L	Mean NO^3-N mg/L	TDP µg/L	mean TDP µg/L	Sediment P µg/g	Sus. Sed. mg/L
4/28	548032.92	10.38		80.00			
4/29	831835.69		11.17		105.55		
4/30	682594.58		11.17		105.55		
5/1	572498.68		11.17		105.55		
5/2	535800.04		11.17		105.55		
5/3	523567.17		11.17		105.55		
5/4	481975.38	11.96		131.07		77.58	
5/5	437937.02		14.00		116.80		
5/6	415917.84		14.00		116.80		
5/7	381665.79		14.00		116.80		
5/8	352306.88		14.00		116.80		
5/9	352306.88		14.00		116.80		
5/10	313161.67		14.00		116.80		
5/11	362093.18	16.03		102.50		389.25	
5/12	1022668.58		14.34		68.18		
5/13	1127871.33		14.34		68.18		
5/14	880767.20		14.34		68.18		
5/15	731526.09		14.34		68.18		
5/16	653235.67		14.34		68.18		
5/17	574945.25		14.34		68.18		
5/18	521120.59		14.34		68.18		
5/19	484421.96		14.34		68.18		
5/20	450169.90	12.64		33.85		406.75	
5/21	423257.57		10.84		39.23		
5/22	406131.54		10.84		39.23		
5/23	401238.39		10.84		39.23		
5/24	381665.79		10.84		39.23		
5/25	376772.63	9.03		44.61		301.75	
5/26	411024.69		10.39		146.51		
5/27	408578.12		10.39		146.51		
5/28	391452.09		10.39		146.51		
5/29	396345.24		10.39		146.51		
5/30	386558.94		10.39		146.51		
5/31	369432.91		10.39		146.51		
6/1	347413.73		10.39		146.51		
6/2	335180.85		10.39		146.51		
6/3	344967.15	11.74		248.46		446.75	
6/4	638556.22		11.63		155.29		
6/5	477082.23		11.63		155.29		
6/6	403684.97		11.63		155.29		
6/7	366986.33		11.63		155.29		
6/8	342520.58		11.63		155.29		
6/9	322947.97		11.63		155.29		

6/10	308268.52		11.63		155.29		
6/11	332734.27	11.51		62.18		319.25	
6/12	359646.61		12.87		84.89		
6/13	342520.58		12.87		84.89		
6/14	320501.40		12.87		84.89		
6/15	305821.94		12.87		84.89		
6/16	291142.49		12.87		84.89		
6/17	278909.61		12.87		84.89		
6/18	278909.61		12.87		84.89		
6/19	318054.82		12.87		84.89		
6/20	371879.48	14.22		107.64		444.25	
6/21	381665.79		13.21		106.71		
6/22	313161.67		13.21		106.71		
6/23	281356.19		13.21		106.71		
6/24	259337.01		13.21		106.71		
6/25	242210.98		13.21		106.71		
6/26	232424.68		13.21		106.71		
6/27	220191.80		13.21		106.71		
6/28	205512.35	12.19		105.82		535.92	
6/29	195726.04		10.20		83.09		
6/30	183493.17		10.20		83.09		
7/1	171260.29		10.20		83.09		
7/2	161473.99		10.20		83.09		
7/3	154134.26		10.20		83.09		
7/4	149241.11		10.20		83.09		
7/5	173706.86	8.20		60.36		431.75	
7/6	310715.09		6.66		99.22		
7/7	543139.77		6.66		99.22		
7/8	411024.69		6.66		99.22		
7/9	271569.89		6.66		99.22		
7/10	227531.53		6.66		99.22		
7/11	237317.83	5.11		138.07		402.58	473.00
7/12	303375.37		6.27		134.19		
7/13	256890.43		6.27		134.19		
7/14	207958.92		6.27		134.19		
7/15	178600.01		6.27		134.19		
7/16	161473.99		6.27		134.19		
7/17	146794.53		6.27		134.19		
7/18	137008.23		6.27		134.19		
7/19	124775.35		6.27		134.19		
7/20	117435.63		6.27		134.19		
7/21	110095.90	7.42		130.38		480.92	416.67
7/22	105202.75		5.51		119.58		
7/23	97863.02		5.51		119.58		
7/24	92969.87		5.51		119.58		
7/25	90523.30		5.51		119.58		
7/26	85630.14		5.51		119.58		

7/27	105202.75	3.59		108.85		401.75	320.00
7/28	127221.93		3.75		116.52		
7/29	173706.86		3.75		116.52		
7/30	156580.83		3.75		116.52		
7/31	119882.20		3.75		116.52		
8/1	97863.02		3.75		116.52		
8/2	85630.14	3.90		124.23		350.08	673.67
8/3	80736.99		3.08		69.76		
8/4	80736.99		3.08		69.76		
8/5	83183.57		3.08		69.76		
8/6	80736.99		3.08		69.76		
8/7	80736.99		3.08		69.76		
8/8	73397.27		3.08		69.76		
8/9	68504.12		3.08		69.76		
8/10	66057.54		3.08		69.76		
8/11	61164.39	2.26		15.31		415.92	566.65
8/12	66057.54		4.30		55.74		
8/13	146794.53		4.30		55.74		
8/14	249550.71		4.30		55.74		
8/15	205512.35		4.30		55.74		
8/16	141901.38	6.33		96.17		483.42	370.00
8/17	117435.63		5.54		266.08		
8/18	107649.32		5.54		266.08		
8/19	97863.02		5.54		266.08		
8/20	88076.72		5.54		266.08		
8/21	80736.99		5.54		266.08		
8/22	733972.66		5.54		266.08		
8/23	2199471.42	4.74		436.00		400.08	646.67
8/24	1629419.31		5.98		266.49		
8/25	944378.16		5.98		266.49		
8/26	751098.69		5.98		266.49		
8/27	650789.10		5.98		266.49		
8/28	472189.08		5.98		266.49		
8/29	379219.21		5.98		266.49		
8/30	320501.40		5.98		266.49		
8/31	271569.89		5.98		266.49		
9/1	234871.25		5.98		266.49		
9/2	205512.35	7.22		96.98		394.25	390.00
9/3	181046.59		5.73		115.84		
9/4	159027.41		5.73		115.84		
9/5	144347.96		5.73		115.84		
9/6	134561.66		5.73		115.84		
9/7	122328.78		5.73		115.84		
9/8	112542.48	4.24		134.72		190.92	430.00
9/9	105202.75		4.42		108.29		
9/10	100309.60		4.42		108.29		
9/11	95416.45		4.42		108.29		

9/12	95416.45		4.42		108.29		
9/13	90523.30		4.42		108.29		
9/14	90523.30		4.42		108.29		
9/15	90523.30		4.42		108.29		
9/16	85630.14		4.42		108.29		
9/17	83183.57		4.42		108.29		
9/18	83183.57		4.42		108.29		
9/19	92969.87		4.42		108.29		
9/20	95416.45		4.42		108.29		
9/21	85630.14	4.59		81.89		105.92	480.00
9/22	78290.42		4.33		74.34		
9/23	75843.84		4.33		74.34		
9/24	75843.84		4.33		74.34		
9/25	73397.27		4.33		74.34		
9/26	75843.84		4.33		74.34		
9/27	75843.84		4.33		74.34		
9/28	75843.84	4.06		66.79		122.58	360.00

Beaver Creek

Date 2002	Discharge m^3/day	NO^3-N mg/L	Mean NO^3-N mg/L	TDP µg/L	Mean TDP µg/L	Sediment P µg/g	Sus. Sed. mg/L
4/28	726632.94	11.96		53.07			
4/29	1575594.65		9.93		145.64		
4/30	1179249.41		9.93		145.64		
5/1	929698.71		9.93		145.64		
5/2	819602.81		9.93		145.64		
5/3	716846.63		9.93		145.64		
5/4	623876.76	7.90		238.21		56.75	
5/5	555372.65		9.93		548.90		
5/6	523567.17		9.93		548.90		
5/7	481975.38		9.93		548.90		
5/8	445276.75		9.93		548.90		
5/9	423257.57		9.93		548.90		
5/10	379219.21		9.93		548.90		
5/11	437937.02	11.96		859.64		6.75	
5/12	1277112.43		11.62		452.49		
5/13	1587827.53		11.62		452.49		
5/14	1201268.59		11.62		452.49		
5/15	981076.79		11.62		452.49		
5/16	831835.69		11.62		452.49		
5/17	699720.61		11.62		452.49		
5/18	616537.04		11.62		452.49		
5/19	562712.38		11.62		452.49		
5/20	518674.02	11.29		45.38		72.58	
5/21	491761.68		10.16		33.46		
5/22	467295.93		10.16		33.46		
5/23	464849.35		10.16		33.46		
5/24	430597.30		10.16		33.46		
5/25	445276.75	9.03		21.54		61.75	
5/26	503994.56		10.16		52.31		
5/27	486868.53		10.16		52.31		
5/28	467295.93		10.16		52.31		
5/29	599411.01		10.16		52.31		
5/30	604304.16		10.16		52.31		
5/31	543139.77		10.16		52.31		
6/1	484421.96		10.16		52.31		
6/2	459956.20		10.16		52.31		
6/3	433043.87	11.29		83.08		19.25	
6/4	503994.56		11.62		72.63		
6/5	526013.74		11.62		72.63		
6/6	467295.93		11.62		72.63		
6/7	437937.02		11.62		72.63		
6/8	413471.27		11.62		72.63		

6/9	391452.09		11.62		72.63		
6/10	393898.66		11.62		72.63		
6/11	447723.32	11.96		62.18		66.75	
6/12	491761.68		12.75		138.50		
6/13	472189.08		12.75		138.50		
6/14	433043.87		12.75		138.50		
6/15	403684.97		12.75		138.50		
6/16	389005.51		12.75		138.50		
6/17	364539.76		12.75		138.50		
6/18	357200.03		12.75		138.50		
6/19	1487517.93		12.75		138.50		
6/20	3205013.96	13.54		214.91		12.58	
6/21	1524216.56		11.85		153.90		
6/22	1039794.61		11.85		153.90		
6/23	848961.71		11.85		153.90		
6/24	672808.28		11.85		153.90		
6/25	587178.13		11.85		153.90		
6/26	521120.59		11.85		153.90		
6/27	464849.35		11.85		153.90		
6/28	462402.78	10.16		93.09		30.08	
6/29	425704.14		9.36		103.55		
6/30	403684.97		9.36		103.55		
7/1	357200.03		9.36		103.55		
7/2	310715.09		9.36		103.55		
7/3	293589.07		9.36		103.55		
7/4	318054.82		9.36		103.55		
7/5	318054.82	8.56		114.01		80.92	
7/6	330287.70		7.70		79.56		
7/7	384112.36		7.70		79.56		
7/8	347413.73		7.70		79.56		
7/9	274016.46		7.70		79.56		
7/10	259337.01		7.70		79.56		
7/11	278909.61	6.84		45.11		74.25	354.00
7/12	342520.58		5.82		55.31		
7/13	322947.97		5.82		55.31		
7/14	269123.31		5.82		55.31		
7/15	242210.98		5.82		55.31		
7/16	220191.80		5.82		55.31		
7/17	207958.92		5.82		55.31		
7/18	198172.62		5.82		55.31		
7/19	190832.89		5.82		55.31		
7/20	183493.17		5.82		55.31		
7/21	173706.86	4.79		65.50		14.25	203.00
7/22	171260.29		3.72		64.10		
7/23	166367.14		3.72		64.10		
7/24	156580.83		3.72		64.10		
7/25	154134.26		3.72		64.10		

7/26	154134.26		3.72		64.10		
7/27	171260.29	2.65		62.69		70.08	313.33
7/28	207958.92		4.14		72.31		
7/29	242210.98		4.14		72.31		
7/30	278909.61		4.14		72.31		
7/31	234871.25		4.14		72.31		
8/1	198172.62		4.14		72.31		
8/2	154134.26	5.62		81.92		5.92	360.48
8/3	151687.68		5.77		90.77		
8/4	171260.29		5.77		90.77		
8/5	205512.35		5.77		90.77		
8/6	300928.79		5.77		90.77		
8/7	344967.15		5.77		90.77		
8/8	259337.01		5.77		90.77		
8/9	212852.07		5.77		90.77		
8/10	200619.19		5.77		90.77		
8/11	193279.47	5.92		99.62		92.58	482.00
8/12	188386.32		7.22		119.21		
8/13	702167.18		7.22		119.21		
8/14	1030008.30		7.22		119.21		
8/15	697274.03		7.22		119.21		
8/16	469742.50	8.81		138.80		110.08	680.00
8/17	364539.76		7.34		157.50		
8/18	344967.15		7.34		157.50		
8/19	340074.00		7.34		157.50		
8/20	291142.49		7.34		157.50		
8/21	254443.86		7.34		157.50		
8/22	327841.12		7.34		157.50		
8/23	863641.17	5.87		176.23		483.42	393.00
8/24	680148.00		5.53		134.71		
8/25	518674.02		5.53		134.71		
8/26	530906.89		5.53		134.71		
8/27	428150.72		5.53		134.71		
8/28	330287.70		5.53		134.71		
8/29	281356.19		5.53		134.71		
8/30	251997.28		5.53		134.71		
8/31	232424.68		5.53		134.71		
9/1	215298.65		5.53		134.71		
9/2	198172.62	5.19		93.21		429.25	290.00
9/3	178600.01		4.18		66.80		
9/4	163920.56		4.18		66.80		
9/5	159027.41		4.18		66.80		
9/6	149241.11		4.18		66.80		
9/7	144347.96		4.18		66.80		
9/8	134561.66	3.16		40.38		123.42	310.00
9/9	129668.50		5.08		74.34		
9/10	124775.35		5.08		74.34		

9/11	122328.78		5.08		74.34		
9/12	119882.20		5.08		74.34		
9/13	114989.05		5.08		74.34		
9/14	112542.48		5.08		74.34		
9/15	110095.90		5.08		74.34		
9/16	105202.75		5.08		74.34		
9/17	97863.02		5.08		74.34		
9/18	100309.60		5.08		74.34		
9/19	110095.90		5.08		74.34		
9/20	159027.41		5.08		74.34		
9/21	234871.25	7.00		108.30		195.08	283.00
9/22	198172.62		6.10		138.50		
9/23	163920.56		6.10		138.50		
9/24	146794.53		6.10		138.50		
9/25	137008.23		6.10		138.50		
9/26	132115.08		6.10		138.50		
9/27	129668.50		6.10		138.50		
9/28	129668.50	5.19		168.68		186.75	293.00

APPENDIX B

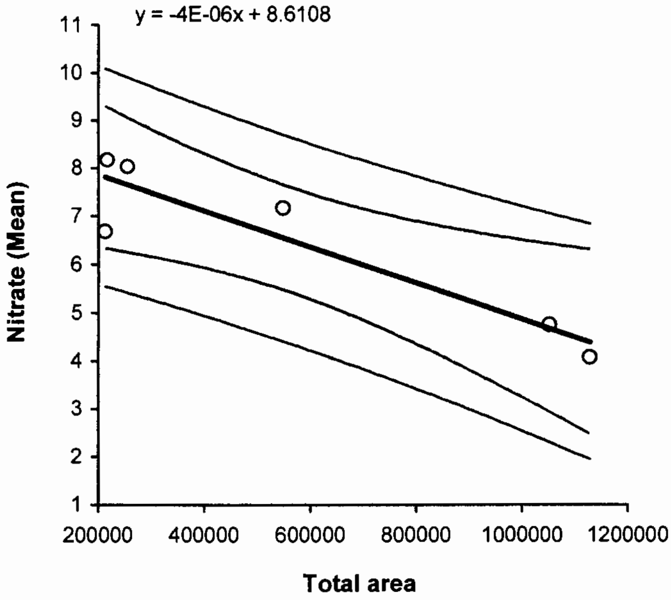
LINEAR REGRESSION

Test	**Linear regression**		
Fit	Nitrate (Mean) v Total area		
Performed by	Chad Fields	**Date**	13 July 2004

n	6
R^2	0.86
Adjusted R^2	0.82
SE	0.7161

Term	**Coefficient**	**SE**	**p**	**95% CI of Coefficient**
Intercept	8.6108	0.5206	<0.0001	7.1655 to 10.0562
Slope	0.0000	0.0000	0.0078	0.0000 to -0.0000

Source of variation	**SSq**	**DF**	**MSq**	**F**	**p**
Due to regression	12.518	1	12.518	24.41	0.0078
About regression	2.051	4	0.513		
Total	14.569	5			

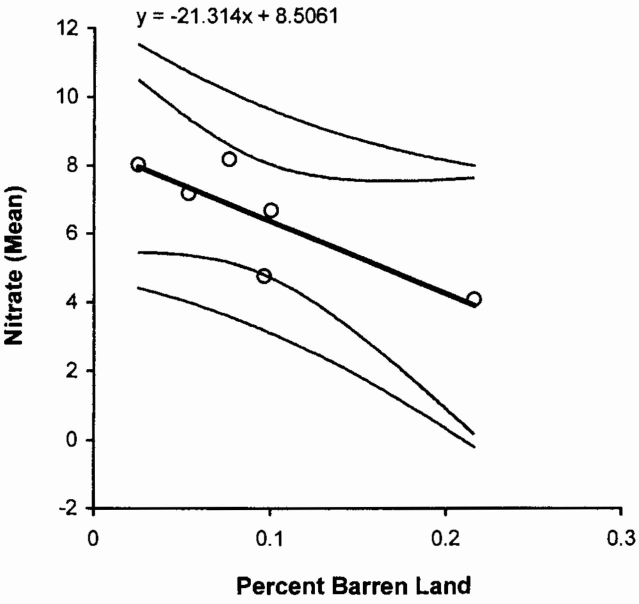


Test	**Linear regression**		
Fit	Nitrate (Mean) v Percent Barren		
Performed by	Chad Fields	**Date**	13 July 2004

n	6
R^2	0.68
Adjusted R^2	0.59
SE	1.0869

Term	Coefficient	SE	p	95% CI of Coefficient
Intercept	8.5061	0.8296	0.0005	6.2027 to 10.8095
Slope	-21.3143	7.3837	0.0447	-41.8148 to -0.8139

Source of variation	SSq	DF	MSq	F	p
Due to regression	9.844	1	9.844	8.33	0.0447
About regression	4.725	4	1.181		
Total	14.569	5			

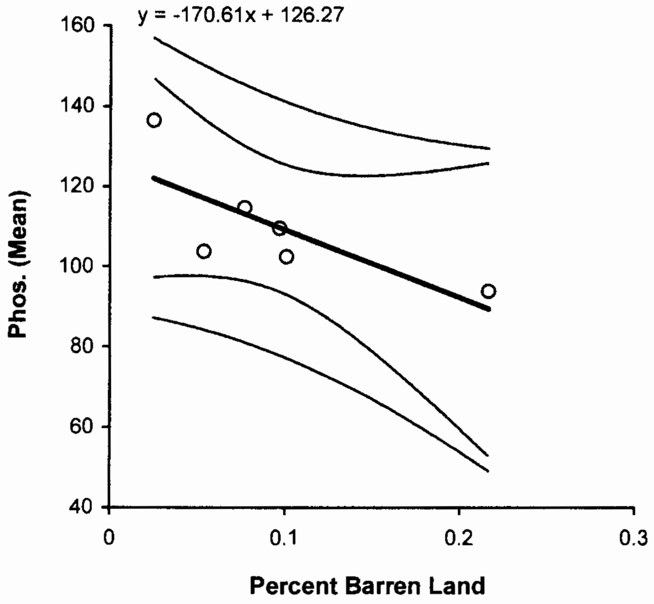


Test	**Linear regression**		
Fit	Phos. (Mean) v Percent Barren		
Performed by	Chad Fields	**Date**	13 July 2004

n	6
R^2	0.58
Adjusted R^2	0.48
SE	10.6399

Term	**Coefficient**	**SE**	**p**	**95% CI of Coefficient**
Intercept	126.2735	8.1214	<0.0001	103.7249 to 148.8221
Slope	-170.6139	72.2811	0.0776	-371.2984 to 30.0706

Source of variation	**SSq**	**DF**	**MSq**	**F**	**p**
Due to regression	630.743	1	630.743	5.57	0.0776
About regression	452.828	4	113.207		
Total	1083.572	5			

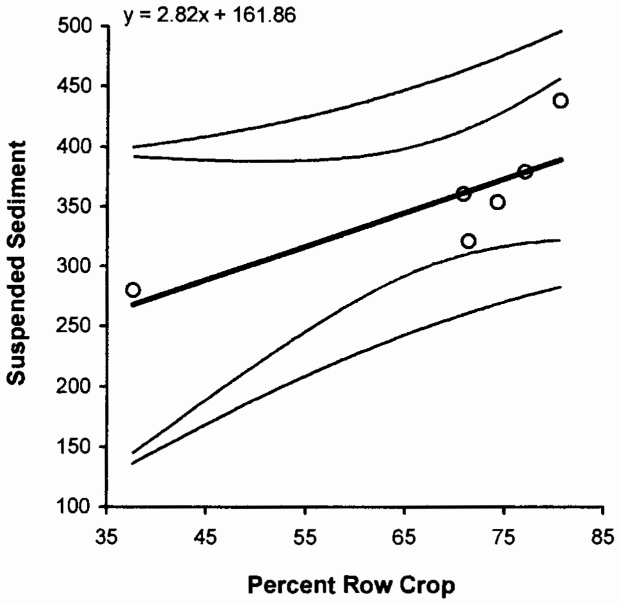


Test	**Linear regression**		
Fit	Suspended Sediment v Percent Row Crop		
Performed by	Chad Fields	**Date**	13 July 2004

n	6
R^2	0.68
Adjusted R^2	0.60
SE	33.9248

Term	Coefficient	SE	p	95% CI of Coefficient
Intercept	161.8581	68.0862	0.0762	-27.1796 to 350.8957
Slope	2.8200	0.9712	0.0440	0.1235 to 5.5165

Source of variation	SSq	DF	MSq	F	p
Due to regression	9702.912	1	9702.912	8.43	0.0440
About regression	4603.569	4	1150.892		
Total	14306.481	5			



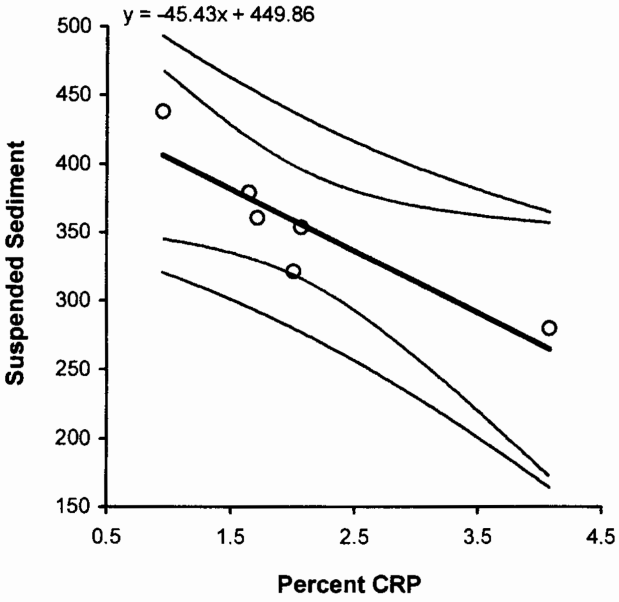
Test	**Linear regression**		
Fit	Suspended Sediment v Percent CRP		
Performed by	Chad Fields	**Date**	13 July 2004

n	6

R^2	0.81
Adjusted R^2	0.76
SE	26.3323

Term	Coefficient	SE	p	95% CI of Coefficient
Intercept	449.8621	25.5310	<0.0001	378.9767 to 520.7476
Slope	-45.4300	11.1394	0.0151	-76.3579 to -14.5021

Source of variation	SSq	DF	MSq	F	p
Due to regression	11532.923	1	11532.923	16.63	0.0151
About regression	2773.557	4	693.389		
Total	14306.481	5			

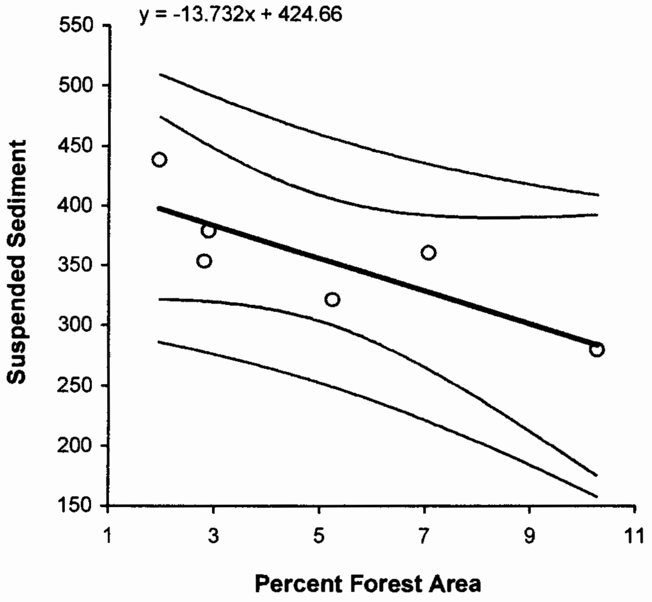


Test	**Linear regression**
Fit	Suspended Sediment v Percent Forested Area
Performed by	Chad Fields
Date	13 July 2004

n	6
R^2	0.67
Adjusted R^2	0.58
SE	34.5867

Term	**Coefficient**	**SE**	**p**	**95% CI of Coefficient**
Intercept	424.6554	28.3132	0.0001	346.0454 to 503.2653
Slope	-13.7319	4.8673	0.0478	-27.2456 to -0.2181

Source of variation	**SSq**	**DF**	**MSq**	**F**	**p**
Due to regression	9521.513	1	9521.513	7.96	0.0478
About regression	4784.967	4	1196.242		
Total	14306.481	5			



Test	**Linear regression**		
Fit	Sediment P v Percent Wetland		
Performed by	Chad Fields	**Date**	13 July 2004

n	6

R^2	0.69
Adjusted R^2	0.61
SE	50.1314

Term	Coefficient	SE	p	95% CI of Coefficient
Intercept	332.6123	35.6506	0.0007	233.6305 to 431.5942
Slope	-249.2942	84.0259	0.0413	-482.5875 to -16.0008

Source of variation	SSq	DF	MSq	F	p
Due to regression	22121.639	1	22121.639	8.80	0.0413
About regression	10052.630	4	2513.157		
Total	32174.269	5