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# Assessment of Sediment and Nutrient Loadings in the Davis Creek Watershed, Southwestern Michigan using the SWAT Model

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# ASSESSMENT OF SEDIMENT AND NUTRIENT LOADINGS IN THE DAVIS CREEK WATERSHED, SOUTHWESTERN MICHIGAN USING THE SWAT MODEL

by

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Peter Kibowen Kimosop

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Peter Kibowen Kimosop, M.A.

Western Michigan University, 2005

The Davis Creek Watershed has been impaired for many years by nonpoint source pollution. A recent modeling research on the watershed simulated both nutrient and sediment movements for the single storm events. This study simulates the movement of sediments and nutrients (nitrogen and phosphorus) in the watershed continuously using the Soil and Water Assessment Tool (SWAT) for assessing water quality in the watershed. Multiple databases for climate, soil types, DEM, land use and agricultural management practices were used to derive inputs for the SWAT. Subsequently, the SWAT model was run for the period of 1998-2004. The simulated results show that the urbanized regions of the Davis Creek are the critical sources of sediments and nutrient loads. Four management scenarios were developed: no till, conversion of agricultural land to urban, expansion of wetland area, and construction of retention ponds in the residential area, were simulated for nonpoint source pollution management. The results show that no till and construction of retention ponds would reduce sediment and nutrient loads in the watershed while conversion of agricultural land to urban would increase the loadings. This information, while valuable and useful, needs to be further verified in the field for supporting water quality decision making in the Davis Creek.

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# INTRODUCTION

In 1987, the 1972 Clean Water Act was amended after the realization that most point sources were under control through regulatory enforcement, capital investment in pollution abatement technology, pollution control standards and better management of municipal and industrial infrastructure (Daniel et al., 1998). For instance, any point source discharge is required to have a National Pollutant Discharge Elimination System (NPDES)[1] permit which complies with the Clean Water Act provisions. Violations of these permits are subject to criminal penalties (Garrett, 2003). Following success of the NPDES permit requirement for all point sources, the federal government shifted its focus to water quality issues related to nonpoint sources.

## 1.1 Nonpoint Source Pollution

The 1987 amendment of the original law required states to develop inventories and carry out assessments of nonpoint source pollution[2] while developing strategies to address these problems. Agriculture has been identified by the United States Environmental Protection Agency (USEPA) as

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[1] The National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States (USEPA, 2003).

[2] Nonpoint source pollution "is caused by rainfall or snowmelt moving over and moving through the ground and carrying natural and human-made pollutants into lakes, rivers, wetlands, estuaries, other coastal waters, and ground water. Atmospheric deposition and hydrologic modification are also sources of nonpoint pollution." (Witte and Ross, 2003)

the main source of nonpoint pollution for lakes and rivers (Daniel et al., 1998). Other significant sources of nonpoint source pollution include silvicultural runoff and increasing urbanization (Witte and Ross, 2003). Carpenter et al (1998) identifies some examples of nonpoint sources that are recognized by the statutes of the United States as:

- Agricultural runoff including return flow from irrigated agriculture
- Runoff from pasture and rangelands
- Urban runoff from unsewered areas and sewered areas with a population less than 100,000 people
- Runoff from septic tank leaching and failed septic systems
- Runoff from construction sites with areas not exceeding 2 hectares
- Atmospheric deposition over a water surface
- Land activities that generate contaminants such as logging and construction

These sources of pollution are difficult to regulate and measure due to the extent of the contributing activities that are dispersed over wide areas as well as having temporal variability attributed to different weather phenomenon (Carpenter et al., 1998). States are currently required to develop management strategies to reduce agricultural nonpoint source pollution especially on surface waters. Imbalance of agricultural phosphorus and other nutrients through the application of an enormous volume of fertilizer as well as other nonpoint sources of pollution are putting pressure on local, state and federal organs to develop Total Maximum Daily Loads (TMDLs)[3] on their watersheds to reduce nonpoint source pollution (Carpenter et al., 1998).

The USEPA has identified nonpoint source pollution as the primary source of water quality problems across the United States. This has prompted the federal government to spend substantial funds for restoring and repairing damaged areas. Approximately 40% of rivers, lakes, and estuaries across the United States are not clean enough to meet basic uses such as drinking, swimming or fishing. A 2005 National Water Quality Inventory analysis indicated that over 60% of impaired river miles and more than half of impaired lake area can be attributed to pollution originating from agricultural activities (USEPA, 2005b).

## 1.2 Eutrophication

Eutrophication is the aging of a lake, reservoir or a river over time through mineral or nutrient enrichment leading to changes in the aquatic ecosystem (Heathwaite, 1994). Enrichment of waterbodies can eventually lead to faster rates of sediment deposition and ultimately the lake or pond could finally be replaced by terrestrial communities. Eutrophication only affects *lentic* (slow-moving) waterbodies. Landuse change in rural and urban environments through agricultural intensification, urbanization and

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[3] A Total Maximum Daily Load "is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount

industrialization has accelerated the rate of eutrophication in fresh waters (Heathwaite and Sharpley, 1999). Symptoms of eutrophication in freshwater are manifested through increased growth of cyanobacteria (blue-green algae) which may contribute to other water-related problems such as: an increase in biomass of phytoplankton, an increase in macrophyte species, an increase in biomass of benthic and epiphytic algae, a change in phytoplankton to bloom-forming species, a reduction of oxygen amounts in water, reduced water transparency and increased incidents of fish kills and fish loss due to large variations of oxygen (Heathwaite, 1994).

Approximately 50% of impaired lake areas and 60% of impaired river reaches are affected by eutrophication across the United States (Carpenter et al., 1998). This problem can either be tackled from the source or, once a problem occurs, it can be mitigated in-situ. However, tackling the problem at the source is far cheaper and far more efficient than dealing with the pollution problems once they have occurred (Heathwaite and Sharpley, 1999).

## 1.3 Phosphorus and Nitrogen

Phosphorus and nitrogen loading in fresh waters is mainly attributed to nonpoint source pollution. Nonpoint sources from agriculture and urban land uses have also contributed significantly to eutrophication which is apparent in some coastal regions of the world including the Gulf of Mexico, the North Sea and the Mediterranean Sea as a result of excessive phosphorus and nitrogen

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to the pollutant's sources" (USEPA, 2005a) in their respective catchments (Heathwaite and Sharpley, 1999). In the United States, phosphorus and nitrogen still contribute more than 90% of nonpoint source pollution to more than a third of American rivers (Carpenter et al., 1998). Agriculture contributes over 50% of phosphorus nutrients in most impaired waters through fertilizer and manure application on farmlands (Daniel et al., 1998). Research shows that between 1950 and 1995, approximately $600\times10^6$ Mg of phosphorus fertilizer was applied to crops worldwide, of which approximately $250\times10^6$ Mg was removed through harvest. On the other hand, nitrogen fixation of fertilizer has steadily increased since the 1940's from nearly zero to the current value of approximately $80\times10^6$ Mg per year. About 18% of nitrogen is removed through harvest and the remainder is leached, eroded or wasted to the atmosphere through volatilization (Carpenter et al., 1998). In addition to crop cultivation, intensive animal production also generates enormous amounts of organic wastes which are often difficult to dispose off in an environmentally sound manner. Therefore, unseasoned manure is sometimes applied to cropland which at times could be excessive, thus leading to infiltration and runoff of nutrients to fresh waters. Besides agriculture, pollution from urban-related nonpoint sources such as construction sites, lawn fertilizer, pet wastes and unsewered developments also contribute to more than 25% of lake deterioration (Carpenter et al., 1998). Phosphorus and nitrogen cause eutrophication because they are in short supply. For instance, phosphorus availability in waterbodies is limited compared to its concentration in plants.

Alternatively, nitrogen is less limiting than phosphorus because it is highly soluble and can easily be fixed by organisms such as the blue-green algae (Carpenter et al., 1998).

The USEPA has set the Maximum Contaminant Levels (MCL) for nitrate-N ($NO_3$-N) for drinking water at 10mg $l^{-1}$ while phosphorus ($P_2O_5$) concentrations available in soils for crop growth ranges between 0.20 and 0.30 mg $l^{-1}$ (Heathwaite and Sharpley, 1999). However, phosphorus range concentrations for controlling eutrophication is between 0.01 and 0.02 mg $l^{-1}$ which is far lower than phosphorus available for plant growth in the soil, hence phosphorus pollution caused by agricultural runoff is crucial to the trophic status of surface water. The threshold values for inorganic and total phosphorus concentrations should not exceed 0.05 mg $L^{-1}$ in streams and 0.025 mg $L^{-1}$ within lakes and reservoirs (Daniel et al., 1998). Trophic status for lakes and rivers can be determined by calculating the ratio of nitrogen to phosphorus. If nitrogen to phosphorus ratio exceeds the ratio16:1 then Phosphorus is the limiting factor and if the ratio is less than 16:1 then the limiting nutrient is possibly nitrogen (Heathwaite, 1994). However, the main factor influencing nutrient movement to lakes and rivers relates to the existing transport mechanisms.

Phosphorus transport in a watershed depends on land management and phosphorus availability in the soil. Other variables to be considered include; rainfall, topography, soils (structure, texture, and permeability), ground water and water storage temperature (Daniel et al., 1998).

Phosphorus export is mainly through surface runoff although a small proportion is transported via sub-surface flow. The main source of particulate ‘P’ is agriculture with approximately 60-90% transported from cultivated lands.

## 1.4 Effects of Phosphorus and Nitrogen Contamination

Nitrate pollution has a direct health impact on both humans and animals. For instance, a high concentration of $NO_3$ is linked to methemoglobinemia in infants (Carpenter et al., 1998). The USEPA has therefore set maximum contaminant levels for $NO_3$-N at 10mg/L for drinking water in order to protect infants below 6 months[4] of age. Cattle are also affected by nitrate ($NO_3$) concentration which may result in abortions as well as methemoglobinemia. Phosphorus apparently has no direct health risk on humans and animals and that is why drinking water standards for phosphorus have not been established by USEPA (Carpenter et al., 1998). Nevertheless, the main concern for nutrient concentration in fresh waters has shifted in focus from perceived health risks such as ‘the blue-baby syndrome’, stomach cancer and neurological diseases to the management of phosphorus, nitrogen and manure in farmlands (Heathwaite and Sharpley, 1999). High phosphorus concentrations in fresh water also limits the use of the water for fisheries, recreation, industry, and public consumption due to massive growth of undesirable algae and weeds. Surface blooms could lead to tastelessness of drinking waters and fish kills. When blooms die, they release hepatoxins, which can kill livestock as well as representing a risk to humans (Daniel et al., 1998). In regard these pollution issues, several forms of legislation have been passed in recent years to try and control nonpoint source pollution.

## 1.5 The Clean Water Act

In 1948, the Federal Water Pollution Control Act (FWPCA) was enacted to provide federal funds for state water pollution control programs (Adler et al., 1993). The FWPCA was revised in 1972 with the objective of restoring and maintaining the chemical, biological and physical status of the nation's waters while continuing the previous existing water quality standards. This federal legislation of 1972 was renamed the Clean Water Act (CWA). It has been regarded the most extensive in regulating water quality (National Research Council, 1999). It was amended in 1977 with provisions for toxic pollutants and the implementation of best management practices. In 1987, the U.S Congress further amended the act and adopted new guidelines for the CWA to address pollutants from runoff. The revised act also provided for civil penalties for storm water discharges. Included in the 1987 Act was CWA section 319 which was geared towards the creation of nonpoint source pollution control programs. In 1998, the Clinton administration introduced the Clean Water Action Plan to focus on watershed based planning. This allowed

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[4] Infants between the ages of 2-6 months are vulnerable because bacteria in their digestive tract can reduce $No_3$ to nitrite thus hemoglobin changes to methemoglobin.

for the implementation of strategies for controlling contaminated runoff. These programs include the TMDL program under section 303(d) of the CWA (National Research Council, 1999; Garrett, 2003; Adler et al., 1993). This program will be introduced in the following section.

## 1.6 Total Maximum Daily Loads (TMDLs)

TMDLs refer to the maximum amount of pollutants from all sources including natural background sources that are allowed to enter any given waterbody while still meeting the required water quality standards (USEPA, 2004; Beale and Sheldon, 2003). A TMDL has two components: a Wasteload Allocation (WLA) and a Load Allocation (LA). WLA is that portion of a TMDL allocated to the existing and future point sources of pollution while LA is the portion allocated to the existing and future nonpoint sources of pollution (Beale and Sheldon, 2003). TMDLs are required to have an implementation plan with a list and timeline of actions that include monitoring, verification of compliance and allocation of load reductions to different sources (Boyd, 2000). In the United States, more than two-fifths of the nation's surface water does not meet legal water quality standards, hence the need to establish TMDLs for each of the impaired water bodies (USEPA, 2004). With the existing legislation, each state is responsible for monitoring water quality issues within their jurisdiction with help from federal agencies.

## 1.7 Nonpoint Source Pollution in Michigan

Michigan first developed a Nonpoint Pollution Control Management Plan in 1988, consisting of programs such as the nonpoint source watershed initiative and the Best Management Practices (BMPs) initiative to limit nonpoint source contamination of surface water. Despite the development of this plan, the Michigan Department of Environmental Quality (MDEQ) still noted that in the late 1990's, about 95% of the states' waters were affected by nonpoint source pollution attributed to improper urban and agricultural land use practices (Davis Creek News, 1999). Phosphorus loadings in most Michigan watersheds have been identified to be high. Control of this pollution requires a concerted effort from federal, state and local agencies. This has been accomplished in some watersheds through the TMDL implementation, while many others remain in violation of federal standards (MDEQ, 2002).

## 1.8 The Study Area

The Davis Creek watershed, a tributary of the Kalamazoo River watershed, is located in Kalamazoo County in Southwest Michigan. The watershed covers an area of approximately 9,310 acres and flows northwest from its main tributary at the East Lake on Pavilion Township and through some urbanizing areas of the County before joining the Kalamazoo River (Figure1).

Figure 1: Location of the Davis Creek Watershed in Kalamazoo County, Michigan

The Davis Creek watershed has faced tremendous change in recent years, changing from being predominantly agricultural in the late 1970's to predominantly urban due to pressure from residential and urban development. The watershed has received enormous attention from the United States Environmental Protection Agency (USEPA) and the Michigan Department of Environmental Quality (MDEQ) particularly regarding point and nonpoint source pollution. There has been some success, however, as the USEPA and MDEQ efforts have substantially reduced the rate of point sources through the NPDES permit requirement (Davis Creek News, 1999; Garrett, 2003). This permit requirement has eliminated or reduced the number of point source discharge within the state. The Davis Creek watershed does not currently have a single point source discharge.

The Davis Creek watershed ranges in elevation between 230 and 280m above sea level. The watershed is associated with glacial till plains and ponded areas resulting from past complex glacial activities (Austin et al., 1975). These glacial and ponded areas have influenced the types of soils in the area. Davis Creek watershed soils range from poorly drained Adrian mucks, Gilford sandy loams, Houghton Sebewa and Glendora sandy loams to the well-drained Kalamazoo loams and Oshtemo sandy loams. A detailed description of the Davis Creek watershed soils compiled by the USDA-SCS in the mid 1970's can be reviewed in appendix 1. These soils have influenced the vegetation in the area. The original vegetation of the watershed consisted mainly of hardwood forests including maple, elm, beech, hickory and sycamore. However, as the need for lumber, urban development and agriculture increased, these forests were cleared and the only parts of the original forests remaining are woodlots (Austin et al., 1975).

Field crops (mainly corn and soybeans) remains the major land use of the watershed accounting for over 29% of the entire area (GIS Research Center, 1996). Other land uses include: industrial - 14%, residential - 12%, rangeland - 13%, transportation - 8%, wetlands - 8%, forests - 7% and less than 5% commercial and water (Figure 2). The population within the Davis Creek watershed was estimated at 13,000 in 1996 but continued urban population growth and sprawl within Kalamazoo County suggests that the population within the Davis Creek watershed has continued to increase (River Partners Program, 1996). This land use trend is putting pressure on the available water resources resulting in water related problems such as nonpoint source pollution.

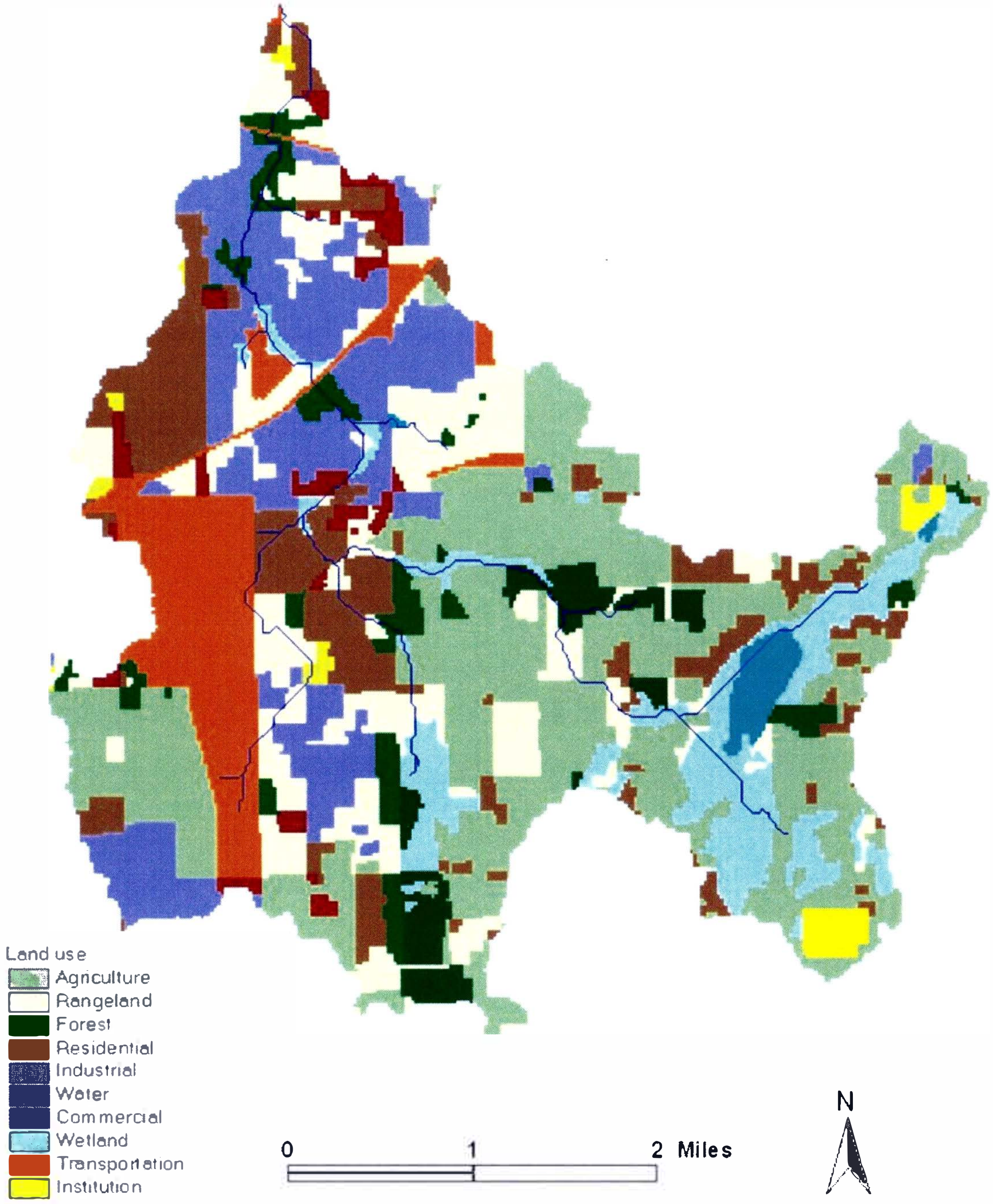

Figure 2: 1996 Land use in the Davis Creek
(Source: GIS Research Center, 1996)

## 1.9 The Problem Statement

The Davis Creek watershed, a tributary of Kalamazoo River has been identified as the most polluted tributary in Kalamazoo County. Agriculture as well as runoff from industrial, commercial and residential developments in the watershed have been identified as the main sources of nonpoint source pollution. The urbanizing trend of the watershed (sprawl) is headed towards the source of the Davis Creek and unless sustainable urban and agricultural practices in the watershed are implemented, nonpoint source pollution will continue to be a setback. Recent research on the watershed using the Agricultural Nonpoint Source Model (AGNPS) simulated both nutrient and sediment movements, but the loading results were incomplete since the original model is a single event model and lacks the capability of simulating groundwater influences (Limlahapun, 2002). This study is intended to simulate the movement of sediments and nutrients (nitrogen and phosphorus) in the watershed using the Soil and Water Assessment Tool (SWAT) with the goal of providing recommendations on the best management practices (BMPs) that can be adopted to control and reduce nonpoint source pollution.

## 1.10 The Objectives

The objectives of this study are:

1. Simulate the dynamics of nutrient movement within the Davis Creek watershed by ArcView Soil and Water Assessment Tool (AVSWAT);
2. Estimate the rate and quantity of sediment, phosphorus and nitrogen loading in the watershed through a seven-year period (1998 to 2004) to establish baseline estimate; and
3. Identify the best management practices (BMPs) scenarios to reduce nonpoint source pollution in the watershed.

# CHAPTER 2

# LITERATURE REVIEW

Concerns of climate change, large scale flooding, impacts of land utilization and water management have directly motivated scientists in developing hydrological models (Arnold et al., 1998). The watershed protection approach involving the use of water quality monitoring, spatial data collection and modeling at the watershed scale has been identified as the best strategy for solving water quality problems. Some of the required data inputs include variables related to land use, soil texture, topography, and land management practices (Arnold et al., 1998).

## 2.1 A Watershed Approach to Controlling Water Pollution

Watersheds are important spatial entities being used to plan and control water resource pollution issues. For instance, the USEPA developed a “watershed protection approach” to solve, restore and maintain the integrity of water resources across the nation. The watershed protection approach relies heavily on analysis using hydrological boundaries rather than political boundaries. This emphasizes the chemical, physical and biological elements of the watershed (National Research Council, 1999). The U.S Department of Agriculture (USDA) and the Natural Resource Conservation Service (NRCS) have also developed watershed related approaches directed towards the scientific management of natural resources. All these watershed approaches are people-oriented since they involve stakeholders in identifying problems and implementing solutions. Since the early 1970's, the federal government has invested colossal amounts of money in improving the nation's waters particularly regarding point source pollution. However, nonpoint sources stemming from urban runoff, farms and transportation systems are still of great concern (National Research Council, 1999).

## 2.2 Nonpoint Source Simulation Models

Soil erosion, sediment and nutrient models have often been developed to understand and manage soil erosion and pollution. Both the USEPA and the USDA have contributed financially and technically towards the success of these transport models (Merritt et al., 2003). These models depend on the analysis of physical processes, model algorithms and data availability. However, the overall choice of any model depends on its intended final application and the characteristics of the watershed.

Simulation models can be categorized into three groups: a.) empirical; b.) conceptual; and c) physics-based (Merritt et al., 2003). Empirical models are based on analyzing observations. Thus, this approach is preferred where data and parameter inputs are limited. Conceptual models however, represent catchments as a series of internal storages and incorporate transfer mechanisms of sediment and runoff in their structure.

Physics-based models require standard equations to describe stream flow and sediment and nutrient generation. They rely on standard equations such as the equation of conservation of mass for sediment and the set of equations related to the conservation of mass and momentum estimates for flow (Merritt et al., 2003).

Empirical, conceptual and physics-based models have been incorporated in developing watershed-scale hydrologic and nonpoint source pollution models. Sediment and nutrient loading in watersheds can be easily determined through the application of empirical models. For example, phosphorus loading concepts founded on the idea that phosphorus is a limiting nutrient of lake, river, pond and reservoir eutrophication can be determined through the following simple empirical models: (a) the Vollenweinder loading plots are based on the idea that shallow lakes are more prone to eutrophication in comparison to deep lakes; (b) Budget models depend on phosphorus budget data; (c) Trophic state correlations use phosphorus concentrations to predict other variables that could have a direct influence on eutrophication. These phosphorus loading conceptual models have been widely applied because they are easy to apply and their outputs are based on empirical observations (Chapra, 1997).

## 2.3 Erosion and Sediment Transport Models

In 1965, the USDA developed the Universal Soil Loss Equation (USLE) to estimate annual soil erosion from hillslopes (Merritt et al., 2003). Since then, the USLE has undergone tremendous modifications and improvements. The Chemical, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model was the first nonpoint source model to be developed to simulate the impact of land management on sediments, water and nutrients leaving the edge of a field (Merritt et al., 2003; Williams et al., 1985). The hydrological components of the CREAMS model were later modified to take into account factors such as simultaneous computations for several sub-basins, the return flow component, reservoir storage component, a weather simulation model, a simple flood routing component, sediment routing component and calculation of transmission losses. Several other related models were subsequently developed for phosphorus contamination analysis such as the Sediment Phosphorus Nitrogen Model (SPNM) designed to simulate agricultural effects on water pollution. The SPNM was developed to predict sediment phosphorus and nitrogen yields for individual storms on small basins (Williams 1980). Another model developed to predict the effects of management decisions on water and sediment yields for ungaged rural basins was the Simulator for Water Resources in Rural Basins (SWRRB) model with its initial framework based on the CREAMS model (Williams et al 1985). The SWRRB model was eventually modified to form the Soil and Water Assessment Tool (SWAT) model.

## 2.4 SWAT

The SWAT model was developed in the early 1990's by the USDA-Agricultural Research Service to predict the impacts of land management on water, sediment and agricultural chemical yields in gauged, ungauged and complex watersheds of varying land use, soils and management conditions (Arnold et al., 1998). It runs on a daily time step producing either long-term or short-term predictions. The model is computationally efficient, uses readily available inputs and is capable of simulating long-term impacts of management changes (Arnold et al., 1998). SWAT has been modified from other simulation models just like some other simulation models.

SWAT is a direct modification of the Simulator for Water Resources in Rural Basins (SWRRB) model (Williams et al., 1985). SWAT was developed because the SWRRB model was limited to a small watershed extending to a few a hundred square kilometers in size, prompting the need to develop a model that could simulate steam flows extending over several thousand kilometers. Currently, SWAT is among the powerful nonpoint source simulation models. Other watershed scale hydrologic and nonpoint source simulation models include: a.) the Agricultural Nonpoint Source Pollution(AGNPS) model - an event-based model used to simulate sediment, runoff, nitrogen and phosphorus transport, and chemical oxygen demand for single rainfall events; b.) the Areal Nonpoint Source Watershed Environmental Response Simulation (ANSWERS) model - models runoff, infiltration erosion and subsurface drainage for a single event; c.) the Hydrologic Simulation Program, Fortran (HSPF) - a continuous watershed simulation model used to determine water quality and quantity for both agricultural and urban watersheds; d.) the Annualized Agricultural Nonpoint Source Pollution (AnnAGNPS) model - a continuous simulation model used to predict pollutant loadings; e) the Precipitation-Runoff Modeling System (PRMS) - developed to evaluate the response of various combinations of precipitation, climate and land use practices in a watershed (Borah et al., 2003 and Merritt et al., 2003).

Obviously, there is a need for the spatial representation of this data across the watersheds incorporated in any study area. Because of this need, interfaces of SWAT have been developed in visual basic, Geographic Resources Analysis Support System (GRASS) and ArcViewGIS. The most recently developed interface - ArcView SWAT2000, provides a powerful tool for spatial hydrological modeling. The model performs flow routing through streams and reservoirs with the routing command successfully simulating a basin subdivided into grid cells. The data input component for each subbasin/grid are organized into the following categories with sub-routines for each; climate, Hydrologic Response Units (HRUs), ponds and wetlands, reach draining the subbasin and ground water.

The water balance is the major force for the prediction of transport for sediments, nutrients and pesticides within the watershed. However, in order to successfully simulate the hydrologic cycle within the basin, the land phase and the water phase have to be taken into consideration.

## 2.5 SWAT in Basin Management

SWAT is currently being used by a number of organizations and institutions including the USEPA, the National Oceanic and Atmospheric Administration (NOAA) and the NRCS. The model has been used in a number of watersheds worldwide. These previous applications provide useful background data for the current application. Francos et al (2000) applied the model to assess the impact of climate changes and agricultural management practices on nitrogen and phosphorus loads in a medium-sized watershed in Finland. Spruill et al (2000) used SWAT to describe monthly and daily stream flows from a small watershed in Central Kentucky. Inamdar et al (2001) assessed the impacts of pre- and post-BMPs (no-tillage, filter strips, and nutrient management) on phosphorus and nitrogen loads for Nomini Creek watershed, Virginia. Kirsch et al (2002) used SWAT to quantify phosphorus sources and evaluate the impacts of basin-wide BMPs application. Santhi et al (2000) used SWAT to assess the effects of BMPs related to dairy manure management and waste treatment plant and Picq (2004) used SWAT to assess TMDL implementation in the Macatawa watershed in Michigan.

In short, past successes suggest that the use of this model for this research on the Davis Creek watershed is appropriate. The next chapter will introduce the methodology used in the current research.

# CHAPTER 3

# METHODOLOGY

This research uses the SWAT model for data analysis of nonpoint source pollution in the Davis Creek. The SWAT model requires a number of inputs including; topography, land use, soil, climate, fertilizer applications, tillage systems and other management information for successful modeling outcomes (Neitsch et al., 2002). Each of these inputs will be discussed below.

## 3.1 Topographic Variables

A 30 meter resolution Digital Elevation Model (DEM) for Davis Creek watershed was downloaded into SWAT from the USGS website http://www.seamless.com. The first step in SWAT modeling was to delineate subwatersheds from the DEM. The DEM was then projected using the Universal Transverse Mercator zone 16. A minimum size (threshold area) of subwatersheds was set to 100 hectares to provide for a more detailed description of each subwatershed since the total size of the Davis Creek watershed is very small (3,400 ha). When this was complete, streams and their respective outlets are displayed on the DEM. The main outlet of the Davis Creek was then added to this layer resulting in the creation of the complete watershed with 21 subbasins (Figure 3).

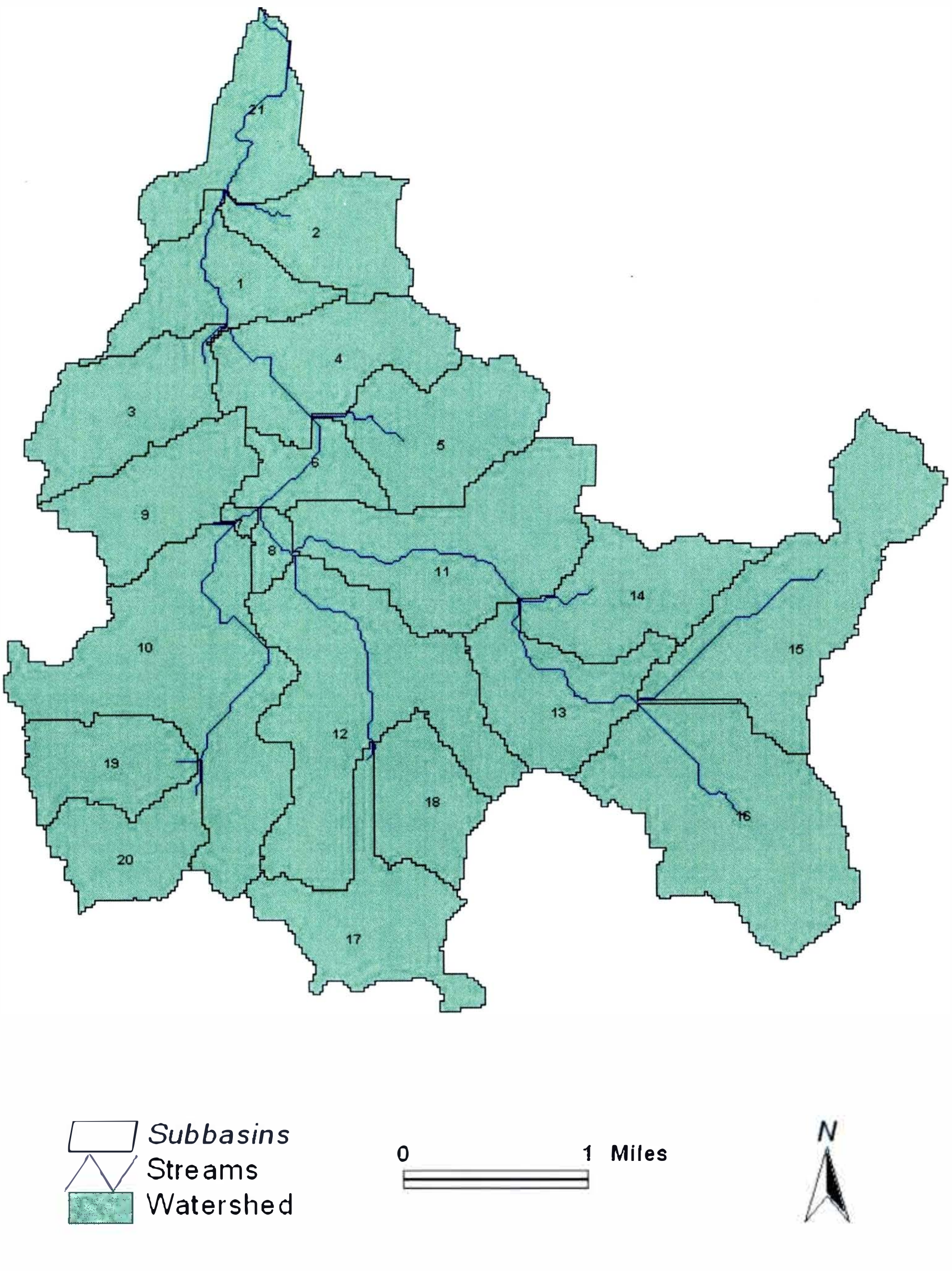

Figure 3: Subbasins of the Davis Creek Watershed defined by SWAT

## 3.2 Land Use and Soils

Use of the SWAT model requires Land Use Land Cover (LULC) and soil files in order to determine the area and the hydrologic parameters for each land use and soil category simulated in the sub-watershed (Di Luzio et al., 2002). Land use and soil map layers were added to the watershed once the creation of the watershed was complete. The 1996 Land Use Land Cover map (scale 1:24000) was obtained from the Department of Geography GIS Research Center of Western Michigan University. This year was the most recent land use map available. The soil map (scale 1:24000) was also obtained from the Department of Geography GIS Research Center of Western Michigan University.

The LULC layer was then added into the watershed with its corresponding land cover codes. The Michigan LULC classification system was then used to assign LULCs to the codes as shown in Table 1. The resulting grid was reclassified so that the land use layer could be loaded into the watershed. A report describing the land use distribution within each subbasin is then generated.

Table 1: Land use land cover codes used for land use classification

| Land cover | Description | Codes | Land use Percentage |
|---|---|---|---|
| Residential | Multi-family high rise/low rise | 111/112 | 12% |
| | Single family/duplex | 113 | |
| | Mobile home park | 115 | |
| Commercial | Shopping center | 122 | 4% |
| | Secondary/strip mall | 124 | |
| Industrial | Industrial | 130 | 14% |
| Institutional | Institutional | 126 | 3% |
| Transport | Air | 141 | 8% |
| | Rail | 142 | |
| | Road | 144 | |
| Agriculture | Cropland | 210 | 29% |
| Rangeland | Shrub and herbaceous rangeland | 320 and 310 | 13% |
| Forest land | Deciduous | 410 | 7% |
| | Coniferous | 420 | |
| Water | Streams/ river | 510 | 2% |
| Wetland | Forested and non forested wetland | 610 and 620 | 8% |

Source: Department of Natural Resources (1975)

The soil layer was developed using the soil series - Soil Survey Geographic Database (SSURGO) which is the most detailed level of soil mapping done by the Natural Resource Conservation Service (NRCS) (Figure

4).

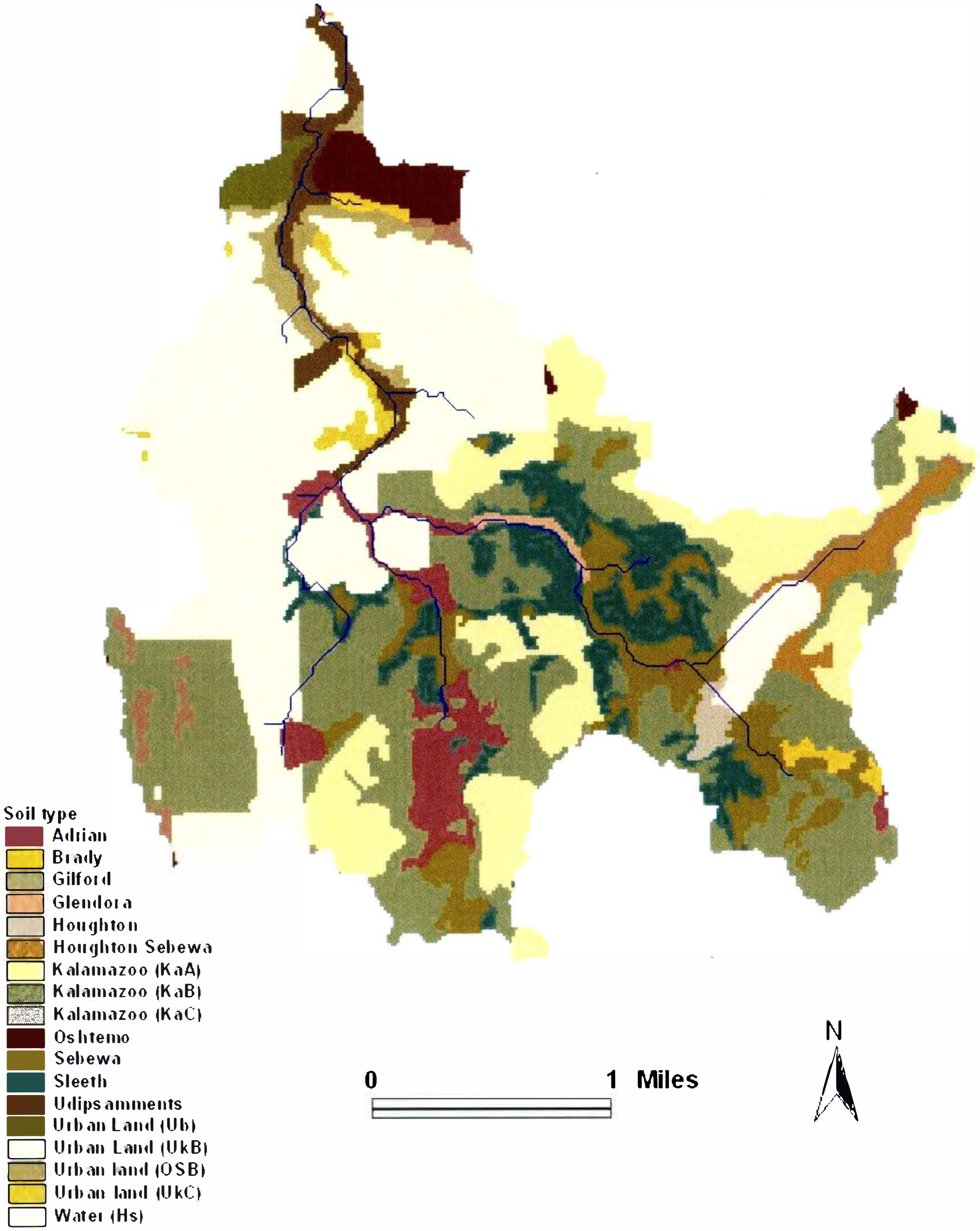

Figure 4: 1979 SSURGO soil map of the Davis Creek Watershed

SSURGO generated a total of 18 soil categories compared to the soil association - State Soil Geographic Database (STATSGO), which generated only 2 soil categories for the entire watershed. The attribute data for each soil type to be used in SWAT included layer thickness (mm), the percentage of silt, the percentage of clay, the percentage of sand, the percentage of organic carbon content, the percentage of available water capacity, the saturated organic conductivity (mm/hr), and the bulk density. These values were obtained from the United States Department of Agriculture - Natural Resource Conservation Service (USDA-NRCS) soil properties for the Kalamazoo County. These soil properties were processed using SSURGO SWAT 1.0 software developed to be used in conjunction with the SWAT (Peschel, 2002). The soil layer was then reclassified after being loaded into the watershed. The Soil and LULC maps were then overlayed together resulting in a land use and soil distribution report.

The next step involved determining Hydrologic Response Units (HRUs) either by dominant land use and soils or by multiple hydrologic response units. HRUs are those portions of a subbasin that contain unique land use, management or soil attributes (Neitsch et al., 2002). The multiple hydrologic response units option was selected for the watershed as it enabled the creation of a different number of HRUs within each subbasin. It also accounted for the many land uses in the watershed. As a result, land uses covering an area less than 10% of the subbasin area were eliminated. On the other hand, thresholds values for soils were set at 10% so that minor soil types were eliminated within a land use area. When this was done, a land use and soil distribution report was generated.

### 3.3 Climate Data

Climate data is vital for the development of runoff models. The climate data was imported after the definition of HRUs was complete. The weather station location was then loaded and weather data assigned to the subwatersheds. Only one weather station located within the watershed (Kalamazoo-Battle Creek International Airport station Lat/Lon: 42.2°N 85.6°W) was used for climate simulation. Rainfall and temperature (maximum and minimum) data from January 1, 1998 to December 31, 2004 was loaded from a climate file while solar radiation, wind speed, and relative humidity were simulated by the model. In addition, weather simulation data was also required in order to define the data used to generate the different weather parameters. Two options are available for weather simulation data; US database and a custom database. The latter option was chosen and data was then calculated and manually entered for weather simulation.

After generating the weather database, 12 other database files for SWAT simulation were required (Di Luzio et al., 2002). They include; the configuration file (.fig), soil data (.sol), weather generator data (.wgn), general subbasin data (.sub), HRU general data (.hru), main channel data (.rte), groundwater data (.gw), water use data (.wus), management data (.mgt), soil chemical data (.chm), pond data (.pnd), stream water quality data (swq). Default values for most of these databases were used except for management practices data such as fertilizer application, crop cultivation and tillage information. Fertilizer application values were obtained from Wilbur-Ellis Company located in Schoolcraft, Michigan while crop cultivation and tillage information were obtained by interviewing staff at the Kalamazoo Conservation District (Wonders, 2005).

## 3.4 Management Information

Wilbur-Ellis Company specializing in fertilizer application in most farms in West Michigan was contacted in the course of this study and they provided fertilizer application information for most common crops grown in the Davis Creek watershed. Corn and soybeans were identified as the common crops utilizing fertilizer N.P.K 18-46-00 for their growth (Wonders, 2005). These fertilizers were applied at the same rate of 46kg per hectare for both corn and soybeans.

The chisel plow was identified as the main tillage operation in both corn and soybean farms within the watershed (Buckham, 2004). Typically, this exposes a significant amount of unconsolidated soil to erosion process.

## 3.5 Applications of SWAT

The model was run using data from January 1998 through December 2004 (a 7-year period). Monthly and yearly rainfall data were used for the precipitation. When all the input data were processed, the model was then run, generating outputs including the Hydrologic Response Unit output file (.sbs), subbasin output file (bsb) and the main channel output file (.rch). Other output files include surface runoff, ground water, sediment and nutrient loadings.

# CHAPTER 4

# RESULTS AND DISCUSSION

Multiple databases for climate (1998-2004), soil types, DEM, land use and agricultural management practices were used to derive inputs for the SWAT. Subsequently, the SWAT model was run for the period of 1998-2004 to simulate the hydrologic processes and to determine the water quality of Davis Creek. The simulated model output for runoff, sedimentation, nitrogen and phosphorus loading are presented and discussed in this chapter.

## 4.1 Verification of the Simulated Results

The simulated results were compared against the observed flow, sediment, nitrogen and phosphorus data for the period of May 1999 through June 2001 to determine their uncertainties. The in-situ data were provided by Dr. Chansheng He, the Department of Geography at Western Michigan University. He and his research team collected flow (daily) and water quality data (bi-weekly) for the period from 1999-2001. But the data collected only covered part of the 1999-2001 period (1999, 222 days; 2000, 306 days; and 2001, 177 days) and no complete data were available to cover the full years of the observation period. This is the only real time in-situ data available for the Davis Creek since there is no gage station in the Davis Creek Watershed. Tables 2 and 3 below shows the comparison of the simulated results and observed data for the period of 1999 - 2001.

Table 2: Comparison of the simulated and observed flow and sediment yield for the Davis Creek for the period of 1999 - 2001

| | Flow ($m^3$/sec) | | | | | Sediment | | |
|---|---|---|---|---|---|---|---|---|
| | Surface Runoff ($m^3$/sec) | Ground Water ($m^3$/sec) | Simulated | Observed | Difference (%) | Simulated (kg/ha/yr) | Observed (kg/ha/yr) | Difference (%) |
| **1999** | 0.2 | 0.6 | 0.8 | 0.1 | 700 | 301 | 2.1 | 14233 |
| **2000** | 0.3 | 0.7 | 1.0 | 0.1 | 900 | 312 | 6.3 | 4852 |
| **2001** | 0.4 | 0.8 | 1.2 | 0.2 | 500 | 402 | 22.7 | 1671 |

Note: Flow = Surface runoff + Ground water

Table 3: Comparison of the simulated and observed total phosphorus and total nitrogen for the Davis Creek for the period of 1999 - 2001

| | **Total Phosphorus** | | | **Total Nitrogen** | | |
|---|---|---|---|---|---|---|
| **Year** | **Simulated (kg/ha/yr)** | **Observed (kg/ha/yr)** | **Difference (%)** | **Simulated (kg/ha/yr)** | **Observed (kg/ha/yr)** | **Difference (%)** |
| **1999** | 0.4 | 0.1 | 300 | 2.5 | 0.3 | 733 |
| **2000** | 0.5 | 0.1 | 400 | 2.7 | 0.3 | 800 |
| **2001** | 0.6 | 0.2 | 200 | 3.5 | 0.7 | 400 |

Table 2 and 3 shows a considerable deviation between the observed and simulated flow, phosphorus and nitrogen variables. Similarly, there is also considerable deviation between the observed and simulated sediment loading. These large discrepancies may be due to inadequate calibration of the model, inaccurate input parameters, and short period of in-situ data. A summary for the total yearly-accumulated sediment, phosphorus and nitrogen loading at the outlet for the 7 years of simulation is presented in Table 4 below.

Table 4: Simulated sediment, phosphorus and nitrogen accumulated at the outlet

| Year | Sediment (Tons) | Phosphorus (Kg) | Nitrogen (Kg) |
|---|---|---|---|
| 1998 | 1,146 | 1,450 | 8,041 |
| 1999 | 1,024 | 1,441 | 8,629 |
| 2000 | 1,060 | 1,671 | 9,293 |
| 2001 | 1,366 | 2,132 | 11,737 |
| 2002 | 717 | 1,338 | 7,437 |
| 2003 | 1,012 | 1,742 | 9,092 |
| 2004 | 1,083 | 1,920 | 10,125 |

The flow of sediments and nutrients in the watershed is largely influenced by the ground water flow and surface runoff. Table 2 shows the contribution of surface runoff and ground water to the general flow of water in the watershed. Surface runoff in the Davis Creek watershed is influenced by the land use and slope characteristics. The model output shows higher surface runoff rates in the industrial, transportation and commercial areas. These land uses are mainly located in the northern and southwestern portion of the watershed. Subbasins 1,4,6,9 and 20 have higher runoff rates compared to other subbasins. Each of these subbasins has industrial facilities covering over 64% except for subbasin 9 with transportation covering over 58% of the subbasin (Table 5). Subbasin 6 (76% industrial and 24% commercial) and subbasin 9 (with approximately 58% transportation facilities and 29% industrial uses) have the highest runoff rates in the entire watershed. Agricultural areas located in the eastern and southeastern portions of the watershed have low runoff rates which could be attributed to low changes in field elevation or slope (Table 5). Slopes in these subbasins are less than 3%. Elevations range between 259 and 262 meters above sea level. Soils in the agricultural area are medium textured and well drained. Subbasins 7 and 8, both totally residential have a medium potential for surface runoff compared to the industrial and commercial areas.

Table 5: Summary of characteristics of the Subbasins in the Davis Creek Watershed.

| **Subbasin no.** | **Elevation (Meters above Sea Level)** | **Area (ha)** | **Major Land use** |
|---|---|---|---|
| 1 | 247.0 | 124 | Industrial, 80%; Residential, 20% |
| 2 | 249.3 | 121.5 | Industrial, 38%; Rangeland, 27%; Residential, 29%; Commercial, 20% |
| 3 | 261.9 | 146 | Residential, 75%; Industrial, 25% |
| 4 | 257.5 | 172 | Transportation, 17%; Industrial, 68%; Rangeland, 15% |
| 5 | 259.2 | 164 | Agriculture, 57%; Rangeland, 43% |
| 6 | 253.5 | 73 | Industrial, 76%; Commercial, 24% |
| 7 | 255.3 | 6 | Residential, 100% |
| 8 | 255.3 | 21 | Residential, 100% |
| 9 | 261.7 | 138 | Transportation, 58%; Industrial, 29%; Rangeland, 13% |

Table 5 - Continued

| Subbasin no. | Elevation (Meters above Sea Level) | Area (ha) | Major Land use |
|---|---|---|---|
| 10 | 263.5 | 359 | Transportation, 49%; Industrial, 14%; Rangeland, 19%; Agriculture, 18% |
| 11 | 259.6 | 260 | Agriculture, 100% |
| 12 | 260.5 | 331 | Residential, 28%; Rangeland, 29%; Agriculture, 43% |
| 13 | 261.8 | 148 | Agriculture, 81%; Rangeland, 19% |
| 14 | 261.9 | 150 | Agriculture, 73%; Residential, 27% |
| 15 | 261.6 | 292 | Agriculture, 52%; Water, 15%; Wetland, 14%; Residential, 19% |
| 16 | 261.7 | 322 | Agriculture, 58%; Wetland, 42% |
| 17 | 260.8 | 170 | Agriculture, 46%; Forested, 33%; Rangeland, 21% |
| 18 | 263.1 | 103 | Wetland, 23%; Residential, 12%; Agriculture, 65% |
| 19 | 266.6 | 107 | Transportation, 14%; Agriculture, 86% |
| 20 | 266.3 | 103 | Industrial, 64%; Agriculture, 19%; Transportation, 17% |
| 21 | 237.4 | 137 | Rangeland, 29%; Industrial, 32%; Forested, 19%; Residential, 30% |

Surface runoff rates for the entire period of simulation shows a peak runoff rate of 12.8 inches in 2001 and low runoff rates of approximately 7 inches in 1998 and 2002 (Figure 5).

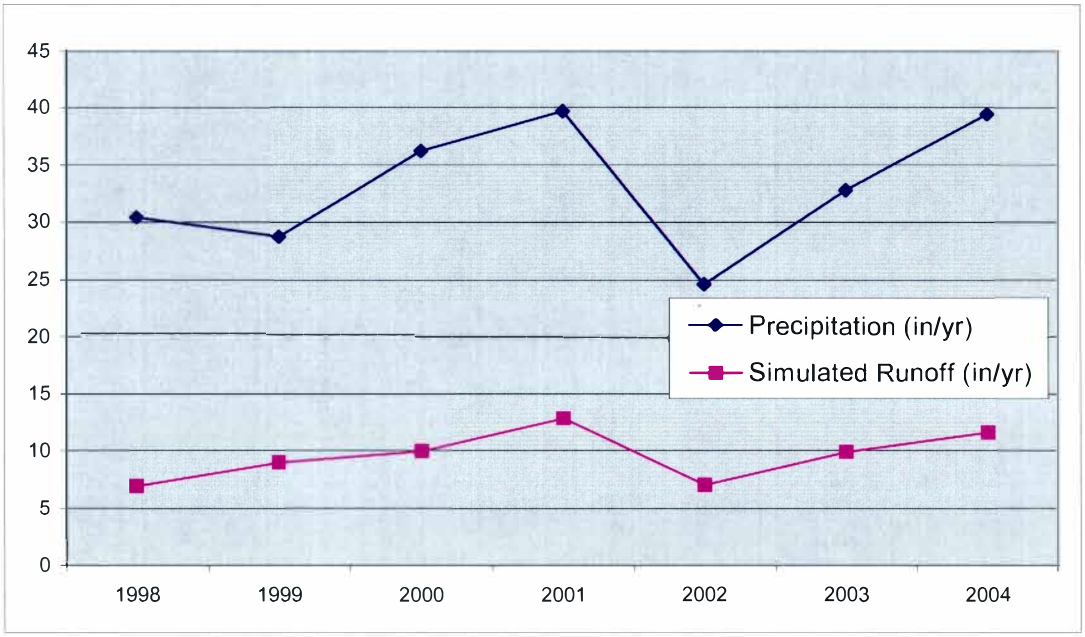

Figure 5: Annual precipitation (in/yr) and the simulated surface runoff (in/yr)

High runoff rates were recorded in the years 2001 and 2004 mainly over the summer (between May and September). This is attributed to summer rainstorms recorded over these months. High precipitation rates occurred between May and July and also between August and September in 2001. In 2004, high rates of precipitation occurred between May and June and also during the fall between October and November. Low runoff rates were recorded both in 1998 and 2002 because there were no significant rainstorms occurring in the area. Low annual precipitation rates were recorded during these two years. Table 6 and 7 shows actual flow, sediment, nitrogen and phosphorus loadings for some storm events that occurred between the years 1999 and 2001 and compared to the simulated results.

Table 6: Simulated flow and sediment with observed storm events

| | | Flow ($m^3$/sec) | | | Sediment (kg/ha) | | |
|---|---|---|---|---|---|---|---|
| **Date** | **Precipitation (inches)** | **Simulated** | **Observed** | **% change** | **Simulated** | **Observed** | **% change** |
| 7/4/1999 | 1.6 | 0.2 | 0.1 | 100 | 14.2 | 2.3 | 517 |
| 8/20/1999 | 1.4 | 0.2 | 0.1 | 100 | 8.7 | 10.3 | -16 |
| 5/13/2000 | 2.3 | 0.4 | 0.1 | 300 | 24.4 | 0.6 | 3967 |
| 4/15/2000 | 1.5 | 0.2 | 0.1 | 100 | 14.9 | 1.8 | 728 |
| 2/17/2001 | 1.4 | 0.1 | 0.2 | -50 | 22.0 | 27.5 | -20 |

Table 7: Simulated phosphorus and nitrogen with observed storm events

| | | Phosphorus (kg/ha) | | | Nitrogen (kg/ha) | | |
|---|---|---|---|---|---|---|---|
| **Date** | **Precipitation (inches)** | **Simulated** | **Observed** | **% change** | **Simulated** | **Observed** | **% change** |
| 7/4/1999 | 1.6 | 0.02 | 0.07 | -71 | 0.6 | 0.1 | 500 |
| 8/20/1999 | 1.4 | 0.01 | 0.06 | -83 | 0.4 | 0.1 | 300 |
| 5/13/2000 | 2.3 | 0.03 | 0.03 | 0 | 0.3 | 0.2 | 50 |
| 4/15/2000 | 1.5 | 0.02 | 0.04 | -50 | 0.6 | 0.1 | 500 |
| 2/17/2001 | 1.4 | 0.00 | 0.14 | -100 | 2.5 | 0.1 | 2400 |

## 4.2 Sediment Loading

The model output shows that sediment loading is higher in the industrial, commercial and residential areas. This is manifested by the total load per year (tons/ha/year) eroded from subbasins 1, 2, 6, 7 and 20 (Figure 6). Other major sources of sediments are agricultural farmlands especially those in subbasins 15 and 16.

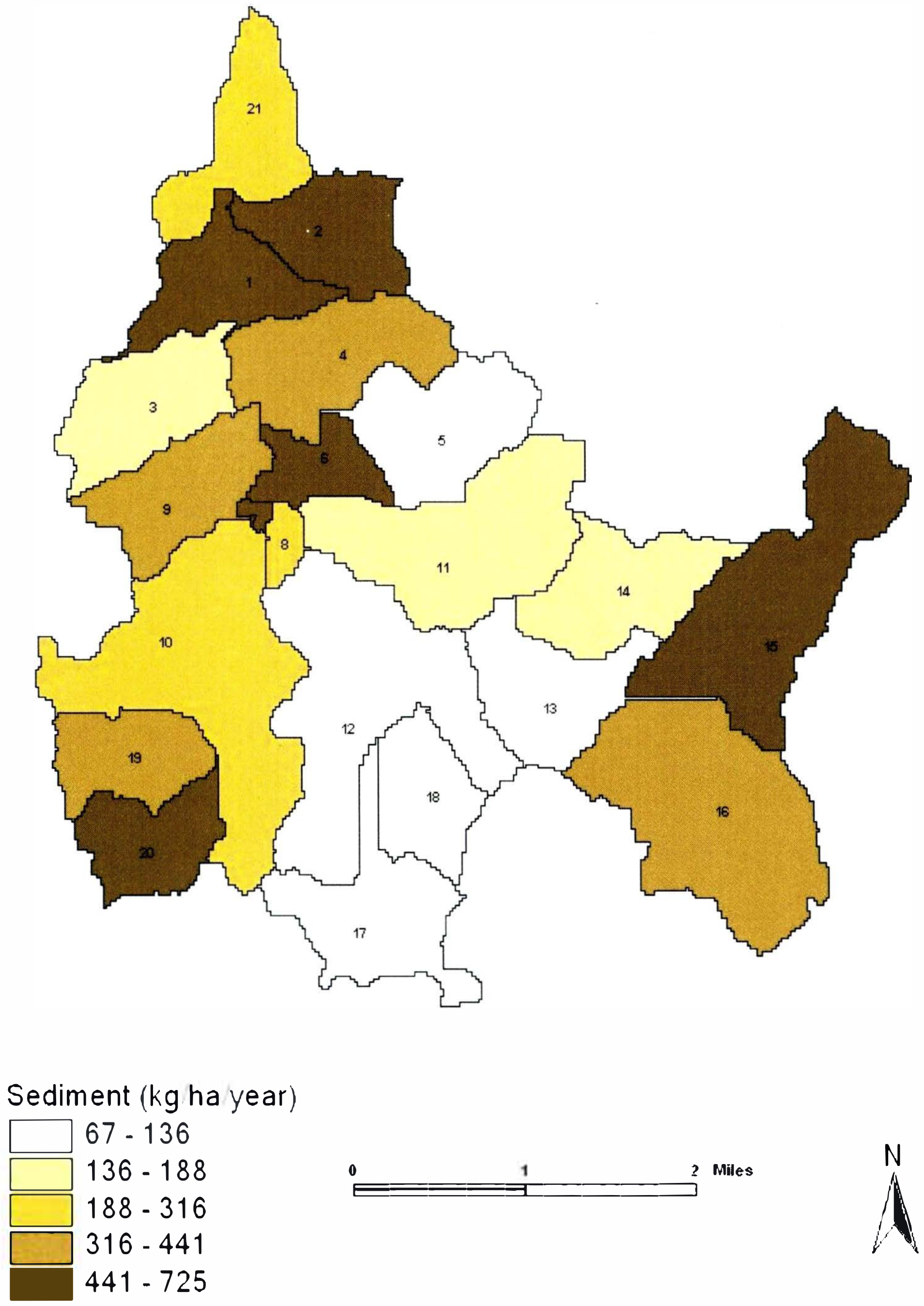

Figure 6: Simulated sediment loading in the Davis Creek for the period of 1998-2004

### 4.3 Phosphorus Loading

Phosphorous loading in the watershed varies highly in the urbanized region. Subbasins 6 (76% industrial and 24%commercial) and subbasin 20 (64% industrial, 17% transportation and 19% agriculture) have the highest phosphorus loading per hectare in the entire watershed (Figure 7). This is attributed to the higher runoff rates occurring within the industrial, commercial and residential areas. Transportation facilities also contribute substantial amounts of phosphorus loadings in the watershed. The simulated results show that agriculture contributes less amount of phosphorus loading than the urban land areas.

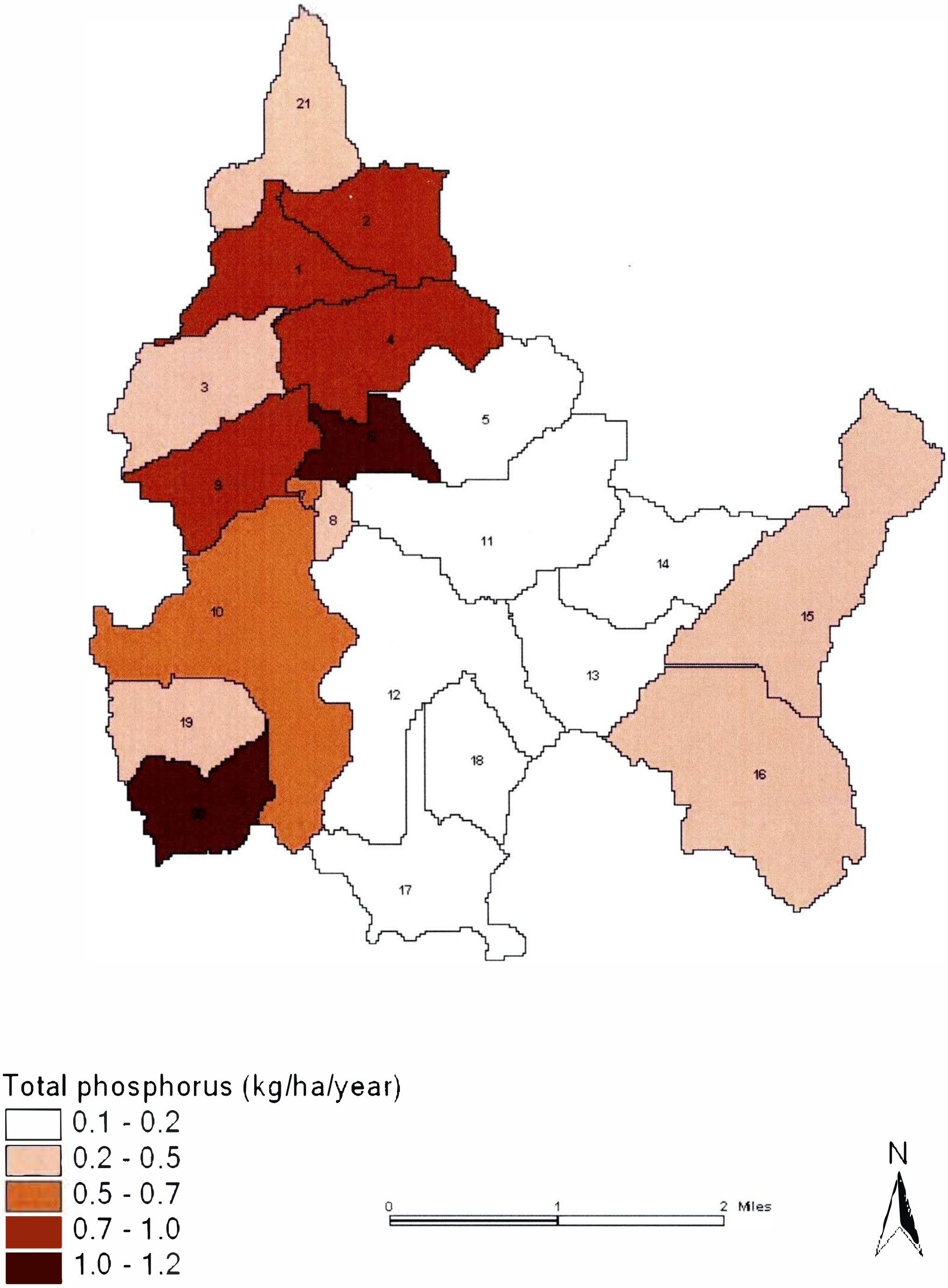

Figure 7: Simulated total phosphorus loading in the Davis Creek for the period of 1998-2004

## 4.4 Nitrogen Loading

Nitrogen loading is highly variable throughout the watershed. Subbasins 1,4,6,9 and 20 recorded high nitrogen loadings over the simulation period. These subbasins are predominantly occupied by industrial, transportation and residential land uses. These land uses contribute more than 5.0 kg/ha/year of nitrogen. Subbasins 15 and 16 mainly agricultural and wetland areas have higher rates of nitrogen loading (Figure 8). Like phosphorus, nitrogen in the agricultural area is highly influenced by fertilizer applications and the presence of medium textured soils. However, varying slopes and other land uses such as wetlands within the agricultural area also influences the rate of nitrogen loadings. High nitrogen loadings in the agricultural portion of the watershed also occur in subbasins 11, 14 and 18.

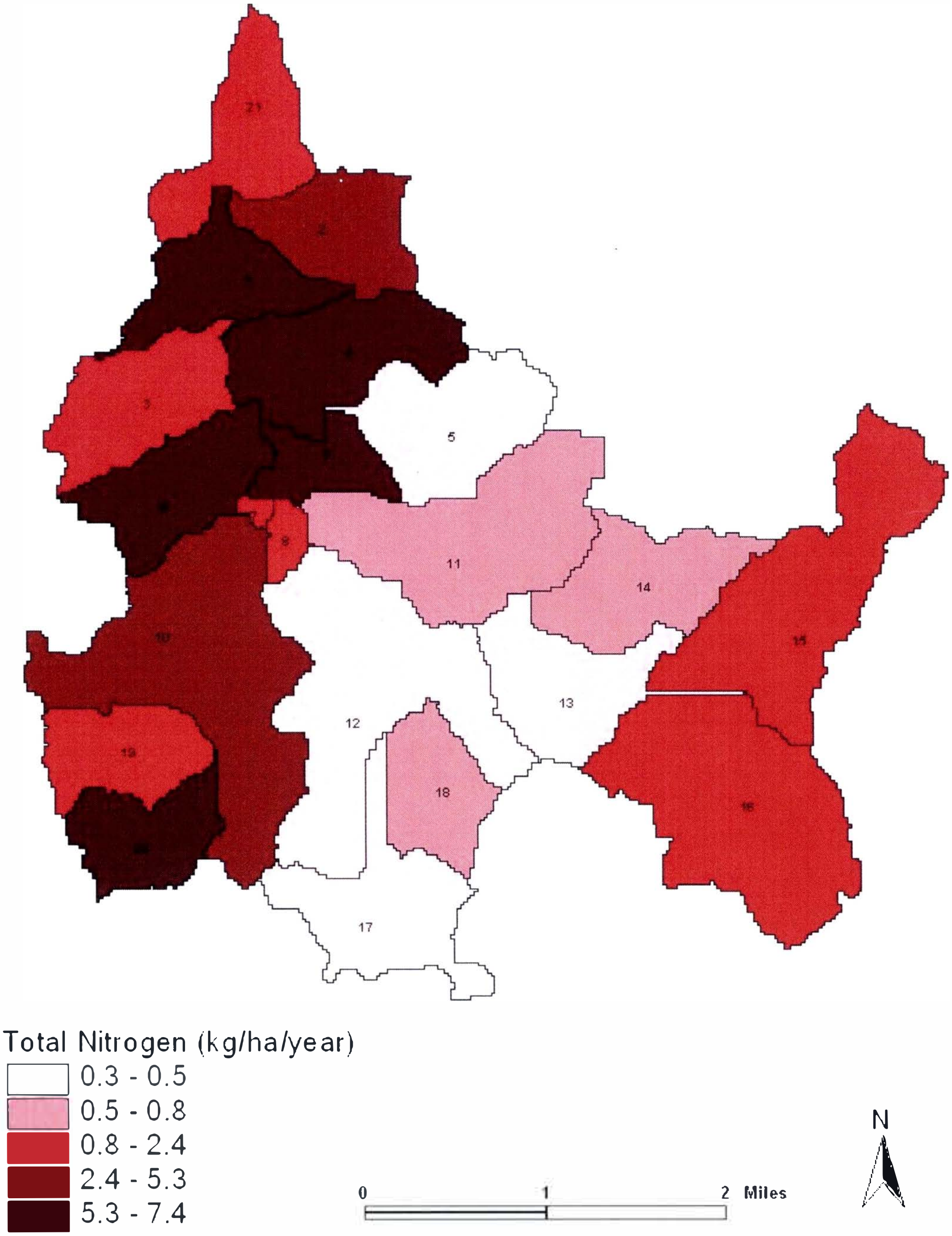

Figure 8: Simulated total nitrogen loading in the Davis Creek for the period of 1998-2004

In summary, the results of this study show that phosphorus and nitrogen output rates are related to the sediment loadings. Areas with high sediment loadings experience higher nutrient loadings and vice versa. These results help us understand the overall loadings of sediment, phosphorus and nitrogen within the Davis Creek and support mitigating and controlling nonpoint source pollution problem in the watershed.

### 4.5 Management Scenarios

To support nonpoint source pollution management in the Davis Creek, several scenarios were developed in this study to evaluate their impact on sediment and nutrient loadings within the Davis Creek. The scenarios range from the most probable foreseeable phenomenon in the future (change from rural to urban) to other BMPs such as no till and construction of retention ponds. The scenarios were developed and simulated for the period of 1998 to 2004. These scenarios are:

- Conversion of agricultural land to urban land - This is a foreseeable scenario because urban population for Kalamazoo County has been steadily increasing since the 1970s, thus, putting developmental pressure on the existing agricultural land. These urban changes are presented in Table 8.

Table 8: The population of Kalamazoo County (1970-2000)

| Year | **1970** | **1980** | **1990** | **2000** |
|---|---|---|---|---|
| Total Population | 201,550 | 212,378 | 223,411 | 238,608 |
| Urban Population | 152,083 | 154,990 | 164,576 | 191,052 |
| % Urban Change | | 1.9% | 6.2% | 16% |

Source: Unites States Census Bureau, 2000

Between the years 1970 and 1980, the Kalamazoo County's urban population increased by 1.9%. Thereafter, between the years 1980 and 1990 an increase of 6.2% in urban population was realized. Between 1990 and 2000 the County's urban population increased substantially by approximately16%. This trend implies that the rate of urbanization in Kalamazoo is gradually increasing, thus, justifying the selection of the scenario.

- Adoption of no till - No cultivation in the agricultural land for the whole growing season. This scenario was applied to cultivated farmlands in November when the harvest operation was over. The no till scenario was chosen in order to find out the impact of tillage operation currently employed in the watershed and whether this can be adopted in the future.
- Expansion of wetland area - 200ha (6% of the entire watershed) agricultural land was changed to wetland. This scenario was

developed to simulate the effects of wetland rehabilitation on the water quality of the creek since there are different types of wetlands in the upper stream of the watershed.

- Construction of retention ponds - 3 retention ponds of 7ha each were constructed in subbasins 3,7 and 8 of predominantly residential areas in the lower portions of the watershed. The scenario was chosen to find out their effectiveness on sediment and nutrient accumulation and retention in residential areas.

The Simulated sediment, phosphorus and nitrogen loadings for the proposed management scenarios were simulated for each of the 4 scenarios (change from agricultural land to urban land, no till, increase in wetland area and construction of retention ponds in residential areas). These changes were then compared with the base conditions (year 2004) of the watershed without any best management practices (Tables 9,10 and 11).

The first scenario - change of agricultural land to urban land is a probable phenomenon if current trends of urban development within the Kalamazoo County continue. This scenario would lead to an increase in sediment loads by 23%, phosphorus by 12% and nitrogen by 8% within the 7 years of simulation.

The no till practice on farmlands after harvest would provide a significant reduction in sediment and nutrient loads. The no till scenario would reduce sediment load by 8%, phosphorus load by 5% and nitrogen by 3%. Expansion of wetland by 200 ha did not provide a meaningful change in sediment and nutrient loads probably because the proposed expansion is too small. The scenario might lead to a reduction in sediment loads by 3% while phosphorus and nitrogen loads remains almost the same.

Construction of 3 retention ponds in the lower portions of the watershed within residential areas could lead to a reduction in sediment loads as well as nutrient loads. Sediment loads could be reduced by 5% while phosphorus and nitrogen loads might be reduced by 1.4% and 1.9% respectively. Addition of more retention ponds may reduce the rate of sediment and nutrient loadings more significantly.

Table 9: Sediment loading (kg/ha/year) under the proposed management scenarios

| *YEAR* | *Base* | *Agri. To Urban* | *Change %* | *No Till* | *Change %* | *Wetland Increase* | *Change %* | *Retention Pond* | *Change %* |
|---|---|---|---|---|---|---|---|---|---|
| 1998 | 337 | 402 | 19.1 | 319 | -5.4 | 338 | 0.2 | 330 | -2.1 |
| 1999 | 301 | 347 | 15.4 | 268 | -10.9 | 290 | -3.6 | 286 | -4.9 |
| 2000 | 312 | 349 | 11.9 | 278 | -10.9 | 290 | -6.9 | 286 | -8.4 |
| 2001 | 402 | 410 | 2.1 | 376 | -6.3 | 351 | -12.6 | 344 | -14.4 |
| 2002 | 211 | 291 | 38.1 | 193 | -8.4 | 204 | -3.5 | 199 | -5.6 |
| 2003 | 298 | 433 | 45.5 | 276 | -7.3 | 297 | -0.2 | 291 | -2.2 |
| 2004 | 319 | 416 | 30.5 | 295 | -7.4 | 335 | 5.3 | 328 | 2.3 |
| Mean | 311 | 378 | 23.2 | 287 | -8.1 | 301 | -3.1 | 295 | -4.9 |

Table 10: Phosphorus loading (kg/ha/year) under the proposed management scenarios

| Year | Base | Agri. to Urban | Change % | No Till | Change % | Wetland Increase | Change % | Retention pond | Change % |
|---|---|---|---|---|---|---|---|---|---|
| 1998 | 0.4 | 0.5 | 6.8 | 0.4 | -2.2 | 0.4 | 2.0 | 0.4 | -0.3 |
| 1999 | 0.4 | 0.5 | 9.8 | 0.4 | -5.3 | 0.4 | -1.2 | 0.4 | -2.9 |
| 2000 | 0.5 | 0.5 | 9.0 | 0.5 | -6.0 | 0.5 | -1.2 | 0.5 | -2.9 |
| 2001 | 0.6 | 0.7 | 5.5 | 0.6 | -3.9 | 0.6 | -2.2 | 0.6 | -3.8 |
| 2002 | 0.4 | 0.5 | 19.9 | 0.4 | -5.1 | 0.4 | -0.4 | 0.4 | -2.2 |
| 2003 | 0.5 | 0.7 | 20.4 | 0.5 | -5.1 | 0.5 | 0.7 | 0.5 | -0.9 |
| 2004 | 0.6 | 0.7 | 16.6 | 0.5 | -5.00 | 0.6 | 4.8 | 0.6 | 3.1 |
| **Mean** | **0.5** | **0.6** | **12.6** | **0.5** | **-4.7** | **0.5** | **0.4** | **0.5** | **-1.4** |

Table 11: Nitrogen loading (kg/ha/year) under the proposed management scenarios

| Year | Base | Agri. to Urban | Change % | No Till | Change % | Wetland Increase | Change % | Retention pond | Change % |
|---|---|---|---|---|---|---|---|---|---|
| 1998 | 2.4 | 2.5 | 7.4 | 2.3 | -2.4 | 2.4 | -0.1 | 2.3 | -2.1 |
| 1999 | 2.5 | 2.7 | 7.3 | 2.4 | -3.7 | 2.5 | -1.2 | 2.5 | -3.2 |
| 2000 | 2.7 | 2.9 | 5.8 | 2.6 | -3.6 | 2.8 | 1.4 | 2.7 | -0.6 |
| 2001 | 3.5 | 3.6 | 3.7 | 3.4 | -2.3 | 3.4 | -1.3 | 3.3 | -3.0 |
| 2002 | 2.2 | 2.4 | 11.2 | 2.1 | -2.8 | 2.2 | -0.3 | 2.1 | -2.2 |
| 2003 | 2.7 | 3.0 | 12.7 | 2.6 | -2.6 | 2.7 | 0.2 | 2.6 | -1.6 |
| 2004 | 3.0 | 3.2 | 8.8 | 2.9 | -2.6 | 3.0 | 1.4 | 3.0 | -0.4 |
| **Mean** | **2.7** | **2.9** | **8.1** | **2.6** | **-2.9** | **2.7** | **0.01** | **2.7** | **-1.9** |

NB: All changes above are based on the base conditions (simulated output from the current land use) without any best management practice

## 4.6 Implications of the Scenarios

These scenarios show the impact of land use change on sediment and nutrient loadings with the no till scenario being the best-case scenario. The scenario shows a reduction in sediment and nutrient loads throughout the agricultural subbasins. Lower sedimentation and nutrient rates are related to the minimal disturbance of the topsoil in the agricultural fields. The construction of retention ponds scenario would lead to a substantial reduction of nutrients and sediment loads in subbasins 3, 7 and 8 where the retention ponds are located. This result should be expected since the scenario was applied to only three particular subbasins. The increase of wetland area scenario shows that increasing wetland area would substantially reduce the sediment and nutrient loadings in the watershed. The 7 years of simulation shows that although the wetland expansion was only by 200 ha, sediment and nutrient loads were simulated to decline slightly especially in 2001 when precipitation rates were high. The change of agricultural land to urban land would increase sediments and nutrients throughout the 7 years of simulation. Higher sediment and nutrient loadings are expected due to high surface runoff in the urban area.

# CHAPTER 5

## CONCLUSIONS AND RECOMMENDATIONS

The Davis Creek watershed has been impaired for many years by nonpoint source pollution. Several local agencies such as the Forum of Greater Kalamazoo were initiated in the 1990s to help restore the impaired watershed. This was mainly through development of action plans such as the Davis Creek Watershed Management Plan of 1996 that provided for both long-term and short-term planning objectives for the watershed. The plan involved encouraging citizen participation in developing and implementation programs such as BMPs to reduce nonpoint source pollution.

This study simulated the movement of sediments and nutrients in the watershed continuously using the Soil and Water Assessment Tool (SWAT). Databases of the Digital Elevation Model, climate, soil types, land use and management practices were used to derive the SWAT inputs. The model was then run for a period of 7 years (1998-2004). The results from the 7-year simulation show that:

- The major sources of sedimentation and nutrient loads in the Davis Creek watershed are from urban land uses specifically from industrial, commercial, residential and transportation facilities. Loadings from these land uses are expected to rise in the future (as seen in the change of agricultural land to urban land use scenario) due to the urbanizing trend of the Kalamazoo County. This rate of urbanization within the County will definitely have an impact on the sediment and nutrient loads in the watershed.

- High pollution areas are located in the urbanized region of the watershed where higher runoff rates occur in comparison with the agricultural areas. Urban land uses such as industrial, transportation, commercial and residential areas are more susceptible to higher pollution rates.
- Construction of retention ponds within the residential areas would reduce sediment and nutrient loads from residential areas.
- Agricultural fields in the watershed contribute large amounts of sediments and nutrients. However, Implementing no till and expanding wetlands would greatly reduce the loading outputs.
- Nonpoint source pollution in the Davis Creek Watershed can be reduced through application of best management practices in both urban and agricultural areas. These practices include: expansion of wetlands; adoption of no till on farmlands in the agricultural areas; and construction of retention ponds in residential areas.

The results obtained from this study can be used to better understand water quality issues in the Davis Creek watershed. They also provide different BMPs scenarios that could be applied or adopted to reduce sediment and nutrient loading in the Davis Creek.

## 5.1 Limitations of the Study

This study simulated the hydrology and nonpoint source loadings in the Davis Creek for the period of 1998 to 2004. While large discrepancies exist between the simulated results and in-situ measurements, these may be attributable to several factors related to model input and calibration and in-situ measurement.

The 1996 land use and soils map were used for this study because they were the only most recent maps available. Additionally, the SWAT model only takes the watershed boundary derived directly from DEM by the model and does not allow use of any other forms of the watershed boundary. For the study area, the watershed boundary derived from DEM by SWAT is about 400 acres smaller than the official watershed boundary defined by the USDA Natural Resources Conservation Service (GIS Research Center, 1996). This may have affected the simulation results.

Another limitation stemmed from the lack of adequate calibration on the results due to limited long-term in-situ data. The only in-situ data available were from May1999 through June 2001.

## 5.2 Recommendations

- With the current rate of urbanization, adopting best management practices seem to be the best strategy for reducing sediment and nutrient loss in the watershed. Nevertheless, BMPs associated with urbanization need further evaluation. To this end, more research should be directed towards creating effective BMPs for commercial, transportation and industrial facilities.
- The Davis Creek watershed does not have readily available data on management practices and river flow. These variables are crucial for any sound hydrological study. Therefore, real time flow data for a more extensive period of time (at least 4 years) need to be collected for future simulations. Management practice information on the watershed such as tillage information, fertilizer and pesticide information also needs to be collected and made available for future research.
- An urban land use model needs to be employed in the future to compare and ascertain the SWAT model output. Although the Davis Creek watershed is still predominantly agriculture, current trends show that in less than a decade, the predominant land use will have changed to urban land use. Therefore, an urban land use model would be effective because SWAT was originally developed to simulate the effect of agricultural management practices on land use.

- The Kalamazoo Conservation District should incorporate multiple learning institutions, residents and other stakeholders in its planning process for BMPs plans and their implementation.

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# APPENDIX 1

## Kalamazoo County Soils

| Soil Type | Symbol | Slope | Drainage | Potential for Surface runoff | Dominant use |
|---|---|---|---|---|---|
| Adrian Muck | *Ad* | 0-2% | poorly drained | very low | cropland |
| Brady Sandy Loam | *BdA* | 0-3% | somewhat poorly drained | low | pasture |
| Gilford Sandy Loam | *Gd* | 0-2% | very poorly drained | very low | pasture |
| Glendora Sandy Loam | *Gn* | 0-2% | very poorly drained | very low | woodland |
| Houghton Muck | *Hn* | 0-2% | poorly drained | very low | cropland |
| Houghton and Sebewa soils | *Hs* | 0-1% | very poorly drained | very low | woodland |
| Kalamazoo Loam | *KaA* | 0-2% | well drained | low | cropland |
| Kalamazoo Loam | *KaB* | 2-6% | well drained | medium | cropland |
| Kalamazoo Loam | *KaC* | 6-12% | well drained | medium | cropland |
| Oshtemo Sandy Loam | *OsB* | 1-6% | well drained | low | woodland |
| Sebewa Loam | *Sb* | 0-2% | very poorly drained | low | cropland |
| Sleeth Loam | *SeA* | 0-3% | somewhat poorly drained | low | cropland |
| Udipsamments | *Ua* | (level-steep) | - | - | - |
| Urban Land | *Ub* | - | - | - | Buildings/ Urban structures |
| Urban Land-Glendora complex | *Ug* | 0-2%. | well drained | low | Building site development |
| Urban Land - Kalamazoo complex | *UkB* | 0-6%. | Very poorly drained | low | Building site development |
| Urban Land - Kalamazoo Complex | *UkC* | 6-12%. | Well drained | medium | Building site development |
| Urban Land - Oshtemo complex | *UoD* | 12-25% | Well drained | high | Building site development |

Austin and Konwinski, 1975

| Tag | Ind 1 | Ind 2 | Bibliographic Data |
|---|---|---|---|
| 000 | | | 01111ccm·a2200289la·45e0 |
| 001 | | | 1147605 |
| 005 | | | 20010405101617.0 |
| 008 | | | 010301s1997····xxusga·········n····eng·d |
| 035 | | | ‡a (OCoLC)ocm38234611 |
| 040 | | | ‡a CIN ‡c CIN |
| 020 | | | ‡a 0793591325 (pbk.) |
| 028 | 3 | 2 | ‡a HL00740107 ‡b H. Leonard |
| 090 | | | ‡a M1621.4.~~B64~~ ‡b B74x 1997<br>-B687 |
| 049 | | | ‡a EXWM |
| 100 | 1 | | ‡a Bolcom, William. |
| 245 | 1 | 0 | ‡a Briefly it enters : ‡b a cycle of songs from poems of Jane Kenyon : for voice and piano / ‡c William Bolcom. |
| 260 | | | ‡a [United States?] : ‡b E.B. Marks ; ‡a Milwaukee, WI : ‡b Exclusively distributed by H. Leonard, ‡c c1997. |
| 300 | | | ‡a 1 score (35 p.) ; ‡c 31 cm. |
| 500 | | | ‡a "1994-1996"--cover. |
| 546 | | | ‡a English words. |
| 505 | 0 | | ‡a Who -- The clearing -- Otherwise -- February: thinking of flowers -- Twilight: after haying -- Man eating -- The sick wife -- Peonies at dusk -- Briefly it enters, and briefly speaks. |
| 600 | 1 | 0 | ‡a Kenyon, Jane ‡x Musical settings. |
| 650 | | 0 | ‡a Song cycles. |
| 650 | | 0 | ‡a Songs (High voice) with piano. |
| 700 | 1 | | ‡a Kenyon, Jane. |
| 948 | | | ‡a 2001;04;05 ‡b dgb ‡c M |
| 994 | | | ‡a E0 ‡b EXW |

## 952 Local Cataloger's Permanent Note (R)

This field contains information primarily of interest to cataloging staff, generally concerning sources consulted during the cataloging process and modifications initiated against an existing record. Field 952 is sometimes referred to as "Cataloging Note" or "Cataloger's Notes." For further information regarding the content of the 952 field, see DCM B9.

Field 952 is not distributed by LC.

### Indicators

Both indicator positions are undefined; each contains a blank (#).

### Subfield Code

#### $a - Cataloger's note (NR)

Contains the entire text of the note.

### Input Conventions

#### Punctuation

Field 952 ends with a period unless another mark of punctuation is present.

### Examples

```
952 ## $a Complete in 12 v.

952 ## $a U.t. deferred.

952 ## $a Imprint from Harrassowitz slip.

952 ## $a Previous ed. cataloged under: ...
```

| Tag | Ind 1 | Ind 2 | Bibliographic Data |
|---|---|---|---|
| 000 | | | 01470ccm·a2200325·a·45e0 |
| 001 | | | 1147634 |
| 005 | | | 20010405100713.0 |
| 008 | | | 010301s1995····nyusga···dei···n····eng·d |
| 010 | | | ‡a 95750243 |
| 035 | | | ‡a (OCoLC)ocm32616374 |
| 040 | | | ‡a OCU ‡c DLC |
| 020 | | | ‡a 0793542391 (pbk.) |
| 028 | 3 | 2 | ‡a HL00740011 ‡b H. Leonard |
| 042 | | | ‡a lccopycat |
| 050 | 0 | 0 | ‡a M1621.4 ‡b .B |
| 090 | | | ‡a M1621.4~~B64~~ ‡b I2x 1995<br>.B687 |
| 049 | | | ‡a EXWM |
| 100 | 1 | | ‡a Bolcom, William. |
| 245 | 1 | 0 | ‡a I will breathe a mountain : ‡b a song cycle from American women poets / ‡c William Bolcom. |
| 260 | | | ‡a [New York?] : ‡b E.B. Marks ; ‡a Milwaukee, WI : ‡b Exclusively distributed by H. Leonard, ‡c c1995. |
| 300 | | | ‡a 1 score (48 p.) ; ‡c 31 cm. |
| 306 | | | ‡a 001700 |
| 505 | 0 | | ‡a Pity me not becuase the light of day / Edna St. Vincent Millay -- How to swing those obbligatos around / Alice Fulton -- The crazy woman / Gwendolyn Brooks -- Just once / Anne Sexton -- Never more will the wind / H. D. -- The sage / Denise Levertov -- O to be a dragon / Marianne Moore -- The bustle in a house / Emily Dickinson -- I saw eternity / Louise Bogan -- Night practice / May Swenson -- The fish / Elizabeth Bishop. |
| 546 | | | ‡a English words; also printed as text (p. 46-48). |
| 500 | | | ‡a Duration: ca. 17:00. |
| 500 | | | ‡a Includes biographical note on the composer and program note. |
| 650 | | 0 | ‡a Song cycles. |
| 650 | | 0 | ‡a Songs (Medium voice) with piano. |
| 948 | | | ‡a 2001;04;05 ‡b dgb ‡c M |
| 994 | | | ‡a E0 ‡b EXW |

indicator value 0) should be first.

## Change of Selection Decision

If an item is received with a slip indicating a change in the selection decision, the cataloger should make the necessary changes to field 925, if this has not already been done, and record the code or initials of the selecting official in subfield $x. If the code or initials are not available, record "Sel Off" in subfield $x.

## Examples

```
925 0# $a acquire $b 2 shelf copies $x policy default

925 0# $a acquire $b 2 shelf copies $x jh 02-19-00 $z r-MRR Alc,
          A. Gardner, 04-15-00

925 0# $a acquire $b 1 shelf copy $x jh 03-19-00 $y o-APLO,
          Hayduchok, 03-25-99 $z r-MRR, A. Gardner, 04-15-00

925 0# $a acquire $b 1 shelf copy $e later edition acquired $x jh
          11-05-00

925 1# $a acquire $b 2 shelf copies $x jh 03-19-00
```

[*Second copy of previous edition discarded*]

```
925 0# $a acquire $b 3 shelf copies $c do not purchase $x rkb
          05-19-00

925 0# $a do not acquire $x xx 11-24-99

925 0# $a do not acquire $d NAL $x J. Buydos 07-15-99

925 1# $a acquire $b 1 shelf copy $x policy default
```

[*Decision to discard from LC collections*]

```
925 0# $a acquire $b 2 shelf copies $x policy default $z send next
          unassigned copy to D.L. Graves (SMCD/MSR I) for CatRef
          assignment

925 0# $a acquire $b 1 shelf copy $e do not retain if CD copy is
          acquired $x policy default
```

[*Commercial sound cassette*]

| Tag | Ind 1 | Ind 2 | Bibliographic Data |
|---|---|---|---|
| 000 | | | 00945ncm·a2200301la·45e0 |
| 001 | | | 1526632 |
| 005 | | | 20040126144112.0 |
| 008 | | | 031211s2000····nyuzza·········n·········d |
| 035 | | | ‡a (OCoLC)ocm53890566 |
| 040 | | | ‡a ORU ‡c ORU |
| 028 | 3 | 2 | ‡a 67966 ‡b Edition Peters |
| 045 | 0 | | ‡b d20000201 |
| 048 | | | ‡a sa02 ‡a sb01 ‡a sc01 |
| 099 | | | ‡a M ‡a 452 ‡a .~~C7976~~x ‡a no.2 ‡a 2000<br>- C833 |
| 049 | | | ‡a EXWM |
| 100 | 1 | | ‡a Cory, Eleanor, ‡d 1943- |
| 240 | 1 | 0 | ‡a Quartets, ‡m strings, ‡n no. 2 |
| 245 | 1 | 0 | ‡a String quartet no. 2 / ‡c Eleanor Cory. |
| 260 | | | ‡a New York : ‡b C.F. Peters Corp., ‡c c2000. |
| 300 | | | ‡a 1 score (34 p.) + 4 parts ; ‡c 28 cm. |
| 306 | | | ‡a 001400 |
| 500 | | | ‡a At end of score: February 1, 2000 New York, NY. |
| 500 | | | ‡a "Sigma Alpha Iota Inter-American music awards"--Cover. |
| 500 | | | ‡a Duration: ca. 14:00. |
| 505 | 0 | | ‡a Energico -- Pensoso -- Giocoso. |
| 650 | | 0 | ‡a String quartets ‡v Scores and parts. |
| 948 | | | ‡a 2004;01;26 ‡b sab ‡c M |
| 994 | | | ‡a E0 ‡b EXW |

**$c - Conditions under which titles can be acquired (NR)**

A brief statement that specifies any conditions under which a title can be acquired; e.g., "do not purchase".

**$d - Disposition of unwanted material—outside agency (R)**

Contains the name of an outside agency to which unwanted material is to be sent. *Note:* Generic terms such as "exchange," which is assumed to be the default, should not be recorded in subfield $d.

**$e - Comment related to selection decision (R)**

Contains any note information relating to a selection decision that is not more appropriately recorded in another subfield of field 925.

**$x - Responsibility for selection decision (NR)**

Contains the code or initials of the staff member making the selection decision recorded in subfield $a, followed by a date. The legend "policy default" will be recorded if no explicit action has been taken by a selecting official, i.e., the decision is in accordance with a general LC collection development policy or practice.

**$y - Office copy request (R)**

Contains an alert to assign an extra copy to the requesting unit. Subfield $y should include the name of the LC unit, the name of the requester, and the date.

**$z - Reference assignment request (R)**

Contains an alert to assign an incoming copy to a reference collection.

## Input Conventions

### Field Order

The 925 field is placed at the beginning of a bibliographic record, immediately following the 906 field.

When a 925 field is added to a record that already contains one, the new field should be added preceding the existing field. The most recent field, containing the current decision (first

| Tag | Ind 1 | Ind 2 | Bibliographic Data |
|---|---|---|---|
| 000 | | | 00968ccm·a2200313la·45e0 |
| 001 | | | 1214996 |
| 005 | | | 20020618073221.0 |
| 008 | | | 020507t19981995nyuzza···hi····n·······d |
| 035 | | | ‡a (OCoLC)ocm38947609 |
| 040 | | | ‡a CIN ‡c CIN ‡d OCL ‡d LVB |
| 020 | | | ‡a 0793574277 |
| 028 | 3 | 0 | ‡a ED 4028 ‡b G. Schirmer |
| 028 | 3 | 0 | ‡a HL50482922 ‡b H. Leonard Pub. Corp. |
| 041 | 0 | | ‡g eng |
| 090 | | | C788<br>‡a M452.C~~68~~5 ‡b Q37x 1998 |
| 049 | | | ‡a EXWM |
| 100 | 1 | | ‡a Corigliano, John, ‡d 1938- |
| 240 | 1 | 0 | ‡a Quartet, ‡m strings |
| 245 | 1 | 0 | ‡a String quartet / ‡c John Corigliano. |
| 254 | | | ‡a Score. |
| 260 | | | ‡a New York : ‡b G. Schirmer ; ‡a Milwaukee, WI : ‡b Distributed by H. Leonard Pub. Corp., ‡c 1998, c1995. |
| 300 | | | ‡a 1 score (34 p.) ; ‡c 31 cm. |
| 306 | | | ‡a 003500 |
| 500 | | | ‡a Duration: ca. 35:00. |
| 500 | | | ‡a Program note by the composer. |
| 505 | 0 | | ‡a Prelude -- Scherzo -- Nocturne -- Fugue -- Postlude. |
| 650 | | 0 | ‡a String quartets ‡v Scores. |
| 948 | | | ‡a 2002;06;18 ‡b dgb ‡c M |
| 994 | | | ‡a E0 ‡b EXW |

items being withdrawn from the collection will be handled by non-cataloging staff.

For further information about field 925, see Bibliographic Workflow Training Document 9.

Field 925 is not distributed by LC.

## Indicators

### First Indicator - Applicability

**0 - Current**

**1 - Former**

### Second Indicator - Undefined

Contains a blank (#).

## Subfield Codes

*Note:* Subfields $a and $x are mandatory in all 925 fields.

### $a - Selection decision for LC shelf copies (NR)

Contains one of the following legends:

**acquire**
Indicates that LC wants shelf copies of the title.

**do not acquire**
Indicates that LC does not want shelf copies of the title. When subfield $a of field 925 contains this legend, the bibliographic record will be suppressed from the OPAC.

**undetermined**
Used in those cases in which it is not possible to make a decision prior to receipt of the material; e.g., serials for which an ISSN has been requested.

### $b - Number of shelf copies/sets desired (NR)

Contains a brief statement in the form “1 shelf copy,” “2 shelf copies,” etc.