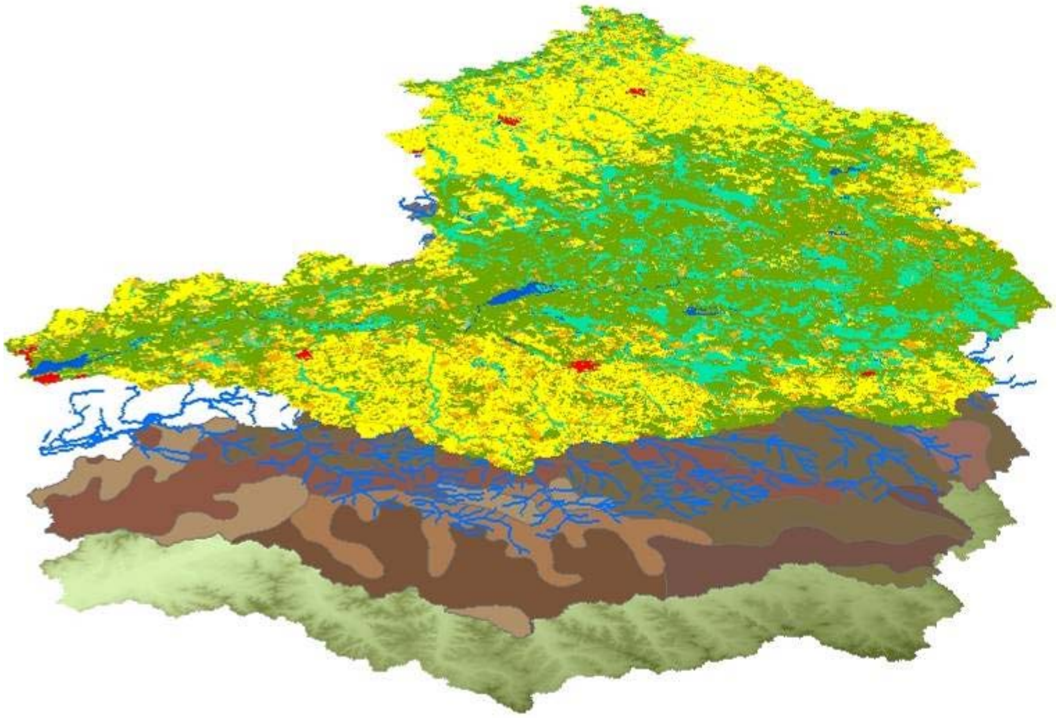
Phosphorus Loading Model for Lake Eau Claire and Lake Altoona



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University of Wisconsin – Stevens Point

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Executive Summary

Quantifying non-point nutrient runoff to Lake Altoona and Lake Eau Claire is a critical step in improving the water quality in these western Wisconsin lakes. Previous studies have shown these lakes to be eutrophic because of excessive phosphorus resulting in increased algal growth and reduced water clarity during the summer months. Similar to many other Wisconsin lakes, non-point nutrient runoff is one of the major sources of phosphorus loading to these lakes. Identifying strategies for reducing phosphorus loads can be costly and time consuming. Computer modeling tools can provide a useful first-step to quantifying nutrient loads and identifying different approaches to reduce nutrient loads. This report describes a computer modeling study in the Eau Claire River Watershed (ECRW) to better understand the sources and potential for reducing nonpoint source phosphorus loading to Lake Altoona and Lake Eau Claire.

An evaluation of the land within the Lake Altoona and Lake Eau Claire watershed was performed as part of this study. Land use and land management was characterized in discussions with Land and Water Conservation Departments in Eau Claire, Clark, Chippewa, Taylor and Jackson Counties and with geographic information systems (GIS) databases that were available at the county and state level. The study developed detailed land management GIS databases that should be useful in future studies of the watershed and lakes.

The entire ECRW watershed is approximately 800 square miles. Within this large watershed, there are many variations in topography, soils and land management systems. A little less than half of the watershed was in forest. Forested land usually has relatively low nutrient loss because of the continuous ground cover and high moisture storage and infiltration in the soil profile. Approximately 162,225 acres or 31% of the entire watershed was in agricultural land use. Agricultural land use often has higher nutrient loss rates because of the periods of low plant cover, areas with more soil compaction, and drainage ways to convey water to streams. This can be particularly important when the land is close to streams in the watershed. Approximately one third of the agricultural land (57,702 acres) was within 200 meters of the drainage network.

The Soil and Water Assessment Tool (SWAT) model was used with the detailed watershed information to simulate how land management influences phosphorus export in the ECRW that drains to Lake Eau Claire and Lake Altoona. Previous monitoring studies were used to calibrate the model. The calibrated model was first used to develop a better estimate of the average annual phosphorus loading to the lake. This model estimated an average phosphorus loading to Lake Eau Claire of approximately 40,000 kilograms (88,000 pounds) with 15,000 kilograms (33,000 pounds) during the summer (May-Sept) months. Lake Altoona has an annual phosphorus loading of 62,000 kilograms (136,000 pounds) with a summer loading of 24,000 kilograms (53,000 pounds). Approximately two-thirds of this annual phosphorus load was attributed to agricultural land management. Similar to how the agricultural land is distributed, the largest phosphorus yields originate from the agriculturally dominated northern and southern parts of the watershed.

The SWAT model was used to explore how agricultural land management changes might be used to effect changes in the phosphorus export from the watershed. The results of these simulations show that implementation of conventional management changes, such as reducing phosphorus applications to the land, increasing sediment reduction practices, and reduced tillage could provide phosphorus export reductions up to thirty percent from the watershed.

Acknowledgements

We wish to acknowledge those groups and individuals who contributed to the successful completion of the project through funding, insight, and support.

This project would not have been possible had it not been for funding sources including Eau Claire and Clark Counties, Lake Altoona and Lake Eau Claire Associations, the University of Wisconsin – Stevens Point, and the Wisconsin Department of Natural Resources.

The development of this project is a culmination of the efforts of many. Model calibration would not have been possible without the previous research conducted by the following: William James and the Eau Galle Aquatic Ecology Laboratory of the U.S. Army Corp of Engineers; Ben Hung and the Wisconsin Department of Water Resources, and the USGS. UW-Stevens Point staff provided assistance during all stages of the project. Digitizing and aerial photo analysis conducted by Alex Smith defined the spatial extent of land management throughout the watershed. The assistance of graduate student Steven Weiss during the data collection and model development periods provided invaluable assistance towards successful model calibration.

This project relied extensively on assistance from Eau Claire County Conservationists Jean Schomisch and Kirsten Cahow-Scholtes, Clark County Conservationists Gregg Stangl and Matthew Zoschke, Taylor County Conservationist Steve Oberle, Chippewa County Conservationist Dan Masterpole, and Jackson County Conservationist Gaylord Olson. They were all integral in providing land management identification, organizing field visits, and offering insight into individual land management changes throughout the watershed. Each Counties staff's ability to foster a positive experience was necessary for project completion and their working knowledge of the land is and will be invaluable to implementing management strategies.

Thanks to Buzz Sorge, Ken Schreiber, and Patrick Oldenburg of the Wisconsin Department of Natural Resources for the active role they played during conceptual development, model evaluation, and alternative scenario design.

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List of Acronyms

AMLE	Adjusted Maximum Likelihood Estimation
AVSWAT	ArcView Soil and Water Assessment Tool
AWC	Available Water Capacity
BMP	Best Management Practice
CLCD	County Land Conservation District
CMS	Cubic Meter per Second
CNOP	Operational Crop Curve Number
CREAMS	Chemicals, Runoff, and Erosion from Agricultural Management Systems
DEM	Digital Elevation Model
ECRW	Eau Claire River Watershed
EPIC	Erosion-Productivity Impact Calculator
ESCO	Evapotranspiration Coefficient
GIS	Geographical Information Systems
GLEAMS	Groundwater Loading Effects on Agricultural Management Systems
HRU	Hydrologic Response Unit
HSG	Hydrologic Soil Group
ID	Internally Drained Closed Depressions
MET	Meteorological Station
NAIP	National Agriculture Imagery Program
NASS	National Agriculture Statistical Service
NCDC	National Climatic Data Center
NRCS	Natural Resources Conservation Service
PEST	Parameter Estimation
RCN	Natural Resources Conservation Service
SCS	Soil Conservation Service
SBD	Soil Bulk Density
SLSOIL	Slope Length for Lateral Subsurface Flow
SNAP	Soil Nutrient Management Application Program
SOLK	Soil Hydraulic Conductivity
SURQ	Surface Flow Output (.bsb file)
SWAT	Soil and Water Assessment Tool
SWRRB	Simulator for Water Resources in Rural Basin
TIN	Triangulated Irregular Network
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
USDA	United States Department of Agriculture
UWSP	University of Wisconsin at Stevens Point
WDNR	Wisconsin Department of Natural Resources

1.0 Introduction

1.1 Purpose

Lake Eau Claire and Lake Altoona are impoundments within the Eau Claire River that experience algal blooms and reduced water quality during the summer. These water quality problems result from eutrophication caused by excess nutrient enrichment. Eutrophication is the main cause of impaired waters in the United States (EPA 1996). The nutrient exerting the greatest control over eutrophication in most inland lakes is phosphorus, although nitrogen can also impact water quality (Correll 1998). The effects of eutrophication in Midwestern lakes are often observed when concentrations of total phosphorus reach 0.02 mg/L (Shaw *et al.* 2000).

Phosphorus (P) concentrations in lakes are controlled by both internal and external phosphorus loading. Internal phosphorus loading occurs when phosphorus already in the lake system becomes available for use by biota. In eutrophic lakes, lower dissolved oxygen near the sediment creates an anoxic environment favorable for the release of sediment phosphorus. External phosphorus loading is phosphorus transported into the lakes from the watershed or the atmosphere. External loading can be increased by land management that increases the movement or availability of phosphorus. Slowing or reversing eutrophication requires that the external and/or internal loads to the lake be reduced. Because internal loading results from phosphorus already in the lake, it is critically important to understand and reduce, if possible, additional external loading. To efficiently address external loads, it is important to locate and manage the areas within the watershed that are phosphorus contributors.

Several previous studies of Lake Eau Claire and Lake Altoona focused on the lakes themselves. One year water quality studies were conducted at both Lake Eau Claire (1998) and Lake Altoona (2000) by the United States Army Corps of Engineers (USACE) (James *et al.* 1999, James *et al.* 2000). Those studies focused on external loading (suspended sediments and nutrients from the inflow tributaries), internal P loading from the sediment, and measuring in-lake water quality. They concluded that while internal loading of phosphorus within each lake was the contributing factor to algal blooms, the input of phosphorus from external sources (i.e. contributing tributaries) must be addressed prior to mitigating internal sources.

The Eau Claire River Watershed (ECRW) Study described in this report examined the watershed that provides the water and the external nutrient loading for Lake Eau Claire and Lake Altoona. The study developed a predictive simulation model for the watershed to better understand sources of phosphorus and approaches for reducing phosphorus loading to the lakes. This study serves as a preliminary step in identifying and managing P loading from the tributaries that contribute sediment and phosphorus to Lake Eau Claire and Lake Altoona.

1.2 Site Description

The Eau Claire River Watershed (ECRW) consists of approximately 821 square miles (mi^2) located within west-central Wisconsin's Chippewa, Clark, Eau Claire, Jackson, and Taylor counties (*Figure 1*) and includes the urban centers of Altoona, Fall Creek, Augusta, Fairchild, Boyd, Stanley, Thorp, and Lublin (*Figure 2*). Chippewa, Clark, Eau Claire, Jackson, and Taylor counties comprise 9.8, 41.9, 42.5, 1.6, and 4.3% of the watershed area, respectively. The Eau Claire River, the watershed's primary tributary, flows through two reservoirs, Lake Eau Claire and Altoona, before draining to the Chippewa River downstream of Altoona, Wisconsin (*Figure 3*).

Lake Eau Claire is a 1.34 mi^2 (860 acre) impoundment north of Augusta, Wisconsin. The Eau Claire River is the primary discharge tributary contributing to Lake Eau Claire with Muskrat and Hay Creeks acting as secondary tributaries. Lake Eau Claire receives discharge from an approximately 585 mi^2 of the 821 mi^2 ECRW including the North Fork of the Eau Claire River, Mead Lake, Coon Fork, Hay Creek, and Muskrat Creek subwatersheds. Approximately 24 river miles downstream of Lake Eau Claire is Lake Altoona. Lake Altoona is a 1.31 mi^2 (840 acre) impoundment north of Altoona, Wisconsin. The Eau Claire River is the primary tributary to Lake Altoona with subwatersheds of Bridge Creek, and Fall Creek contributing water to the river prior to the lake.

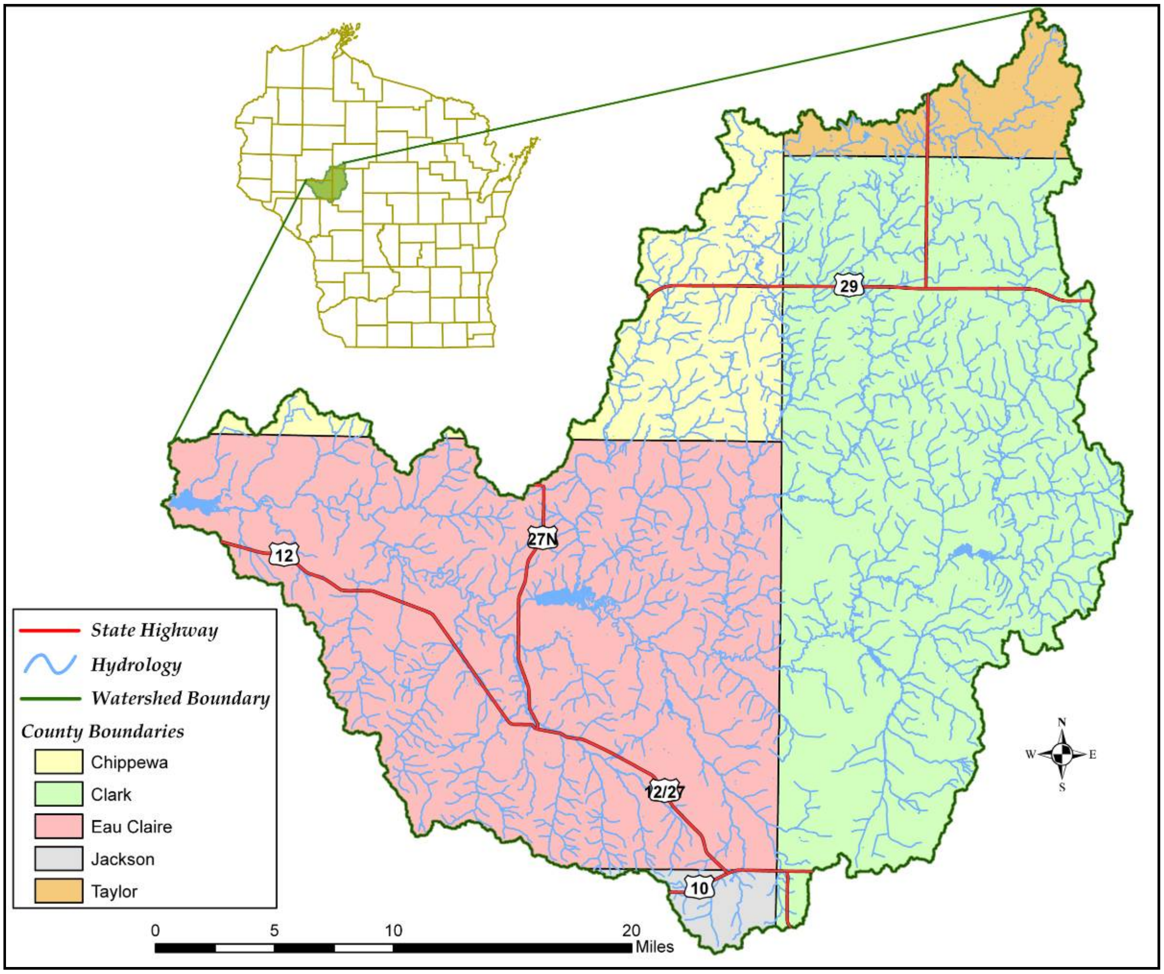

Figure 1 - County Divisions of the ECRW

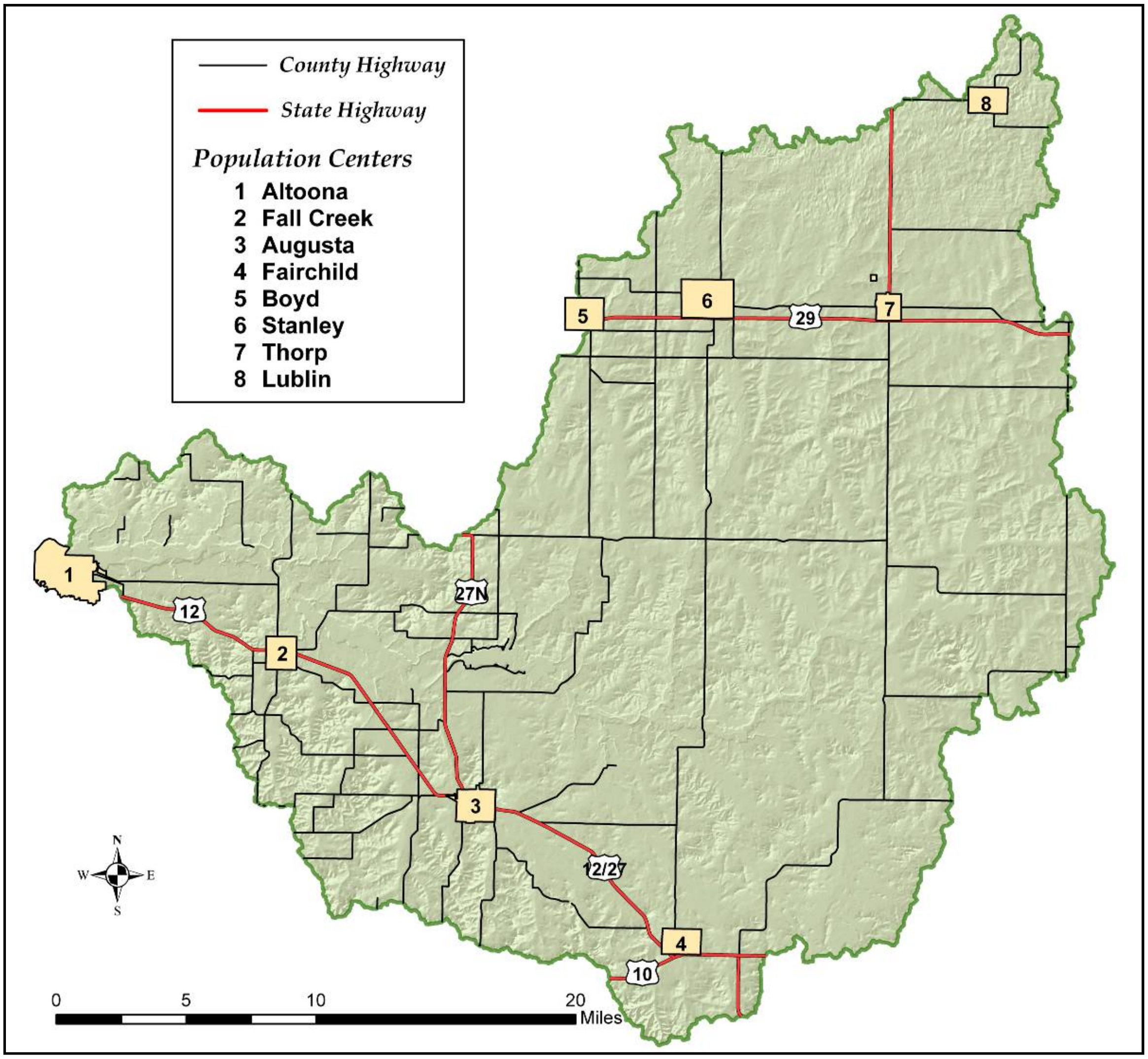

Figure 2 - Population Centers within ECRW

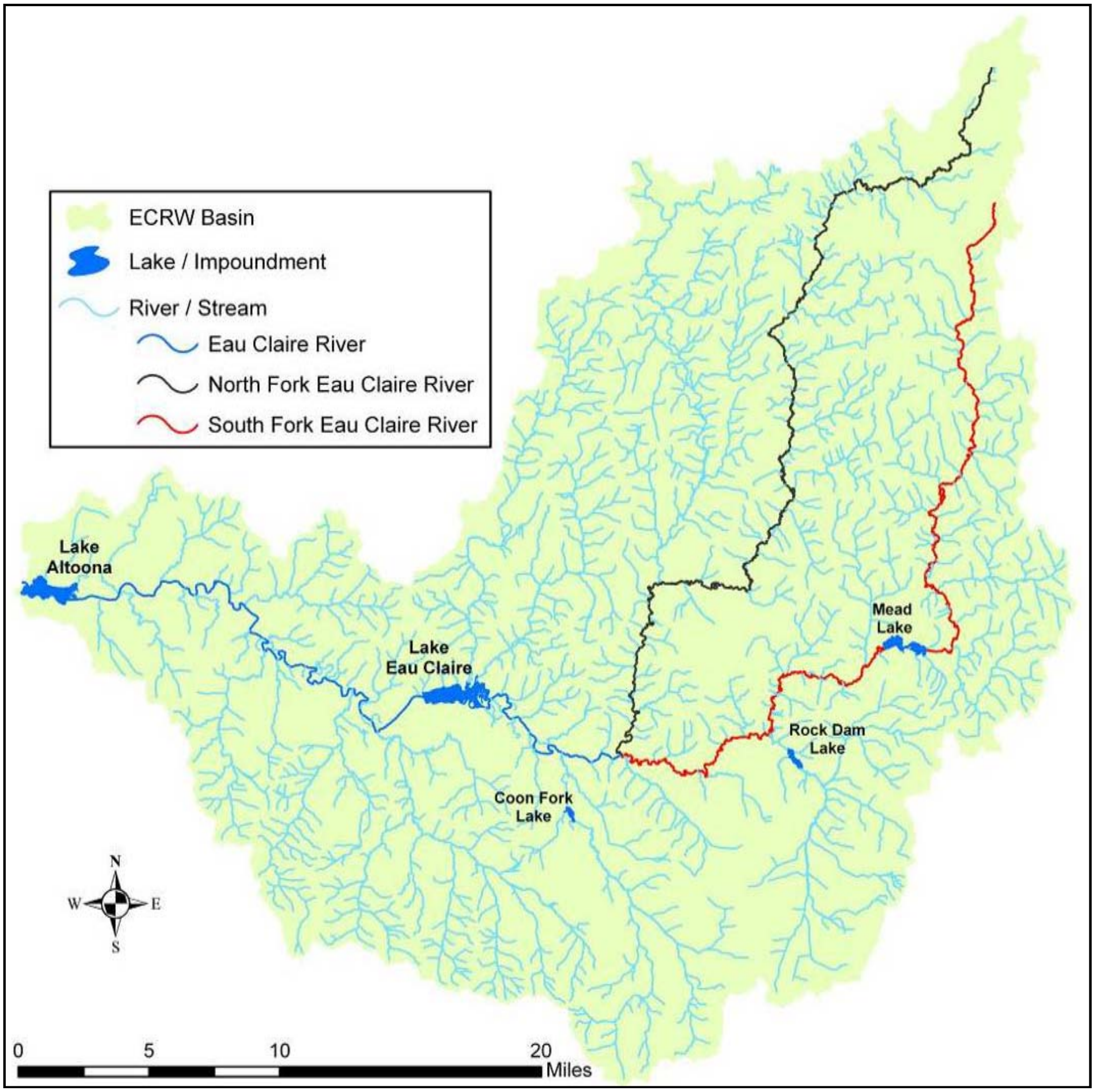

Figure 3 – Drainage Network with the ECRW

2.0 Methods

To understand sediment and phosphorus loading from nonpoint sources within the watershed, a two phase project was developed. The first phase calibrated a watershed-scale model to measured discharge and water quality at a subwatershed and watershed scale. The second phase tested alternate management practices with the calibrated watershed model to determine effective measures of reducing sediment and nutrients to the reservoir.

2.1 SWAT Model Description and Approach

The Soil and Water Assessment Tool (SWAT) model is a physically based, continuous daily time-step, geographic information system (GIS) based model developed by the U.S. Department of Agriculture - Agriculture Research Service (USDA-ARS) for the prediction and simulation of flow, sediment, and nutrient yields from watersheds. The SWAT model uses algorithms from a number of previous models including the Simulator for Water Resources in Rural Basin (SWRRB) model, the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model, the Groundwater Loading Effects on Agricultural Management Systems (GLEAMS), and the Erosion-Productivity Impact Calculator (EPIC) (Neitsch 2002). The SWAT model incorporates the effects of weather, surface runoff, evapotranspiration, crop growth, irrigation, groundwater flow, nutrient and pesticide loading, and water routing for varying land uses (Kirsch *et al*. 2002; Neitsch *et al.* 2002). SWAT was selected because it is being used to simulate P loading for watersheds throughout Wisconsin (Kirsch *et al*. (2002), Baumgart (2005), FitzHugh and MacKay (2000)).

A modified version of the SWAT2000 executable code from Paul Baumgart of the University of Wisconsin at Green Bay was used for all model simulations. This version included modifications to correct the wetland P retention, and correctly kill alfalfa at the end of its growing season. Another modification included using root biomass for the direct computation of the fraction of biomass transferred to the residue fraction when a perennial crop goes dormant is computed using root biomass. For a complete list of the FORTRAN code modifications completed by Paul Baumgart, refer to Baumgart (2005).

Several different model interfaces were used in the SWAT model simulations. The ArcView extension (AVSWAT) (version 1.0) of the SWAT model (Di Luzio *et al.* 2002) was used in this project to linkthe SWAT model with GIS land management and topography layers. The DOS version of the SWAT model was used during calibration with the parameter estimation (PEST) software and in the final simulations of the larger simulations of the entire watershed. An interface with Microsoft Excel spreadsheets was developed using Visual Basic to facilitate file editing and model simulation for the large watershed simulations.

The SWAT model was developed using topography and sampling to divide the watershed into subwatersheds. Most of those subwatersheds contained many different land uses. SWAT was used to split each subwatershed into areas of similar land use and soil. These hydrologic response units (HRUs) were the land areas where SWAT simulated the different processes contributing to nutrient movement. SWAT does not retain the spatial identity of each field and its proximity to the stream reach becomes lost as the subwatershed is split into these HRUs. Landscape processes are simulated within each individual HRU and each HRU is assumed to contribute directly to the stream reach.

The SWAT model was initially adjusted using measurements of streamflow and water quality from previous studies in the watershed, and then the adjusted model was used to make predictions of phosphorus export and control. The initial calibration process compared the SWAT simulated values to data measured in the field and then used adjustments to different model parameters to better fit the measured data set (SWAT Calibration Techniques, 2005). Typically, initial values for these parameters were based on previous measurements or theoretical considerations. The calibrated SWAT model was used to evaluate the sensitivity of watershed phosphorus export to changes in management practices. Different scenarios were simulated by making adjustments in the model to reflect changes in management. While this modeling tool provides a general indication of likely watershed response, the variability of P source and transport mechanisms in the watershed requires understanding the impacts of changes made at the field-scale (Gburek and Sharpley 1998). Ultimately, the modeling results will need to be combined with tools that provide a site-specific evaluation of management changes to develop an implementation strategy.

2.2 Collection of Data

2.2.1 Discharge

Measured stream discharge data is necessary for comparison to the simulated SWAT discharge values. Discharge has been measured sporadically at thirteen locations throughout the watershed (*Figure 4*, *Table 1*). Various federal and state agencies have been involved with measuring the discharge including the United States Geologic Survey (USGS), USACE, and the WDNR. Ten sites where flow had been collected were used for SWAT model calibration. Although the discharge measurements were not collected during the same time period, the SWAT model can be run for a length of time to accommodate all measurements.

2.2.2 Water Quality

Water quality samples (total suspended solids and/or total phosphorus) were collected during some of the previous studies. The USACE studies reported semi-monthly water quality analysis from eight of the eleven sites (encompassing three separate lakes studies within the ECRW) (James, 2005). The WDNR sampled the Coon Fork watershed using similar methodology. This water quality sampling protocol was similar to that suggested by Robertson and Roerish, 1999. The samples collected captured both baseflow and events during the observed stream discharge. The resulting water quality samples were then converted into flow weighted monthly mean load estimates (kg/d) of total phosphorus (TP) and total suspended solids (TSS) with LOADEST, a Fortran-based program developed by the USGS (Runkel *et al* 2004). Input files included instantaneous daily measures of flow. Calibration files included instantaneous measures of TP and TSS taken mostly during the growing season period between 1997 and 2003.

Eleven separate regression models were available through LOADEST. The adjusted maximum likelihood estimation (AMLE) was used to calculate estimated monthly loads. Regression model 2 ($a_0 + a_1 \ln Q + a_2 \ln Q^2$) (where Q is the average daily flow and a_1 and a_2 are fitted constants) was selected because the results were similar to those presented in USACE water quality reports (James *et al.* 1999, 2000).

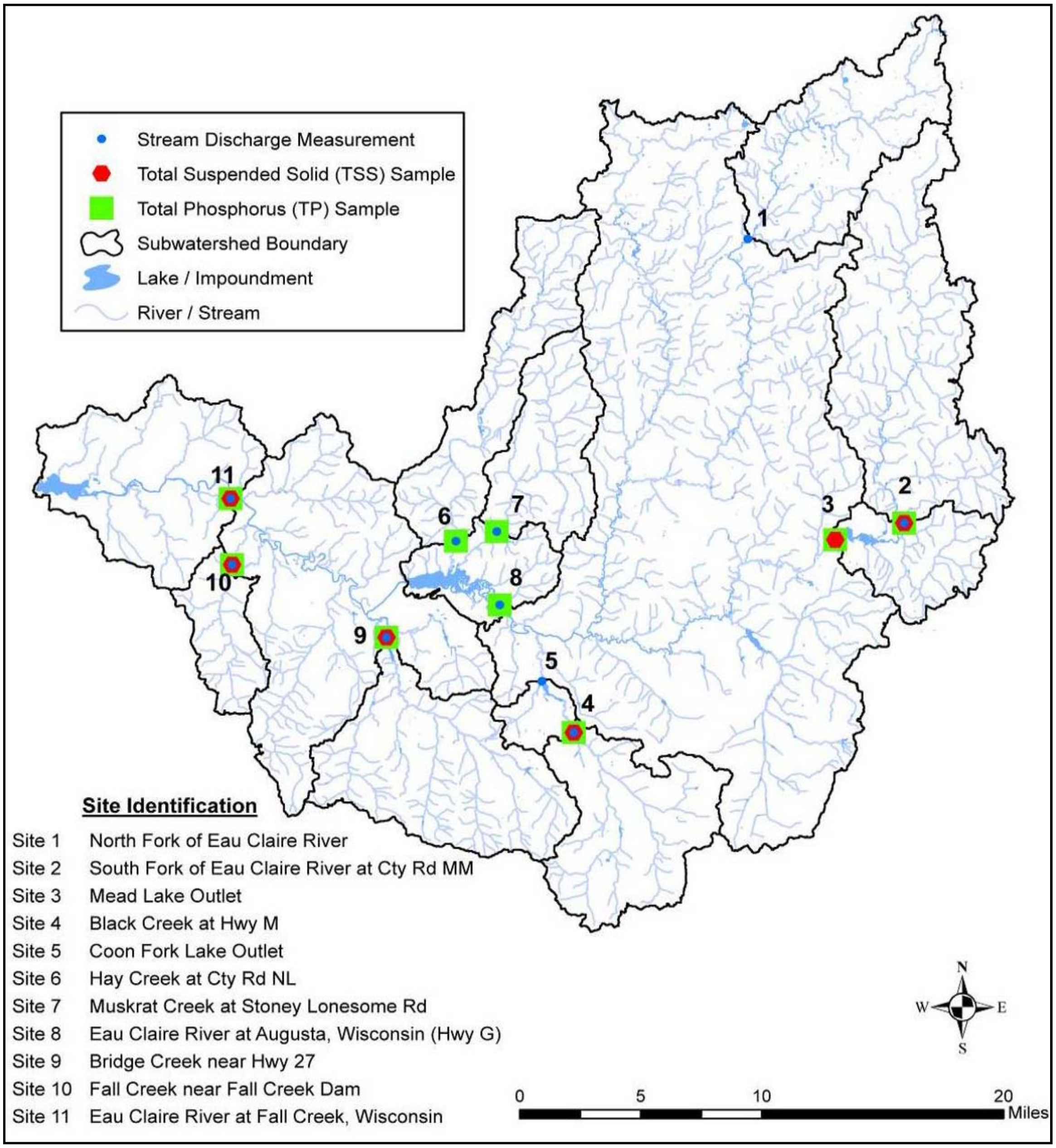

Figure 4 - ECRW Flow, Sediment, and Phosphorus Monitoring Locations

Table 1 – ECRW Discharge and Water Quality Monitoring Locations

Station ID	Site Name	Sample Date	Project ID	Flow	Sediment (TSS)	Phosphorus (TP)
1	North Fork of Eau Claire River at Thorp, WI	04/1986 – 12/2003	USGS Station	Daily, 18 years	NA	NA
2	South Fork of Eau Claire River at Hwy MM	04/2002 – 11/2002, 04/2003 – 10/2003	USACE Mead Lake Study	Daily, 10 months	27 Samples	27 Samples
3	Mead Lake Outlet	04/2002 – 11/2002, 04/2003 – 10/2003	USACE Mead Lake Study	NA	23 Samples	23 Samples
4	Black Creek at Hwy M	05/1997 – 10/1997	WIDNR Coon Fork Lake Study	18 days	18 Samples	18 Samples
5	Coon Fork Lake Outlet	05/1997 – 09/1997	WIDNR Coon Fork Lake Study	Daily, 4 months	NA	NA
6	Hay Creek at Cty Rd NL	02/1998-10/1998	USACE Lake Eau Claire Study	Daily, 9 months	NA	54 Samples
7	Muskrat Creek at Stoney Lonesome Rd	02/1998-10/1998	USACE Lake Eau Claire Study	Daily, 9 months	NA	52 Samples
8	Eau Claire River at Augusta, WI (Hwy G)	02/1998-10/1998	USACE Lake Eau Claire Study	Daily, 9 months	NA	215 Samples
9	Bridge Creek near Hwy 27	05/2000 – 09/2000	USACE Lake Altoona Study	Daily, 5 months	14 Samples	14 Samples
10	Fall Creek near Fall Creek Dam	05/2000 – 09/2000	USACE Lake Altoona Study	Daily, 5 months	34 Samples	34 Samples
11	Eau Claire River near Fall Creek, WI	1996, 1997, 1998, 11/1999 – 11/2000, 2001, 2002, 2003	USACE Lake Altoona Study	8 years	19 Samples	19 Samples

2.3 Model Inputs

2.3.1 Topography

The topographic relief of a watershed influences nutrient transport from subwatersheds to the stream reaches through slope length/degree and by determining the boundaries of the contributing area. Topography is represented within the SWAT model using digital elevation models (DEM). DEM's are terrain elevation points located at regularly spaced horizontal intervals. The SWAT model uses topography to delineate the subwatershed boundaries and define parameters such as average slope, slope length, and the accumulation of flow for the definition of stream networks. The average slope and slope length are calculated per HRU. The ECRW was topographically divided into 11 drainage basins and subdivided into 37 modeled subwatersheds based on the stream network and sampling site location using the statewide 7.5 minute (or 1:24,000 scale) 30-meter grid based DEM obtained from the WDNR (*Figure 5*). A finer resolution (e.g., 10-meter) DEM is not currently available for this watershed. The majority of the ECRW had slopes of 0 to 10 percent. The northern section of the watershed measured lower percent slopes than the southern section of the watershed.

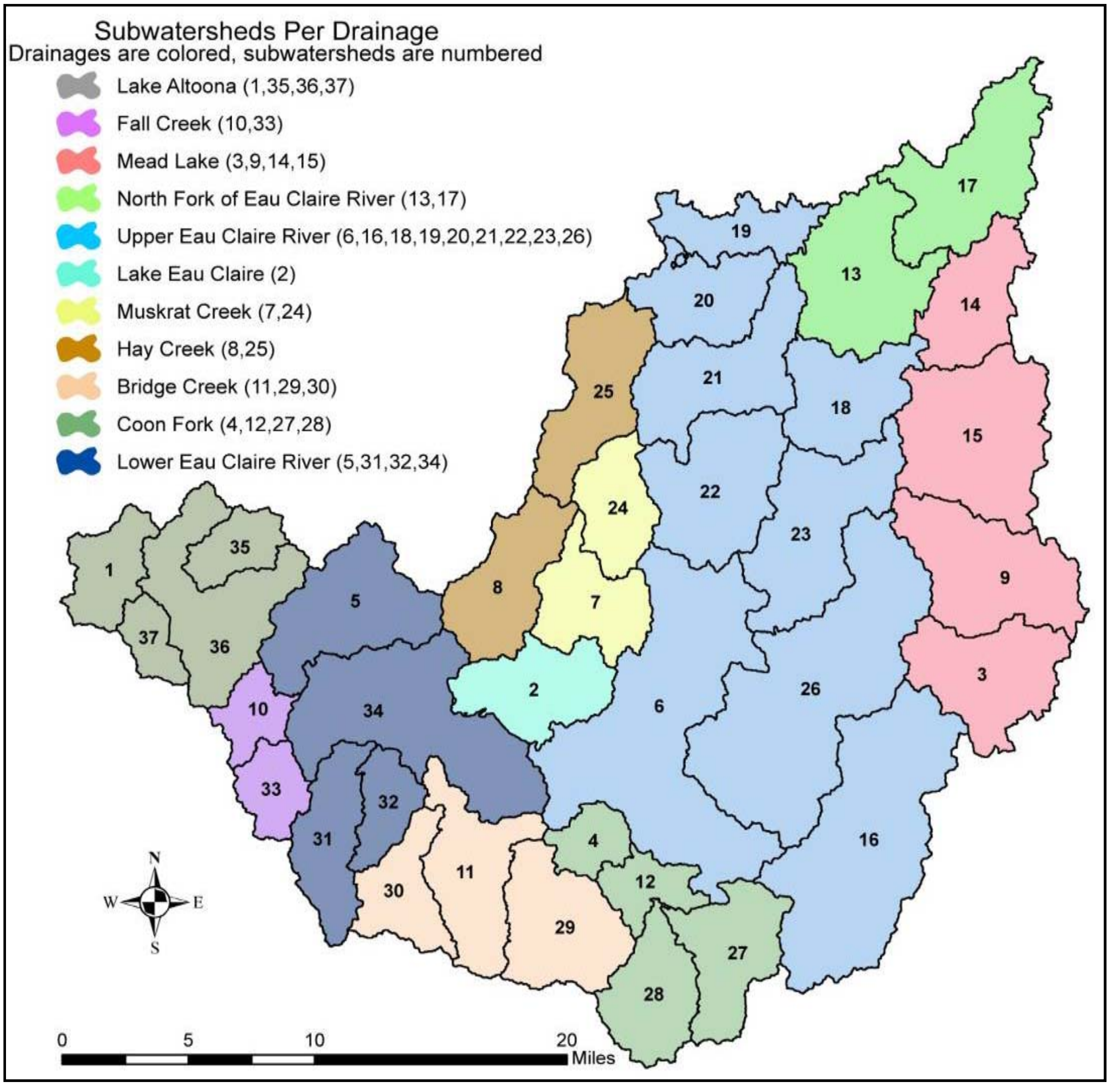

Figure 5 – Modeled Subwatersheds within the Major Drainages of the ECRW

2.3.2 Soils

Soil characteristics, coupled with other landscape factors, are used to determine soil moisture properties and erodibility potential within SWAT. Silt loam, located predominantly in the northern section of the ECRW, is one of the dominant soil textures, consisting of 30% of ECRW. Sand / loamy sand, located in the central section of the ECRW, consists of 40% of the watershed (*Figure 6*). SWAT uses the hydrologic soil group (HSG) to determine the runoff potential of an area (A has the greatest infiltration potential and D is the greatest runoff potential). The ECRW is largely a mixture of the B and C HSG (Figure) with highly permeable A soils within the Eau Claire River valley

(*Figure 7*). The STATSGO soils database created by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) can be used to define soil attributes in SWAT. STATSGO provides a general classification within the ECRW. The ECRW contained 27 STATSGO soil groups. Some of the 27 soil types were grouped together for model calibration based on similar soil properties.

Soil nutrient levels are used as an input for simulating P export from subwatersheds. The University of Wisconsin Soil Testing Laboratories released soil test phosphorus concentrations per Wisconsin county between 2000 and 2004 (UW-Madison Soil and Plant Analysis Lab, 2007). Soil test P is an estimate of the plant available P in the soil and is often used as a measure of labile P in SWAT (Chaubey *et al.* 2006). Average soil test P levels (Bray-1 P) within the ECRW ranged from 40 mg/kg in Clark County to 58 mg/kg in Eau Claire County. Previous research conducted on 517 fields within the Mead Lake watershed in Clark County indicated large variability in soil test P levels (9 to 210 mg/kg)

2.3.3 Hydrologic Network

The stream network is the primary means of surface water and sediment routing. The SWAT model requires a user defined hydrology data set to determine preferred flow paths within the watershed. The Eau Claire River is the primary tributary that contributes discharge to Lake Eau Claire and Lake Altoona. Upstream of the Lake Eau Claire, the Eau Claire River is split into two branches, North and South (*Figure 3*). Multiple secondary tributaries flow into the Eau Claire River or directly into Lakes Eau Claire and Altoona. The secondary tributaries include Norwegian Creek, Rocky Run, Black Creek, Bridge Creek, Fall Creek, Hay Creek, and Muskrat Creek as well as several unnamed creeks. The WDNR 24K hydrography database was used as the hydrology input layer for SWAT. The 24K Hydro layer was processed at double precision to accuracy consistent with national map accuracy standards for 1:24000 scale geographic data.

2.3.4 Closed Depressions

Internally drained (ID) areas are closed depressions that do not contribute overland flow to the stream network as a result of topography. The water draining from these areas only contributes to the subbasin’s water budget in the form of groundwater recharge (baseflow). Frequently the ID areas terminate in disconnected wetlands or small ponds. The ID areas within the ECRW were determined using the ArcGIS extension ArcHydro with a 30-meter DEM and 10-meter vertical threshold to fill topographic sinks. Using a 10-meter threshold, areas that were internally drained were excluded from the watershed delineation. The polygons created from the GIS ID analysis went through a series of quality control steps prior to being accepted. From the GIS derived ID shapefile, Digital Raster Graphics (DRGs) were used to verify the presence of ponds or disconnected wetlands within internally drained areas. A 1000-foot buffered shapefile was created around all streams and all internally drained areas partially or fully within this buffer zone were removed. Approximately 40 percent of the GIS defined internally drained areas were then field verified in the spring and summer, 2007. Field examination was necessary as several ID areas were near the stream network and were interconnected through man-made ditches. Areas in the northern section of the ECRW were relatively flat resulting in possible delineation error related to a 30-meter DEM (*Figure 8*). The results of this analysis suggest approximately 6.3% of the ECRW is internally drained. Of the 6.3% of the land that is ID, 40% of ID is found in the northern subwatersheds (9, 13-15, 17-25). The ID areas were separated by subwatershed to assist in model analysis. In the initial calibration simulations, the internally drained areas were simulated using the pond function, in later calibrations and the final model simulations, the internally drained areas were modeled as separate HRUs without surface runoff (runoff curve number =10).

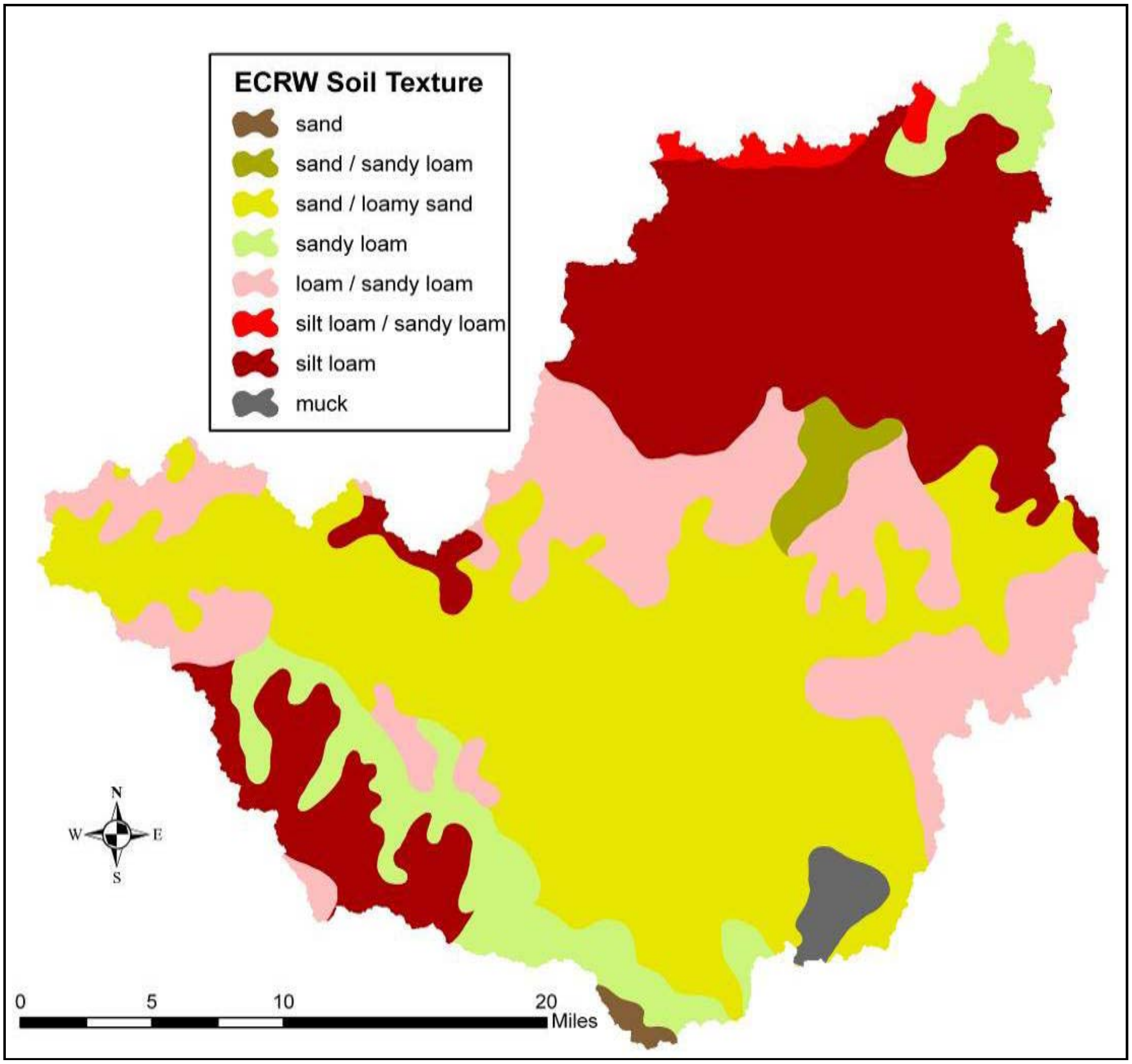

Figure 6 – ECRW Soil Texture Classification

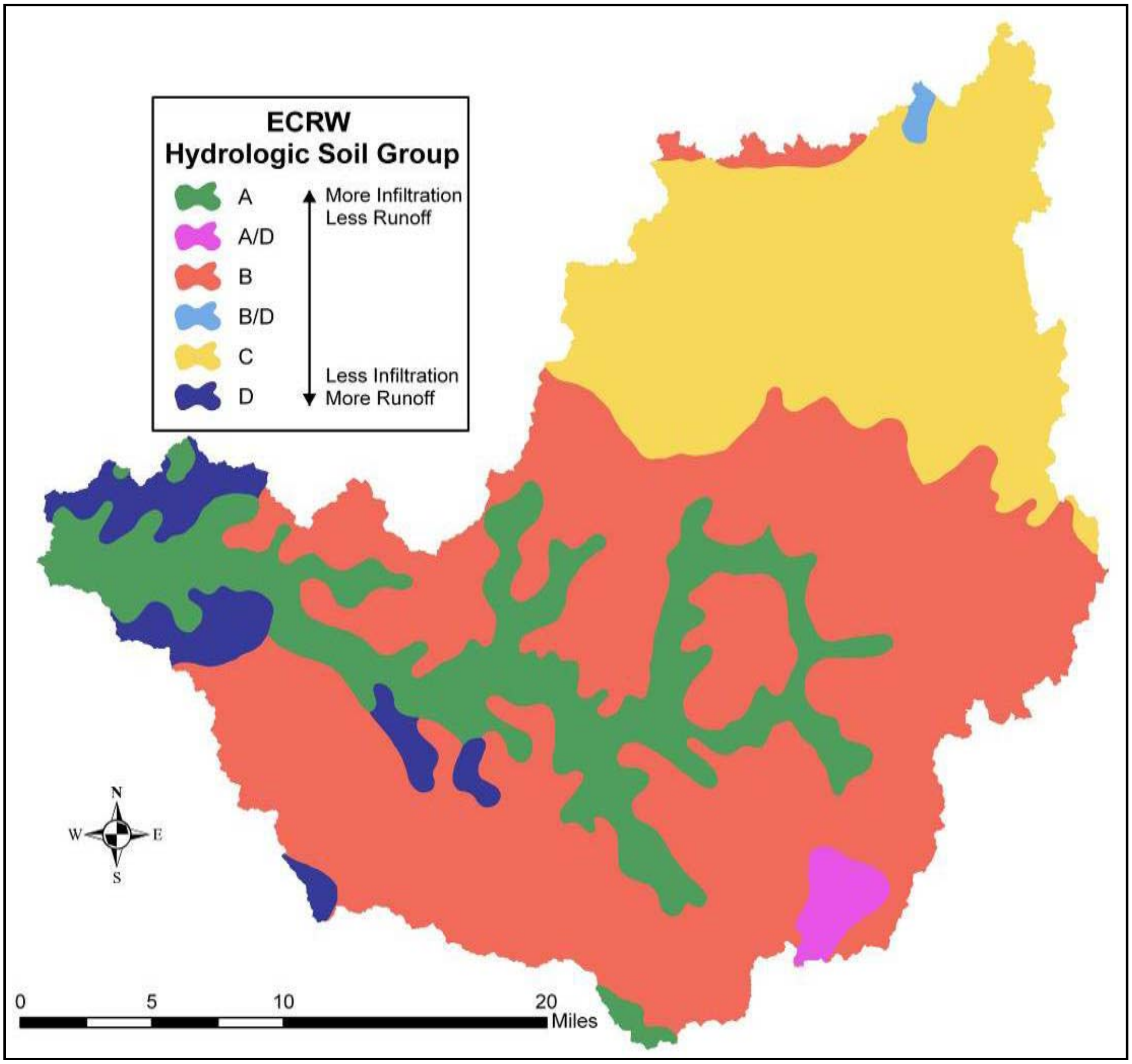

Figure 7 – ECRW HSG Classification

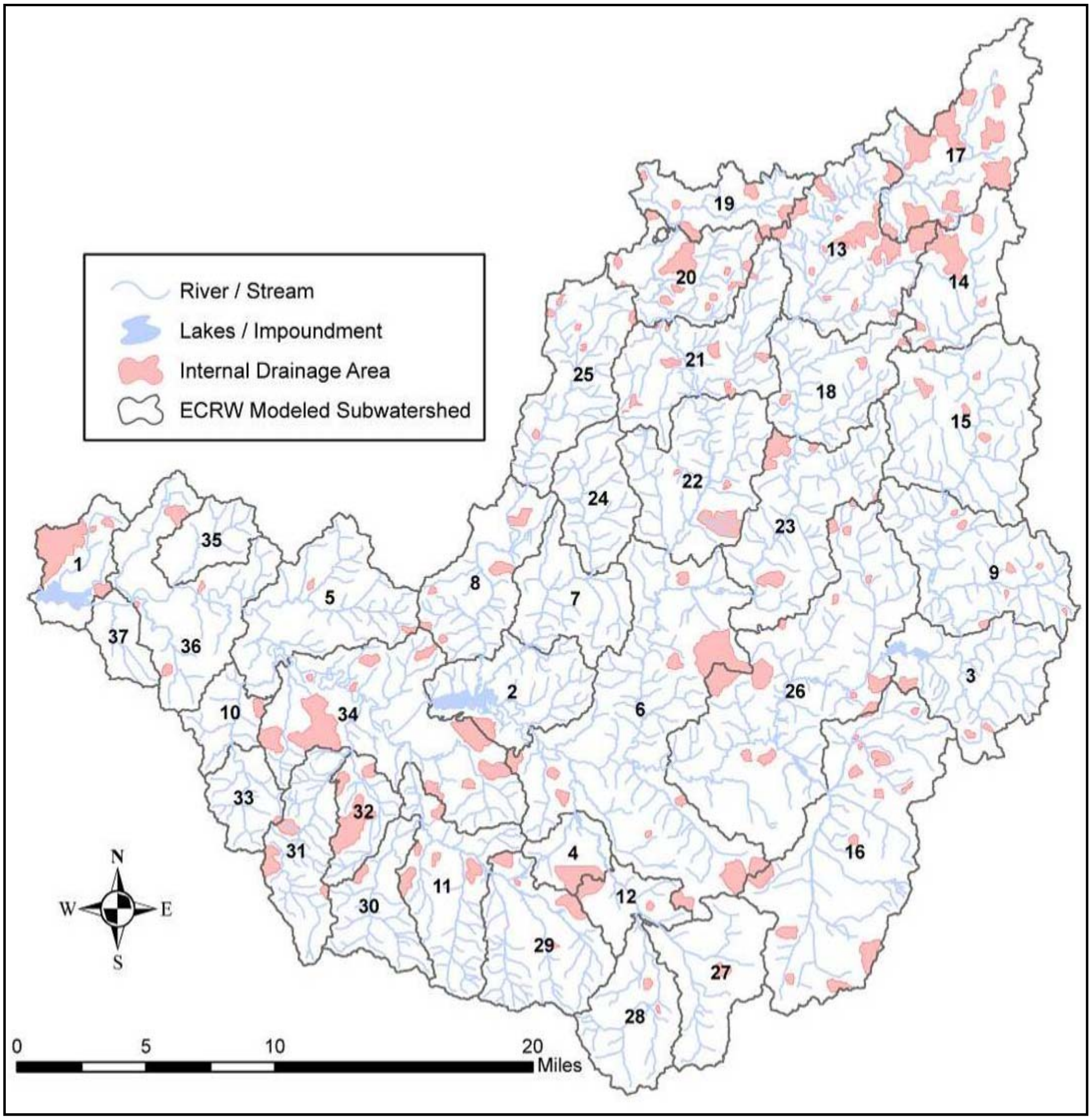

Figure 8 – ECRW Internal Drainage Delineation per Subwatershed

2.3.5 Climate

SWAT can use observed weather data or simulate it using a database of weather statistics from stations across the United States. The use of measured climatological data greatly improves SWAT's ability to reproduce stream hydrographs. Observed daily precipitation and minimum and maximum temperature was used from several weather stations within the Eau Claire River Watershed. Other weather parameters such as solar radiation and wind speed were simulated from a SWAT weather generator database using the closest weather station within the SWAT model's internal database (Neillsville, WI). Historic weather data for 5 monitoring stations was obtained from the National Climatic Data Center (NCDC) (*Figure 9*, *Table 2*). Multiple stations are used for improved weather definition. Each subwatershed uses the individual weather station closest to the subwatershed.

Table 2 - Eau Claire River Watershed Weather Collection Stations and Durations

Station Identification	Climatological Collection Time Period
Eau Claire Regional Airport	10/1949 to 12/2005
Stanley	09/1903 to 11/2005
Fairchild Ranger Station	08/1948 to 08/2002
Owen	07/1946 to 12/2005
Neillsville	01/1893 to 12/2005

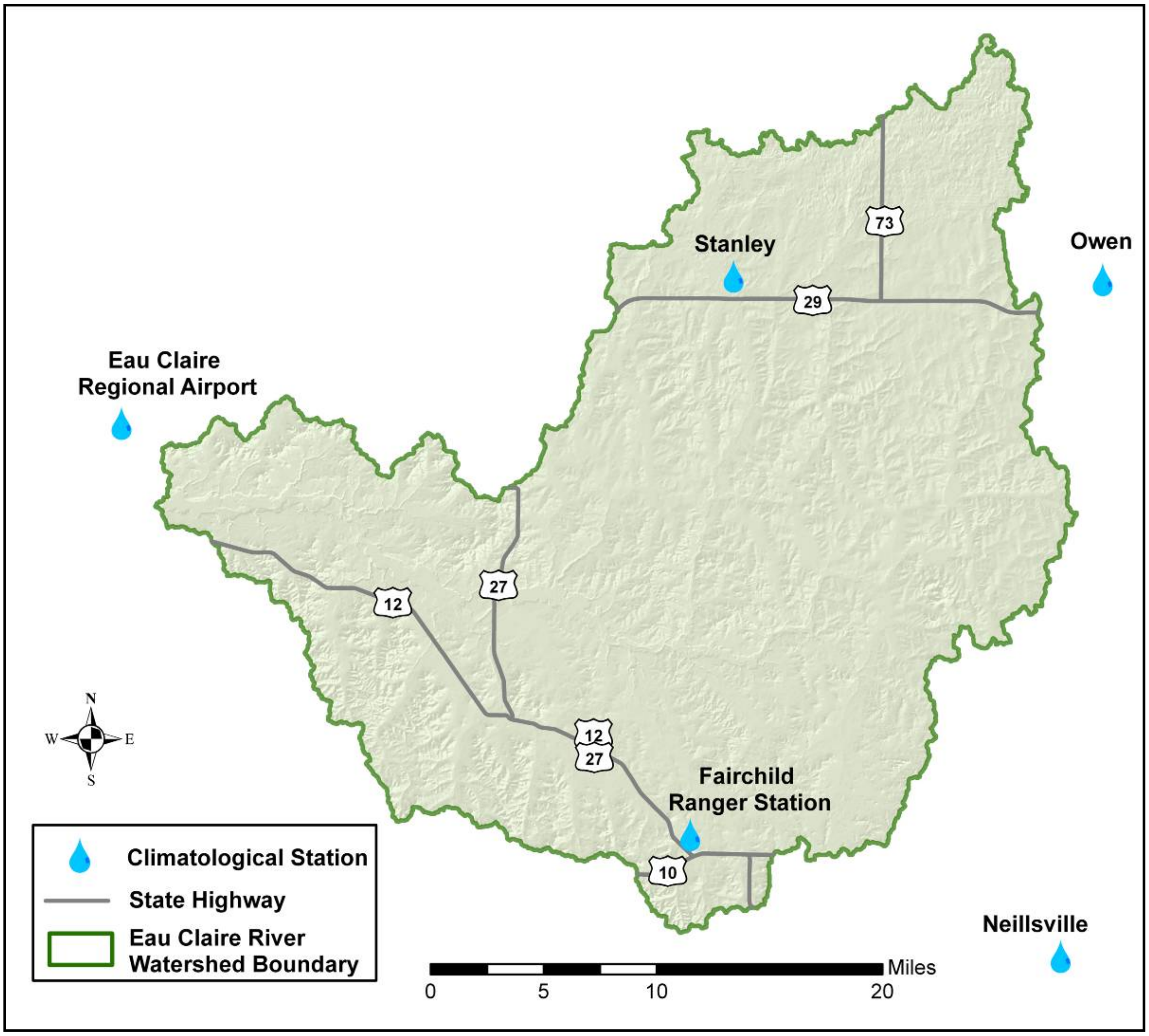

Figure 9 – ECRW Long Term Precipitation Stations

2.3.6 Land Coverage

The ECRW land cover is mixed forest (45%) and agricultural land (31%), with highest percentages of cropped land in the northern and southwestern sections of the watershed (*Figures 10 and 11*, *Table 3*). The current land coverage classification depended on the availability of updated county land delineations. For the modeled land coverage, a modified land coverage GIS layer was developed by merging 2001 Clark County land coverage and a modified version of the WDNR 1992 WISCLAND coverage. Of the five counties within the ECRW, only Clark County (consisting of 41% of the ECRW) had detailed, updated land coverage more current than the 1992 WISCLAND coverage. The 1992 WISCLAND coverage used LANDSAT imagery and the 2001 Clark County coverage was hand digitized from a 1997 aerial photography and verified during a 2001 windshield verification. Refer to Appendix A for land coverage percentages per subwatershed.

Table 3 - Eau Claire River Watershed 2005 Revised Land Coverage

Land Cover	**2006 Landuse Area (Acres)**	**2006 Landuse Percent of Basin**
Cropped Farmland	162,225	31.2
Forest	232,020	44.6
Grassland / Pasture	39,697	7.6
Urban / Impervious	12,291	2.5
Water	4,552	0.9
Wetland	69,301	13.3

The Clark County landuse was categorized into cropped farmland, forested areas, roads, urbanized areas (residential, commercial, etc), and a category for other resource land (ORL). The ORL is land under private ownership including grassland, pasture, wetlands, and upland. The 1992 WISCLAND wetlands layer was merged into the 2001 Clark County land coverage since wetland boundaries were not delineated with the 2001 coverage and the assumption was made that the wetland boundaries did not change considerably between 1992 and 2001. Once the wetland landuse was merged into the 2001 coverage, all remaining ORL was reclassified as grassland / pasture or forest using the 2005 National Agriculture Imagery Program (NAIP) coverage.

For the Eau Claire, Taylor, Chippewa, and Jackson County land coverage the 1992 WISCLAND coverage was modified by overlaying it with 2005 NAIP coverage. The agriculture, grassland, and barren classifications of the 1992 WISCLAND layer were evaluated. In many areas boundary re-delineation and classification was required. These land coverage modifications were time and labor intensive; however, correctly defining the spatial extent of the land coverage is important for evaluating sediment and nutrient contributions to the drainage network.

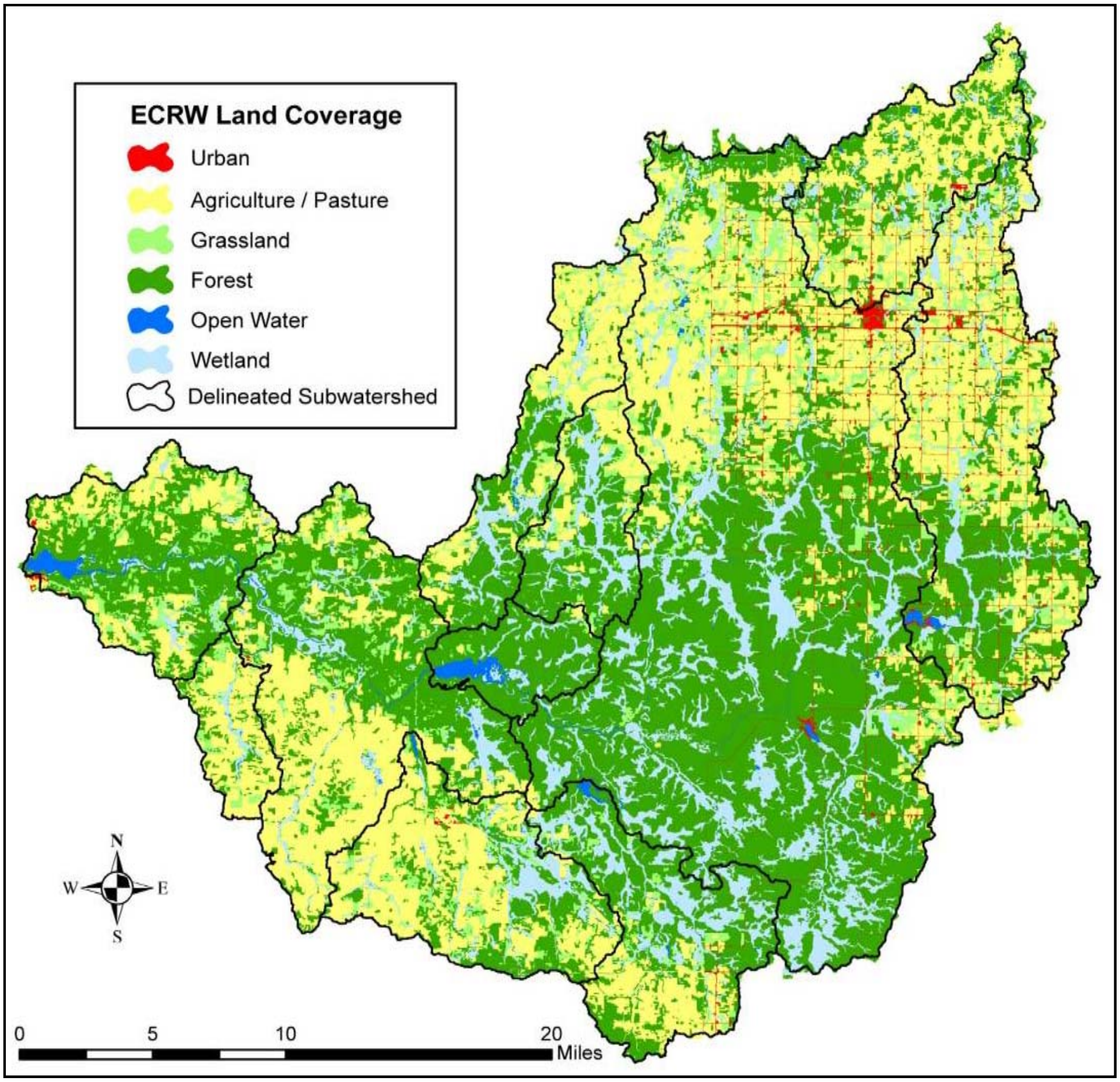

Figure 10 – ECRW Land Coverage Classification per Drainage Area

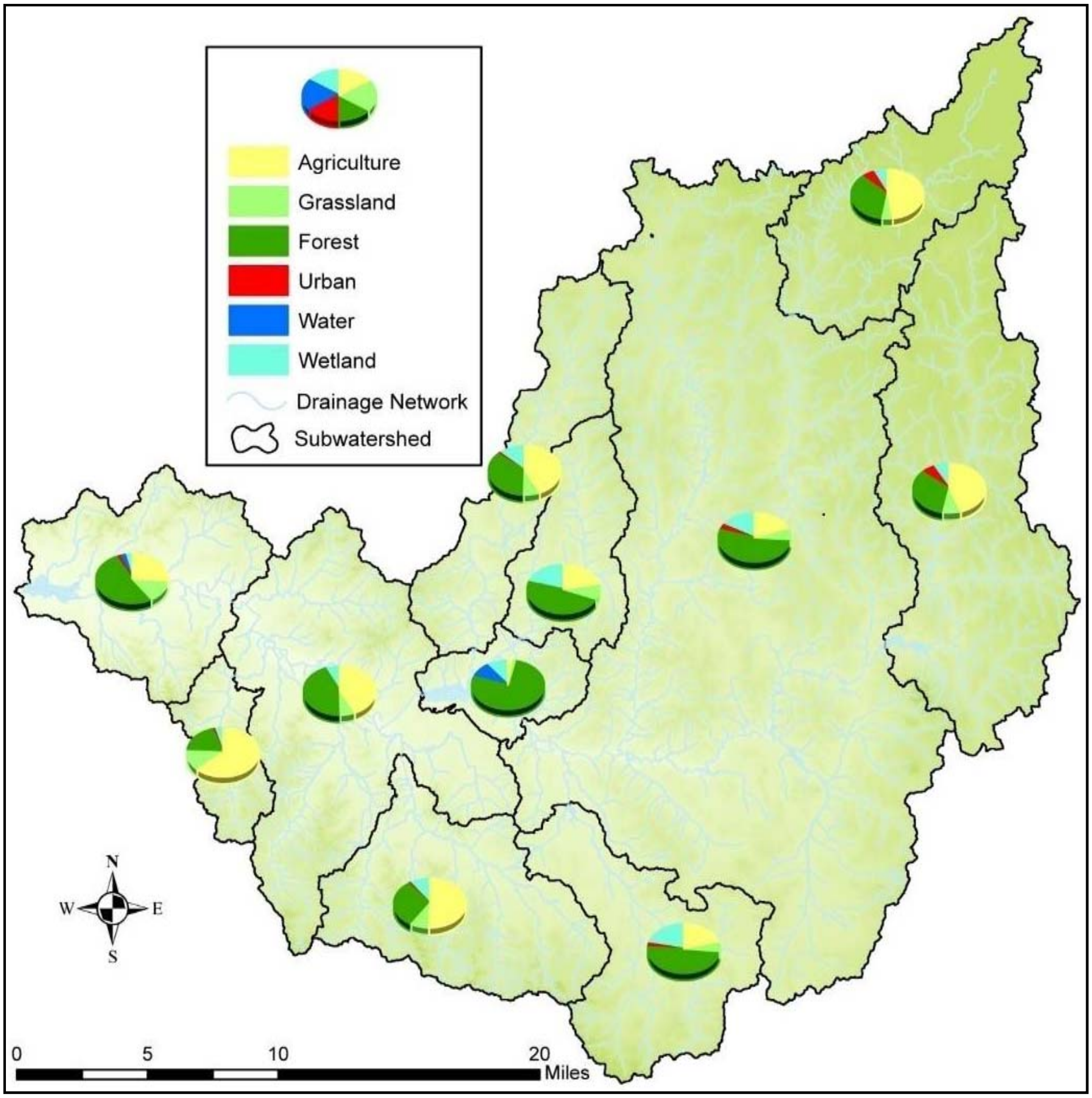

Figure 11 – ECRW Land Coverage Percentages by Drainage Area

2.3.7 Land Management

The land management of the ECRW was assessed using land evaluations completed with Chippewa, Clark, Eau Claire, Jackson, and Taylor Land Conservation departments. Interviews were conducted with individual county Land Conservation personnel and transect surveys were reviewed with Clark and Eau Claire County Land Conservation departments.

Each County Land Conservation Department (CLCD) was given a landuse map for their portion of the watershed. The CLCD worked within their staff to determine and delineate the dominant agricultural management practices based on their knowledge of the area. The agricultural management practices were hand delineated on the map and then entered into GIS for spatial analysis (*Figure 12*). The 1992 WISCLAND land coverage defines all agricultural land as cropped farmland (WISCLAND grid code 110); however, the land coverage was modified so that each cropped farmland polygon had a related management rotation (*Table 4*) assigned to it. The grid code, a numerical value assigned to a landuse in the WDNR 1992 WISCLAND layer, was modified so that each rotation had a unique grid code value. The dominant rotations (those greater than 10% land area within a subwatershed) were used for model simulations.

The spatial land coverage analysis indicated that 162,225 acres (31%) of the ERCW was defined as agricultural. Of those 162,225 acres, 57,702 acres, or 35% of the agricultural land, was within 200 meters of the drainage network. County conservationists indicated approximately 26% of the agricultural land within the watershed was in a dairy rotation (one year corn, one year corn or soybean, one year oats and alfalfa, three 3 years alfalfa) with stored manure.

Transect survey results were also used in the land management mapping. A 1999 transect survey conducted by the Clark CLCD recorded the crops for 1999 within the Mead drainage basin. In 2001, the Eau Claire CLCD conducted a survey that included observation locations within the Fall Creek, Bridge Creek, and Lower Eau Claire River drainage basins. The transect survey points, in conjunction to the CLCD hand drawn management delineations, were used to correlate information related to the management practices into the land management GIS coverage for the ECRW.

The land evaluation, transect surveys, and discussions with the county conservationists from all five counties were used to summarize land and nutrient management. Eight management rotations were developed for MLW simulations.

Each type of management included application rates and types of nutrients. The dairy management rotations were assumed to include 56,043 kg/ha/year of wet manure applied to corn, with a greater amount typically applied in the spring. The Amish rotation (Gridcode 115) incorporated 33,626 kg/ha/year of wet manure. The continuous hay / pasture with grazing included approximately 26,900 kg/ha/year of wet manure. Fertilizers were applied to nearly all of the management rotations. In rotations where manure was not applied, fertilizer was used as the sole nutrient application. Typically, a starter fertilizer such as 09-23-30 or 05-14-42 was applied with planting of corn and soybeans at a rate of 224 kg/ha. A nitrogen based fertilizer such as 46-00-00 was applied in the spring.

Management rotations developed in the SWAT model were based on information from both sources and linked into SWAT using the GIS rotation layer. Refer to Appendix B for detailed management per rotation type.

Measured crop yields were used in combination with SWAT to determine if the model was properly simulating plant growth. Historic annual crop yields (1995-2005) for corn, soybeans, and alfalfa were provided by the National Agriculture Statistical Service (NASS) for each county.

Table 4 - Percentage of Management Practices per Subbasin

		Drainage Basin Percentage and Acreage										
		North Fork – EC River	Mead Lake	Upper EC River	Hay Creek	Muskrat Creek	Lake Eau Claire	Coon Fork	Bridge Creek	Fall Creek	Lower EC River	Lake Altoona
(C-C-C-S-A-A) (111) (Manure Storage)	%	0	2.5	0	0	0	0	0	5.1	0	6.2	0
	Acre	0	686	1	0	0	0	0	925	0	1480	0
(C-S-C-S-C-S) (112) (No Storage / No Manure)	%	0.9	4.0	0.6	2.9	0	0	24.8	2.6	6.5	8.0	0
	Acre	131	1107	256	304	0	0	1668	466	434	1933	2
(C-C-C-A-A-A) (113) (No Manure / No Storage)	%	30.0	28.6	27.1	0	0	0	7.0	0	0	0	0
	Acre	4499	7899	10790	0	0	0	471	0	0	0	0
(C-S-A-A-A-A) (114) (Manure Storage)	%	27.7	52.6	33.9	11.4	11.6	0	22.9	4.5	18.0	5.8	0.8
	Acre	4165	14513	13491	1180	483	0	1542	823	1202	1399	67
(C-A-A-A-C-A) (115) (No Manure Storage)	%	0	10.0	2.0	0	0	0	3.9	43.5	8.7	1.7	0.3
	Acre	0	2767	799	0	0	0	263	7949	580	420	22
(C-C-A-A-A-A) (116) (No Manure Storage)	%	30.1	0	27.1	69.1	74.9	0	19.4	27.9	54.5	49.1	52.1
	Acre	4526	8	10774	7158	3123	0	1302	5103	3640	11822	4615
(C-A-A-A-C-A)(119) (No Manure Storage)	%	0	0	0	0	0	0	4.1	0	0	0	0
	Acre	0	0	0	0	0	0	278	0	0	0	0
Continuous Hay / Pasture (Grazing) (120)	%	11.3	2.3	9.3	16.6	13.5	100	17.9	16.5	12.3	29.1	46.9
	Acre	1699	634	3711	1716	562	182	1201	3017	819	7011	4513

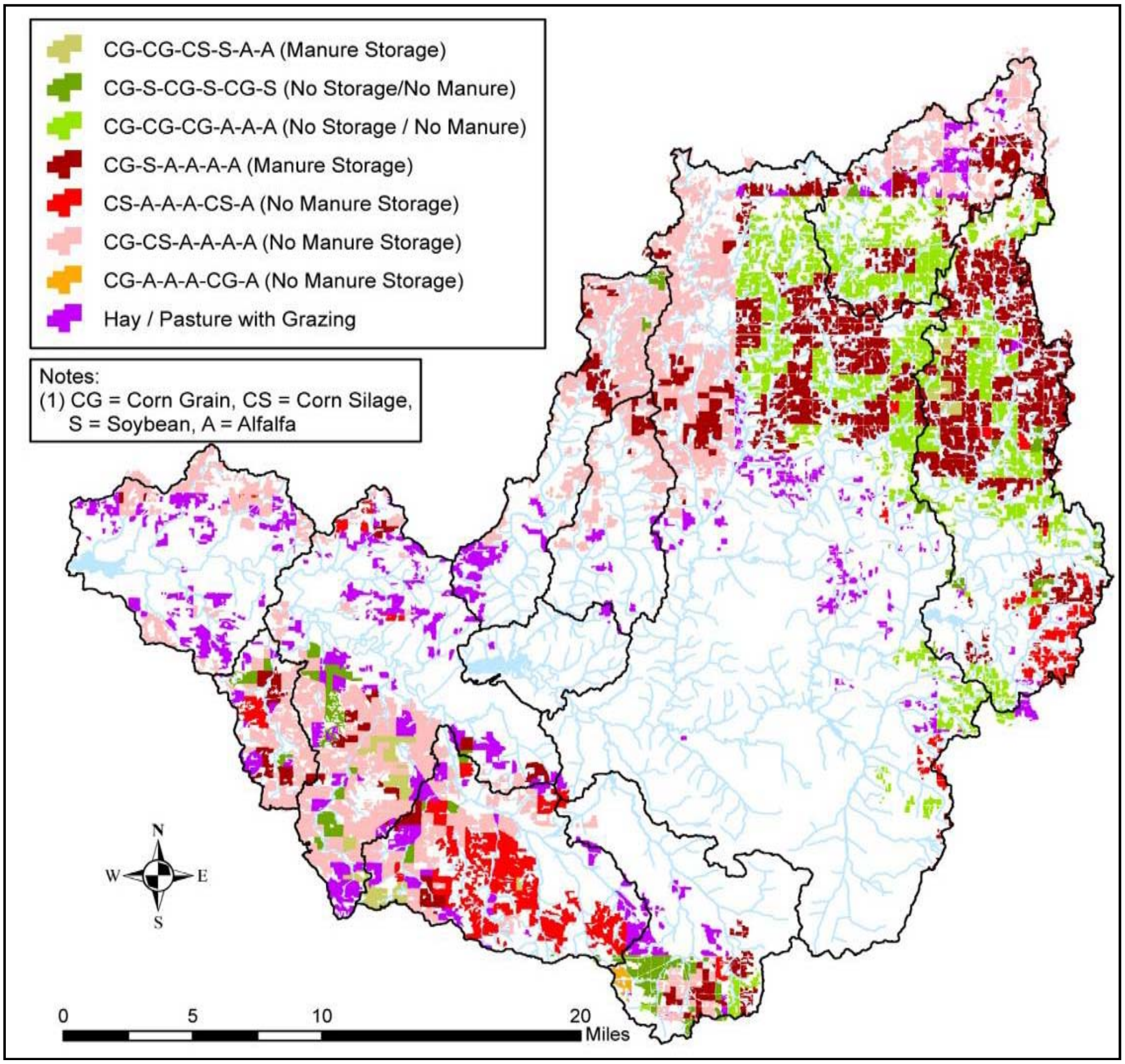

Figure 12 – ECRW Agricultural Land Management Classification

2.4 Calibration

Calibration is the process of matching simulated model results to measured results. Stream discharge, sediment, and nutrient yields were the primary calibration outputs with the SWAT model. The SWAT model allows the user to modify hundreds of input parameters to best simulate the study area. Manual trial and error calibration is the standard approach in calibrating the SWAT model (Van Liew *et al*. 2003, Muleta and Nicklow 2005). The large number of variables makes manual calibration a long, tedious, and subjective process, especially for a complex watershed. A calibration guide created by the SWAT developers directs users to the most sensitive input parameters for flow, sediment, and nutrient simulation (Neitsch *et al.* 2002).

The SWAT model calibration of the ECRW used a parameter estimation tool, the Parameter ESTimation (PEST) software (Doherty 2004). PEST, a freeware tool, can be used with any model by reading a model's input and output files, finding optimum values and sensitivity for each input parameter. PEST allows for a large number of parameters to be fitted from nonlinear models like SWAT. PEST performs iterations using the Gauss-Marquardt-Levenberg algorithm. In addition to the PEST Manual, Lin's (2005) paper "*Getting Started with PEST*" was used for instructional documentation to create the PEST batch file, SWAT model input template files, SWAT model output reading instruction files, and a PEST control file.

Calibration of the ECRW used streamflow measurements and/or measured monthly sediment and phosphorus export for four drainage basins to better understand model calibration for each region. PEST input required the date, measured value, an acceptable input variable range, and current values of the input variables. Previous SWAT model studies were used to identify the parameters to adjust with PEST.

2.5 Statistical Evaluation of SWAT Model

Two statistical measures are typically used in the evaluation of the SWAT model; the coefficient of determination (R^2) and the Nash Sutcliffe coefficient of efficiency (N-S) (Arabi and Govindaraju 2006). The R^2 value is the square of the Pearson's correlation coefficient and ranges from 0 to 1, with a value of 1 representing a perfect correlation between simulated and measured datasets. The N-S has historically been used to evaluate hydrologic models. The N-S values range from negative ∞ to 1, with a value of 1 representing a perfect efficiency between the simulation and measured datasets. The efficiency compares the actual fit to a perfect 1:1 line and measures the correspondence between the measured and simulated flows. Both measures are particularly sensitive to any large differences between observed and simulated values (Krause *et al.* 2005). The R^2 values may be greater than N-S values as individual event outliers tend to have a greater impact on the N-S value (Kirsch *et al*. 2002). Previous studies indicate that N-S values ranging from 0 – 0.33 are considered poor model performance, 0.33 – 0.75 are acceptable values, and 0.75 – 1.0 are considered good (Inamdar 2004; Motovilov *et al*. 1999).

3.0 SWAT Model Simulation

3.1 Subwatershed Calibration

Four subwatersheds within the ECRW were individually calibrated to evaluate parameters and response to the given model inputs. The four subwatersheds evaluated were Coon Fork, Mead Lake, Muskrat Creek, and North Fork of Eau Claire River. All subwatersheds were upstream of Lake Eau Claire. The subwatershed calibrated parameters were then used in the overall calibration of the entire ECRW SWAT model. The calibration of each of the four subwatersheds was completed using similar methodology to simulate discharge, sediment load, and phosphorus load. The same model inputs were applied to each of the model simulations. Each subwatershed relied on staggered agricultural land rotations as shown in Appendix B and model parameter values indicated in Appendix C. The success of calibration is likely dependent on the quality of the measured discharge and water quality data as well as the variation of precipitation across the subwatershed during an event.

To simulate landscape factors for the watershed, discharge was calibrated by adjusting several hydrologic input parameters. Previous studies and observed parameter sensitivities were used to determine the input parameters for calibration. A combination of assigning parameter values based on default and measured values with parameter estimation using the PEST program was used to calibrate the model. The RCNs were maintained at the ratio similar to that in NRCS TR-55 (NRCS, 1985) and similar percentage adjustments were made to all curve numbers in PEST to obtain the best agreement between the observed and simulated daily flow. The model calibration did not use multiple RCN changes within a simulation year and parameter values were limited in how far they were allowed to deviate from default values during calibration. The RCNs were allowed a +/- 20% deviation. In addition to the RCN (SWAT CNOP) other parameters used for hydrologic model calibration were the soil bulk density (SOLBD), soil available water capacity (AWC), soil hydraulic conductivity (SOLK), the evapotranspiration coefficient (ESCO), and groundwater delivery parameters (groundwater delay, alpha baseflow, groundwater revap coefficient, etc). Grouping of soil parameters was part of the model calibration. The soil parameters were first averaged within each soil profile. For example, SOLK may be 1.54 in/hr within the upper 4 inches of subsurface and transition to 2.60, 1.48, and 2.40 in/hr throughout the remainder of the modeled subsurface. For calibration purposes, the values were averaged (2.0 in/hr). The second grouping occurred with soil parameters that were similar because they were within the same HSG.

Sediment and phosphorus concentrations were used to calculate mass loadings on a monthly basis. As previously discussed in Section 2.2.2, the USGS LOADEST program was used to develop mean monthly loads based on the individual water quality and flow measurements. Simulated sediment loss from the reach (metric tons) was totaled from the SED_OUT field in the SWAT main channel output file (.rch). Sediment yield from the HRUs represents a delivered sediment loss because we did not simulate downstream deposition or channel erosion. Sediment load was calibrated using four SWAT input parameters: USLE_P (USLE equation support practice factor), Slope (average slope steepness), APM (peak rate adjustment factor for sediment routing), and FILTERW (sediment trapping efficiency).

The SWAT model simulates P soil input as inorganic P fertilizer, organic P fertilizer, and P tied up in plant residue. During storm events, the P can be transported to the stream reach two ways: organic and mineral P attached to sediment or as soluble P. The phosphorus calibration used the hydrology and sediment calibration with adjustments for groundwater phosphorus concentration, phosphorus partitioning to soil solids, and phosphorus enrichment in the eroded solids. The P related SWAT parameters included modifying five input variables: initial soluble P concentration in soil layer (SOL_LABP), the P soil portioning coefficient (PHOSKD), P availability index (PSP), organic phosphorus enrichment ratio (ERORGP), and groundwater soluble P concentration (GWSOLP). The value of SOL_LABP was determined using a P value based on county average for that subwatershed.

3.1.1 Mead Lake Subwatershed

As part of the USACE Mead Lake assessment (James 2005), average daily stream discharge was calculated for 377 days between 2002 and 2003 at the County Highway MM station. As part of a separate WDNR funded Total Maximum Daily Load (TMDL) study, UWSP completed a SWAT model study for the Mead Lake subwatershed (September 2008) to evaluate sediment and nutrient loss into Mead Lake. The subsequent calibration discussion does not differ in calibration or result from that Mead Lake Watershed Sediment and Nutrient Export Modeling report (Freihoefer and McGinley, 2008).

The SWAT model was calibrated to the 377 days of discharge and model parameter values were adjusted within a small range during calibration. The soil properties (SOLBD, SOLK, and AWC) were allowed +/- 15 percent deviation from the default values used for each soil grouping. In general, AWC retained a value similar to the default range. Three of the four soil groups decreased the calibrated SOLK from the default. This change simulates a more slowly moving soil water. SOLBD increased in value during calibration.

Groundwater parameters were also adjusted to allow for increased baseflow to the Eau Claire River and its tributaries in the PEST calibration. The alpha baseflow (ALPHA_BF), the direct index of groundwater flow response to changes in recharge, was decreased from a default 0.048 days to 0.0095 days using PEST. The groundwater delay was increased from a default 31 days to 255 days. The wetland HRUs were simulated as having a larger evapotranspiration than other land uses.

Overall, SWAT was able to successfully simulate the daily discharge during the 377 non-melt days. The climatic conditions of the MLW in 2002 and 2003 created two extremes in discharge creating challenging conditions for model calibration. Year 2002 was above and 2003 was below average annual rainfall. Simulation of the MLW daily discharge had a R^2 and N-S value of 0.63 and 0.62, respectively. Total simulated discharge was less than one percent greater than the measured. The measured discharges of 2002 and 2003 required PEST to calibrate to an average fit between the two year’s observations points. Individual years yielded slightly different results than the statistical evaluation of the entire measured period. In 2002, the R^2 and N-S values for discharge were 0.58 and 0.52, respectively with an overestimation in discharge of approximately 8%. In 2003, the R^2 and N-S values for discharge were 0.75 and 0.71, respectively with an underestimation in discharge of approximately 8%.

Parameter estimation using PEST was used to identify values for the sediment calibration. The USLE_P value (.mgt) was decreased for agricultural HRUs from a default value of 1.00 to 0.50. Decreasing the USLE_P from the default decreases the amount of sediment transported from the landscape. The USLE_P parameter was the most sensitive of all sediment calibration parameters used with PEST, indicated by relative sensitivity value in the PEST output. The APM (.bsn) parameter was decreased from a default 1.00 to 0.64 to dampen the simulated flashy response from storm events in the watershed. FILTERW was used to trap a portion of the sediment on the landscape and served to simulate the loss of sediment during delivery between individual fields and the stream reach.

The objective of the calibration was to find the best parameter combination for simulating all the monthly sediment loads. We found that several months in particular were difficult to calibrate. Because there is uncertainty in the monthly sediment loads estimates from the USGS LOADEST estimating, we sought to minimize the overall difference between sediment totals on an annual basis and visually sought to match the monthly totals as closely as possible. The SWAT simulation of the eleven months of measured sediment load resulted in R^2 and N-S values of 0.54 and 0.49, respectively. The calibration period yielded a five metric ton underestimation of sediment (0.6% error). The greatest variability in calibrated values occurred during 2002 when above normal precipitation occurred.

The phosphorus calibration used the hydrology and sediment calibration with adjustments for groundwater phosphorus concentration, phosphorus partitioning to soil solids, and phosphorus enrichment in the eroded solids. The P related SWAT parameters included modifying six input variables: initial soluble P concentration in soil layer (SOL_LABP), the P soil portioning coefficient (PHOSKD), P availability index (PSP), the P uptake distribution parameter (UBP), organic phosphorus enrichment ratio (ERORGP), and groundwater soluble P concentration (GWSOLP). The value of

SOL_LABP was determined using the average P value from the soil P measurements within each subwatershed. A value of 20 m^3/kg was used for PHOSKD rather than the default of 175 m^3/kg to reflect lower phosphorus partitioning between solid and solution in the soil. This adjustment was necessary to increase the soluble P quantity in the runoff. Because we used the filter option to trap sediment in the watershed and that also removes soluble P, the change in the PHOSKD was based on matching the relationship between MINP (which is largely the SWAT's soluble P) and the total P in the runoff. The simulation did not include stream processes, so this represents the phosphorus delivered. The PSP was decreased from a default of 0.40 to 0.30. The PSP specifies the fraction of fertilizer P which is in solution after an incubation period. The P uptake distribution parameter (UBP) was decreased to allow for additional P to remain on the landscape.

The groundwater phosphorus was estimated based on observations of low-flow phosphorus concentrations in the stream. A groundwater P concentration of 0.08 mg/L was used to match the stream concentrations. The phosphorus enrichment of eroded solids (ERORGP) is estimated in SWAT based on the suspended solids concentration in the runoff. One of the difficulties with this relationship in SWAT is that when relatively high solids concentrations are generated during event days, the enrichment factor can be quite low. To better approximate the observed enrichment, an enrichment factor of 10 was fixed. This does not allow higher enrichment factors on low suspended solids events, but this increased the phosphorus export consistent with the observed export.

Similar to the sediment calibration, the phosphorus calibration illustrated greater variability in 2002 than in 2003. The SWAT simulation of the eleven months of measured phosphorus resulted in R^2 and N-S values of 0.66 and 0.66, respectively. The calibration period simulation underestimated total phosphorus by 161 lbs (1.1% error).

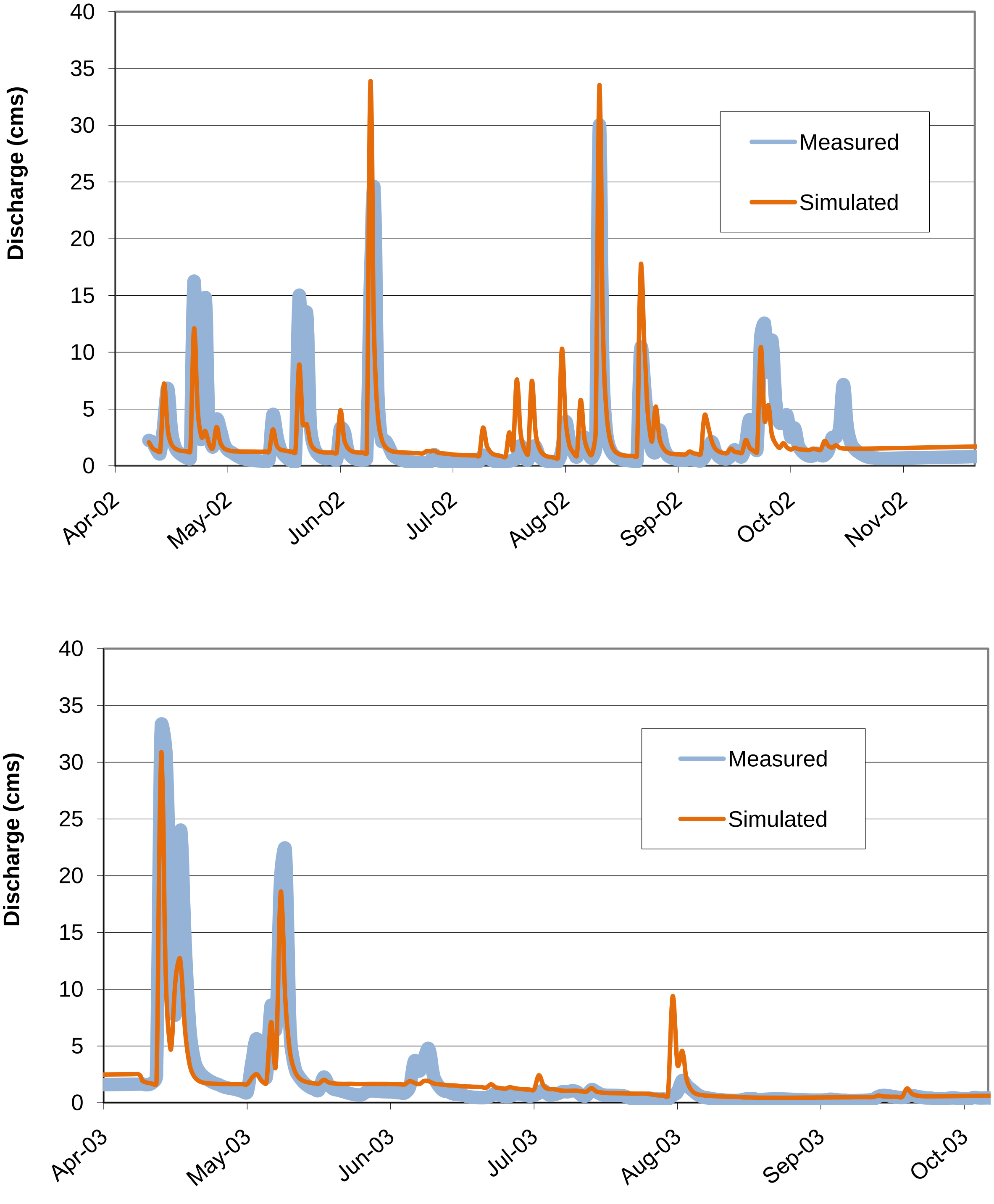

Figure 13 – Mead Lake Subwatershed Discharge Calibration

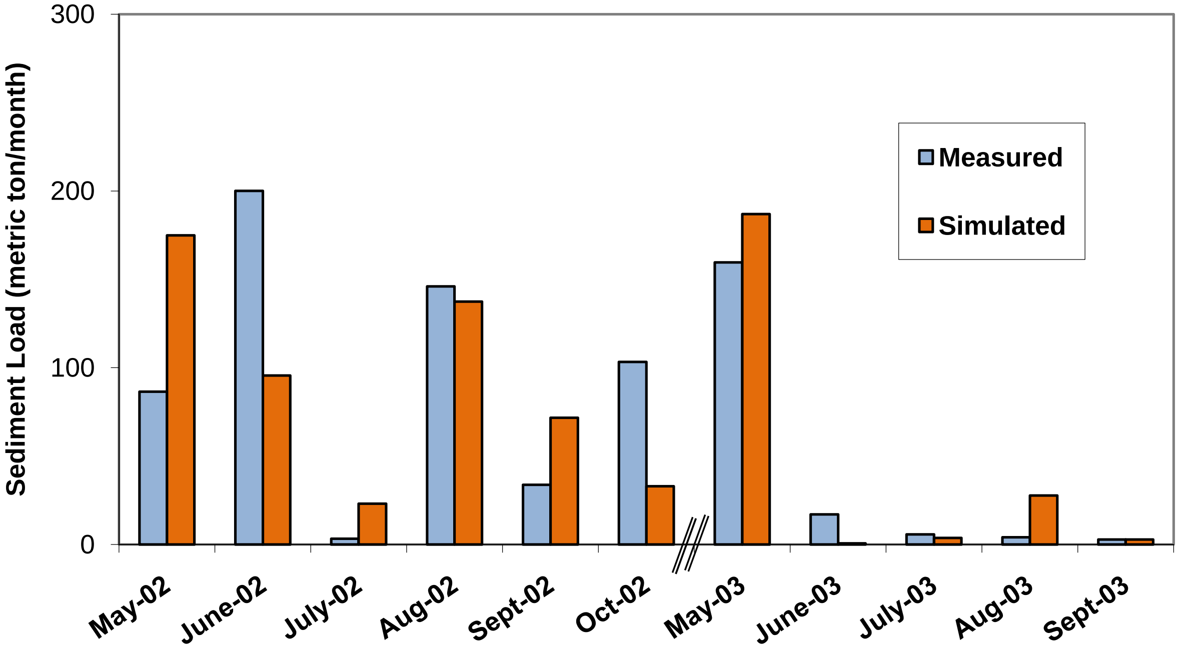

Figure 14 – Mead Lake Subwatershed Sediment Calibration

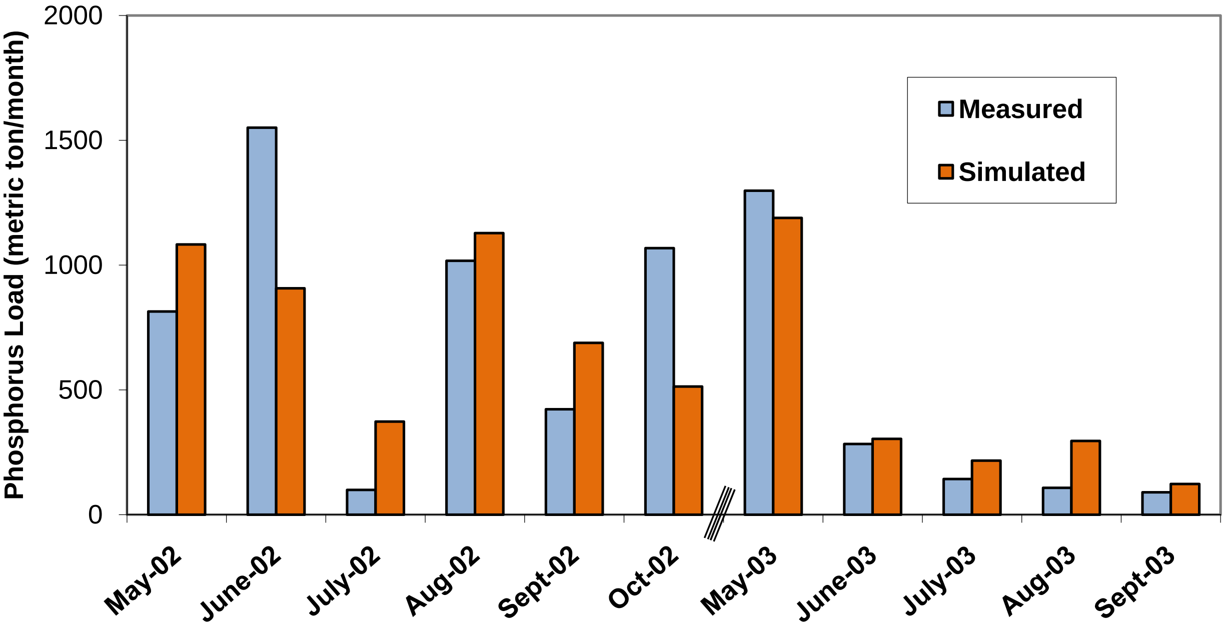

Figure 15 – Mead Lake Subwatershed Phosphorus Calibration

3.1.2 Coon Fork Lake Subwatershed

The Coon Fork Lake Watershed (CFLW) drains approximately 47 mi^2 of mixed landuse before reaching Coon Fork Lake. Coon Fork Lake is a 75 acre impoundment with a retention time typically between 7 to 13 days (Clark County 2004). The subwatershed is located in the southeastern section of the ECRW and includes portions of Eau Claire, Jackson, and Clark counties. The WDNR previously conducted a one-year water quality study for the CFLW. The study consisted of measuring average daily flow at the Coon Fork Lake dam outlet between May 19 and September 15, 1997. Eighteen TSS and TP measurements along with a corresponding instantaneous flow measurement were collected upstream of Coon Fork Lake on Black Creek at Hwy M during the 1997 growing season.

As part of the WDNR Coon Fork Lake assessment (Panuska 1997), average daily stream discharge was measured for 120 days during the 1997 growing season at the Highway M station. The measured discharge includes groundwater and surface water contributions from the watershed.

The calibration of discharge within the CFLW required that some parameters were grouped together for PEST analysis. The calibration of the CNOP used two separate values per land use. The first group consisted of HRUs with soils in the HSG A (Soil IDs 48 and 54). The second group consisted of HRUs with soils in the HSG B (Soil IDs 56 and 62). The PEST calibration used two soil groups, based on similar soil properties, for calibration of SOLBD, SOLK, and AWC. The two groups were WI 48 and 54, and WI 56 and 62.

In general, AWC retained a value similar to the default range. Both groups decreased the calibrated SOLK from the default. This change reflects a larger retention of soil water. SOLBD decreased from the default to the calibrated value. Groundwater parameters were also adjusted to allow for increased baseflow to the Eau Claire River and its tributaries in the PEST calibration. The alpha baseflow (ALPHA_BF), the direct index of groundwater flow response to changes in recharge, was decreased from a default 0.048 days to 0.015 days using PEST. The groundwater delay was increased from a default 31 days to 292 days. The wetland HRUs were simulated as having a larger evapotranspiration than other land uses.

Overall, SWAT was able to satisfactorily simulate the daily discharge during the 120 non-melt days. Simulation of the CFLW daily discharge had a R^2 and N-S value of 0.08 and -0.70, respectively. Although the simulation statistics were poor, the total simulated discharge was less than five percent greater than the measured and the model reproduced many of the storm events.

Parameter estimation using PEST was used to identify values for the sediment calibration. The USLE_P value (.mgt) was decreased for agricultural HRUs from a default value of 1.00 to 0.50. Decreasing the USLE_P from the default decreases the amount of sediment transported from the landscape. The USLE_P parameter was the most sensitive of all sediment calibration parameters used with PEST, indicated by relative sensitivity value in the PEST output. The APM (.bsn) parameter was decreased from a default 1.00 to 0.80 to dampen the simulated flashy response from storm events in the watershed. FILTERW was used to trap a portion of the sediment on the landscape and served to simulate the loss of sediment during delivery between individual fields and the stream reach.

The objective of the calibration was to find the best parameter combination for simulating all the monthly sediment loads. As a result of the uncertainty in the monthly sediment loads estimates from the USGS LOADEST estimating, calibration sought to minimize the overall difference between sediment totals on an annual basis and visually sought to match the monthly totals as closely as possible. The SWAT simulation of the six months of measured sediment load resulted in R^2 and N-S values of 0.00 and -6.36, respectively. The calibration period simulation overestimated sediment by 5.54 metric tons (2.9% error). The first three months of the calibration period underestimated sediment load, while the latter three months overestimated sediment.

During storm events, the P can be transported to the stream reach in two ways: organic and mineral P attached to sediment or as soluble P. The phosphorus calibration used the hydrology and sediment calibration with adjustments for groundwater phosphorus concentration, phosphorus partitioning to soil solids, and phosphorus enrichment in the eroded solids. The P related SWAT parameters included modifying five input variables: initial soluble P concentration in soil layer (SOL_LABP), the P soil portioning coefficient (PHOSKD), P availability index (PSP), organic phosphorus enrichment ratio (ERORGP), and groundwater soluble P concentration (GWSOLP). The value of SOL_LABP was determined using an average soil test P for the county that included the subwatershed. A value of 75 m^3/kg was used for PHOSKD rather than the default of 175 m^3/kg, reflecting lower phosphorus partitioning between solid and solution in the soil and increasing the soluble P quantity in the runoff. Because we used the filter option to trap sediment in the watershed and that also removes soluble P, the change in the PHOSKD was based on matching the relationship between MINP (which is largely the SWAT's soluble P) and the total P in the runoff. Similar to the other subwatershed simulations, the modeling did not include stream processes, so this represents the phosphorus delivered. The PSP was increased from a default of 0.40 to 0.65. The PSP specifies the fraction of fertilizer P which is in solution after an incubation period.

The groundwater phosphorus was estimated based on observations of low-flow phosphorus concentrations in the stream. A groundwater P concentration of 0.08 mg/L was used to match the stream concentrations. The phosphorus enrichment of eroded solids (ERORGP) is estimated in SWAT based on the suspended solids concentration in the runoff. To better approximate the observed enrichment, an enrichment factor of 10 was fixed. This does not allow higher enrichment factors on low suspended solids events, but this increased the phosphorus export consistent with the observed export.

Similar to the sediment calibration, the phosphorus calibration proved difficult as a result of limited data and a variable trend in over and underestimating export. The SWAT simulation of the six months of measured phosphorus load resulted in R^2 and N-S values of 0.01 and -2.40, respectively. The calibrated model underestimated the total phosphorus by 5.4% (80 kg).

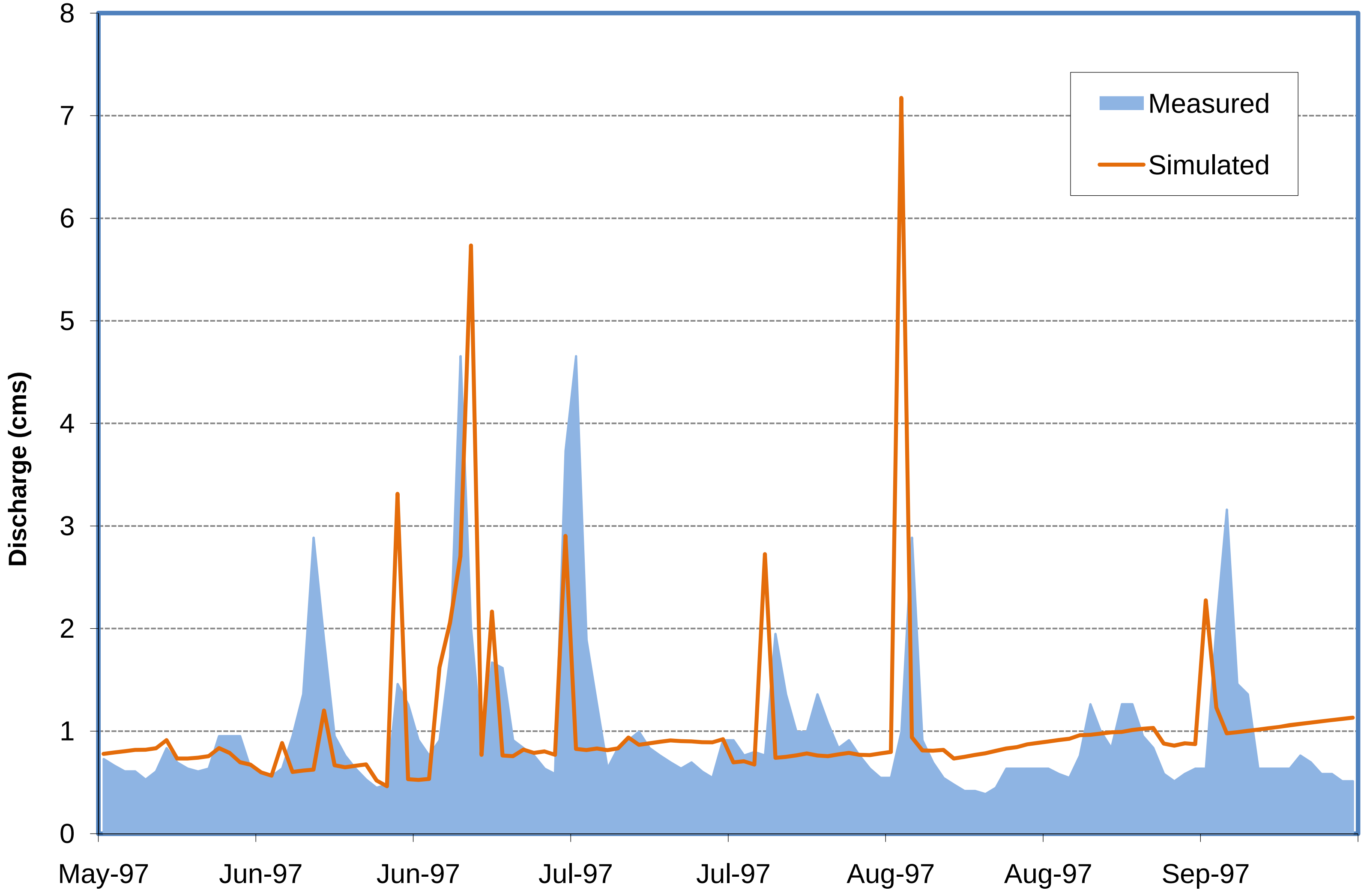

Figure 16 - Coon Fork Lake Subwatershed Discharge Calibration

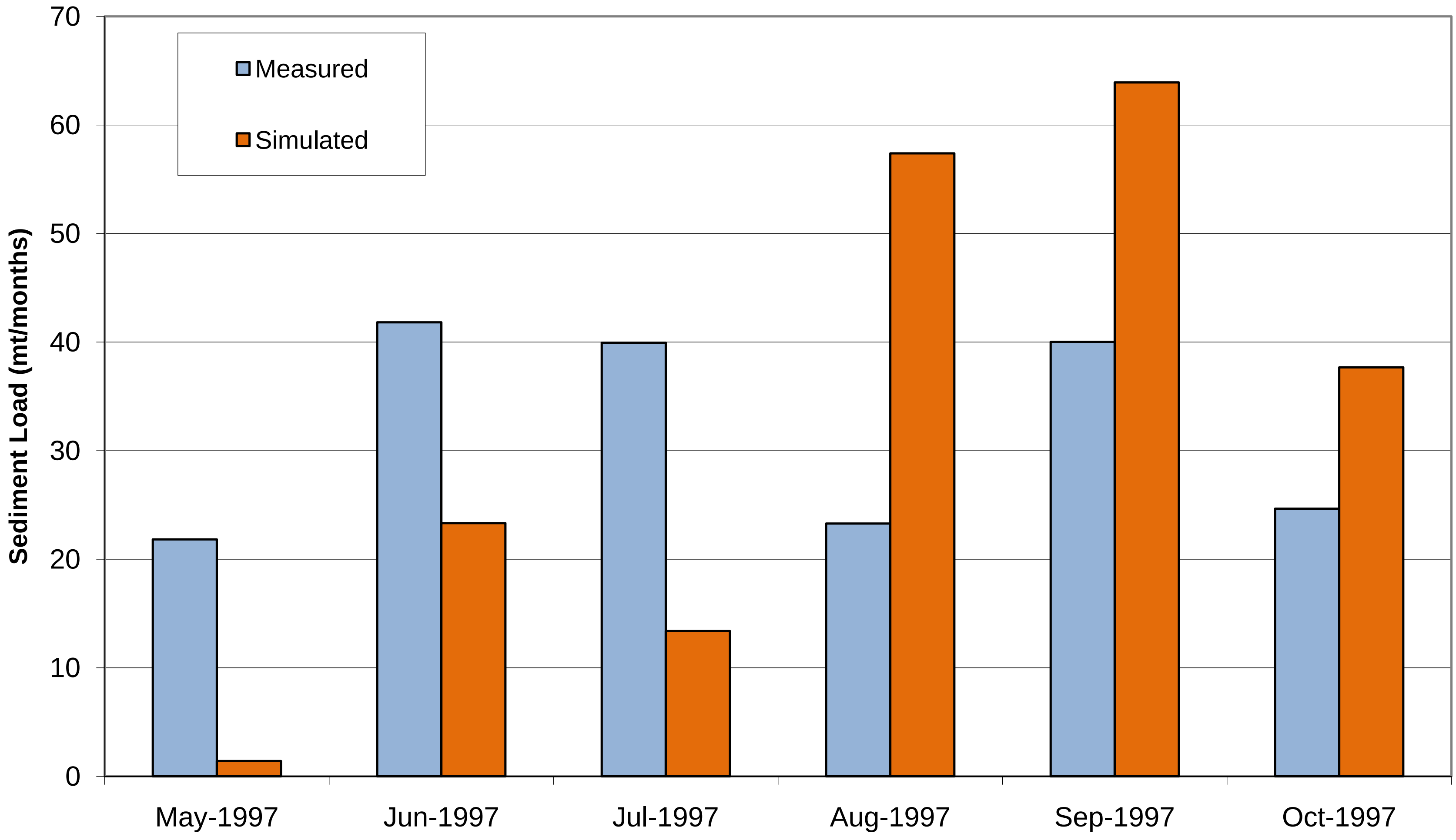

Figure 17 – Coon Fork Lake Subwatershed Sediment Calibration

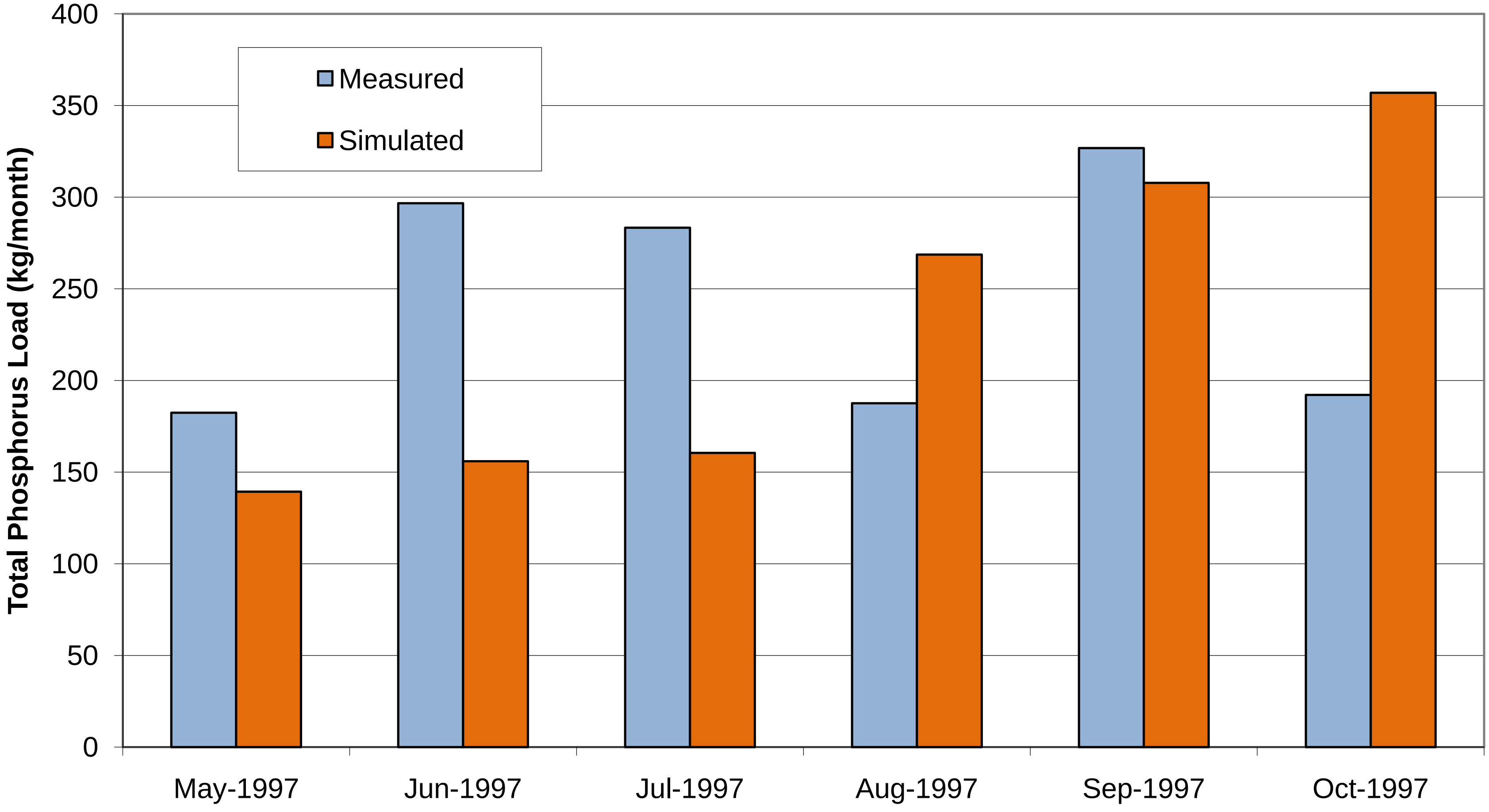

Figure 18 – Coon Fork Lake Subwatershed Phosphorus Calibration

3.1.3 North Fork of Eau Claire River Subwatershed

The North Fork of the Eau Claire River subwatershed is a 51 mi^2 watershed with mixed landuse. The subwatershed is delineated from the USGS discharge gauge (Station 05365707) located 2.5 miles northwest of Thorp, Wisconsin. Between April 1986 and December 2003 mean daily discharge was collected at the site. The North Fork subwatershed represents the most complete discharge dataset that exists within the ECRW, but water quality samples were not collected.

As part of a USGS basin evaluation, average daily stream discharge was measured for 6,484 days and included groundwater and surface water contributions from the watershed. The calibration of discharge within the North Fork required that some parameters were grouped together for PEST analysis. The calibration of the CNOP used two separate values per land use. The first group consisted of HRUs with soils in the HSG B (Soil IDs 13, 20, and 25). The second group consisted of HRUs with soils in the HSG C (Soil IDs 15 and 26). The PEST calibration used the same two soil groupings, based on similar soil properties, for calibration of SOLBD, SOLK, and AWC.

In general, AWC retained a value similar to the default range of 0.09 to 0.18 mm/mm. An increase in the AWC would simulate greater infiltration. Both soil groups were modeled with SOLK values similar to the default values for those soils. Groundwater parameters were also adjusted to allow for increased baseflow to the Eau Claire River and its tributaries in the PEST calibration. The alpha baseflow (ALPHA_BF), the direct index of groundwater flow response to changes in recharge, was decreased from a default 0.048 days to 0.002 days using PEST. The groundwater delay was increased from a default 31 days to 222 days. The wetland HRUs were simulated as having a larger evapotranspiration than other land uses. This simulation was calibrated to year-round measurements and snow melt parameters were also adjusted during the calibration period.

Overall, SWAT was able to satisfactorily simulate the daily discharge during the 6,484 days. Simulation of the North Fork daily discharge had a R^2 and N-S value of 0.54 and 0.52, respectively. The total simulated discharge was less than twelve percent less than the measured and the model reproduced many of the storm events.

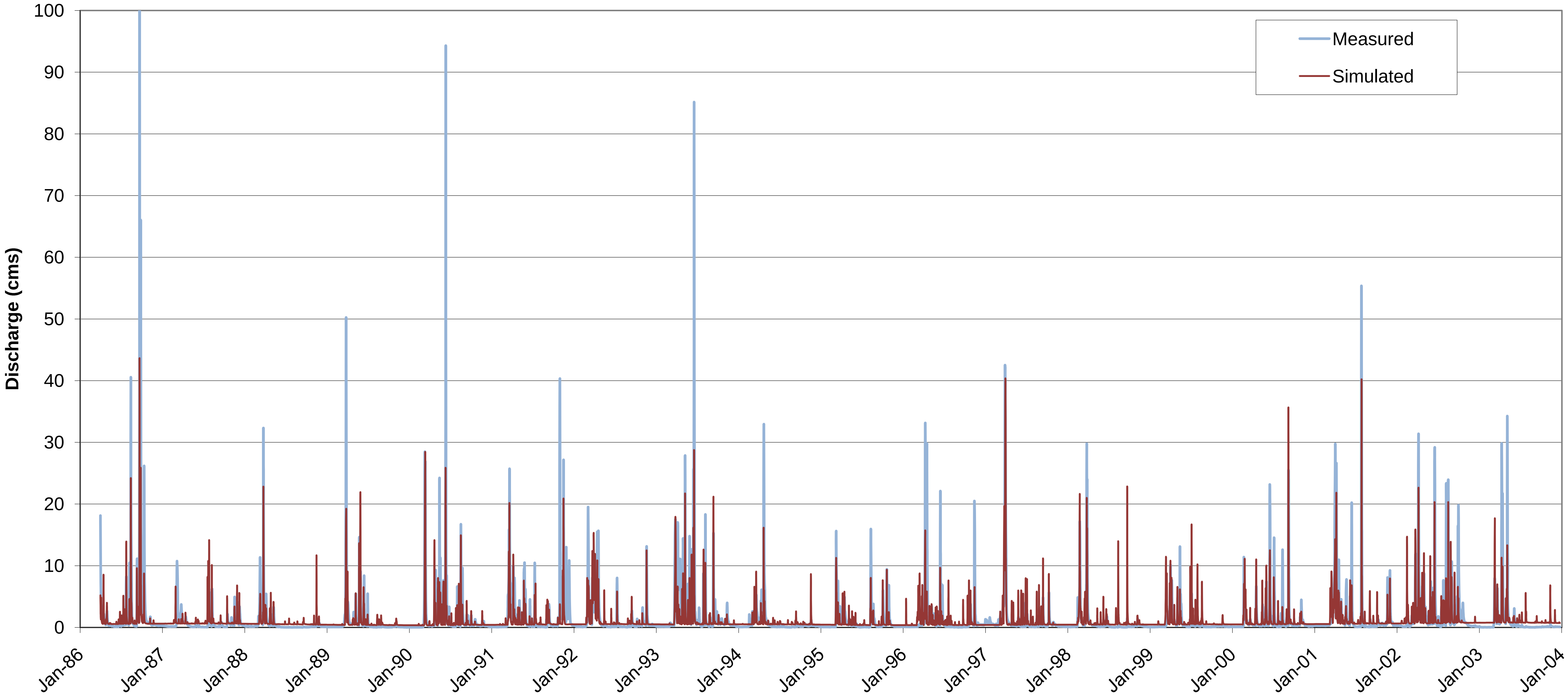

Figure 19 – North Fork of Eau Claire River Subwatershed Discharge Calibration

3.1.4 Muskrat Creek Subwatershed

As part of the USACE Lake Eau Claire assessment (James *et al.* 1999), average daily stream discharge was measured for 246 days between February and October 1998 at Stoney Lonesome Road in northwestern Eau Claire County. Total phosphorus was measured on 52 separate occasions during the 1998 period. Muskrat Creek subwatershed, north of Lake Eau Claire, is a direct tributary to the lake and is similar to the neighboring Hay Creek subwatershed. From its measurement station, 30 mi^2 of mixed landuse contributes discharge to Muskrat Creek before draining into Lake Eau Claire.

The SWAT model was calibrated to the 246 days of measured discharge and model parameter values were adjusted within a small range during calibration. The RCN's were split into 4 groups for calibration and calibrated within +/- 20% of the recommended default RCN. The soil properties (SOLBD, SOLK, and AWC) were allowed +/- 15 percent deviation from the default values used for each soil grouping. In general, AWC retained a value similar to the default range. The large range of AWC is expected as a result of the variations of HSG within the subwatershed. Two of the four soil groups had decreased SOLK after calibration compared to the default. This change reflects a larger retention of soil water. SOLBD increased in three of the four calibrated soil groups from the default to the calibrated value.

Groundwater parameters were also adjusted to allow for increased baseflow to the Eau Claire River and its tributaries in the PEST calibration. The alpha baseflow (ALPHA_BF), the direct index of groundwater flow response to changes in recharge, was decreased from a default 0.048 days to 0.0001 days using PEST. The groundwater delay was increased from a default 31 days to 223 days. The wetland HRUs were simulated as having a larger evapotranspiration than other land uses. As a result of having winter / spring measurements, snow melt parameters were also adjusted during the calibration period.

Overall, SWAT was able to successfully simulate the daily discharge during the 246 days. The single year of measurement and baseflow dominated nature of Muskrat Creek made this subwatershed difficult to calibrate. Simulation of the Muskrat Creek daily discharge had a R^2 and N-S value of 0.86 and 0.86, respectively. Total simulated discharge was less than three percent less than the measured.

The phosphorus calibration used the hydrology and sediment calibration with adjustments for P uptake, P availability, and the soils portioning of P. The P related SWAT parameters included modifying six input variables: initial soluble P concentration in soil layer (SOL_LABP), the P soil portioning coefficient (PHOSKD), P availability index (PSP), and the P uptake distribution parameter (UBP). The value of SOL_LABP was determined using the average P value within each subwatershed field was used in the model simulation since multiple fields may represent a single HRU. Similar to other subwatersheds, the PHOSKD was adjusted to a lower value (20 m^3/kg in this case) rather than the default of 175 m^3/kg to reflect lower phosphorus partitioning between solid and solution in the soil. This adjustment increase the soluble P quantity in the runoff and more closely matched the measured results. Because we used the filter option to trap sediment in the watershed and that also removes soluble P, the change in the PHOSKD was based on matching the relationship between MINP (SWAT's soluble P) and the total P in the runoff. The simulation did not include stream processes, so this represents the phosphorus delivered. The the fraction of fertilizer P which is in solution after an incubation period, the PSP, was decreased from a default of 0.40 to 0.30. The P uptake distribution parameter (UBP) was decreased to allow for additional P to remain on the landscape.

The groundwater phosphorus was estimated based on observations of low-flow phosphorus concentrations in the stream. A groundwater P concentration of 0.08 mg/L was used to match the stream concentrations. The phosphorus enrichment of eroded solids (ERORGP) is estimated in SWAT based on the suspended solids concentration in the runoff. One of the difficulties with this relationship in SWAT is that when relatively high solids concentrations are generated during event days, the enrichment factor can be quite low. To better approximate the observed enrichment, an enrichment factor of 10 was fixed. This does not allow higher enrichment factors on low suspended solids events, but this increased the phosphorus export consistent with the observed export.

Similar to the sediment calibration, the phosphorus calibration illustrated greater variability in 2002 then 2003. The SWAT simulation of the eleven months of measured phosphorus load resulted in R^2 and N-S values of 0.87 and 0.34, respectively. The calibration period yielded a 1630 kg overestimation of total phosphorus (73.5% error). Much of the discrepancy occurred during the month of March, when the TP was overestimated by 720 kg.

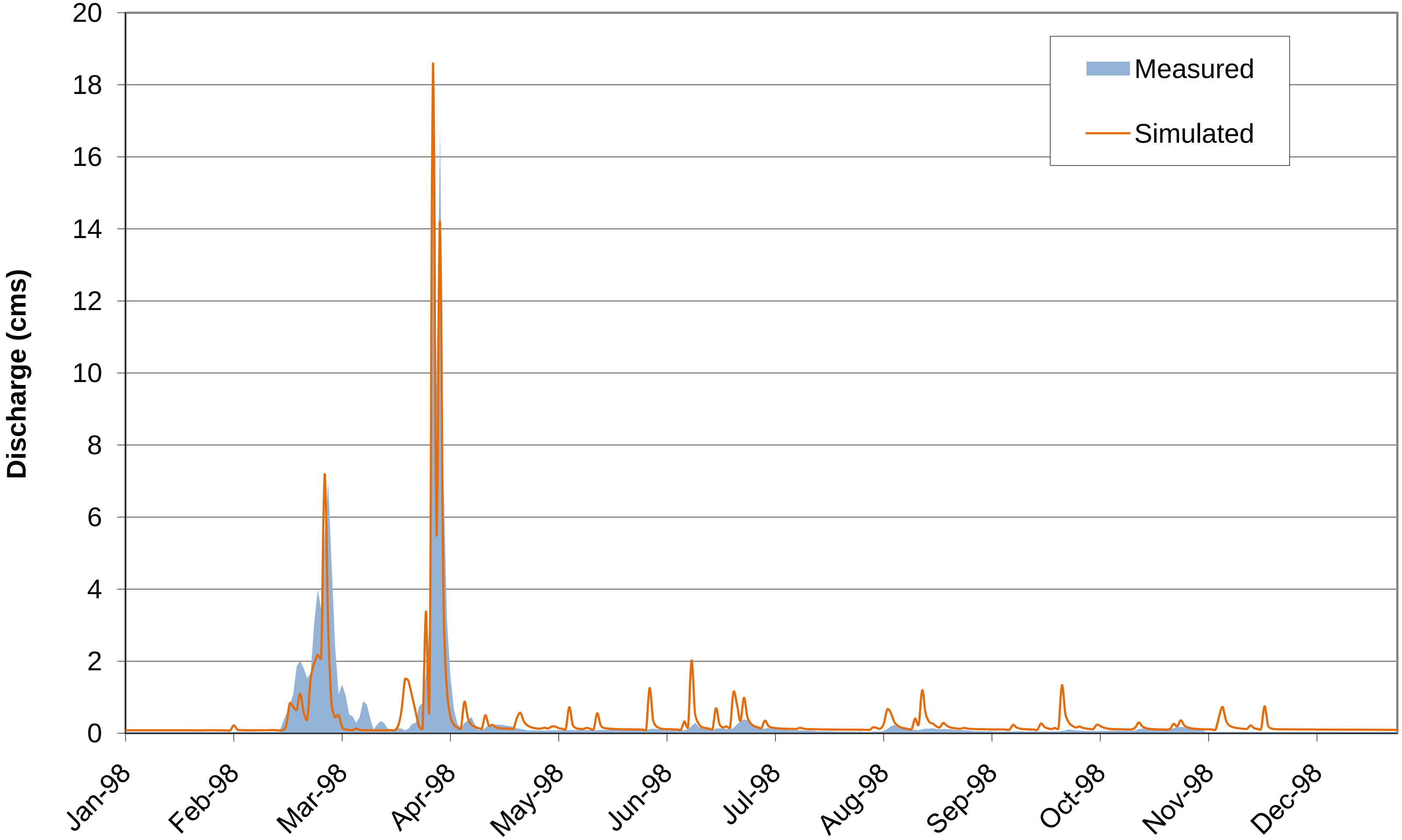

Figure 20 – Muskrat Creek Subwatershed Discharge Calibration

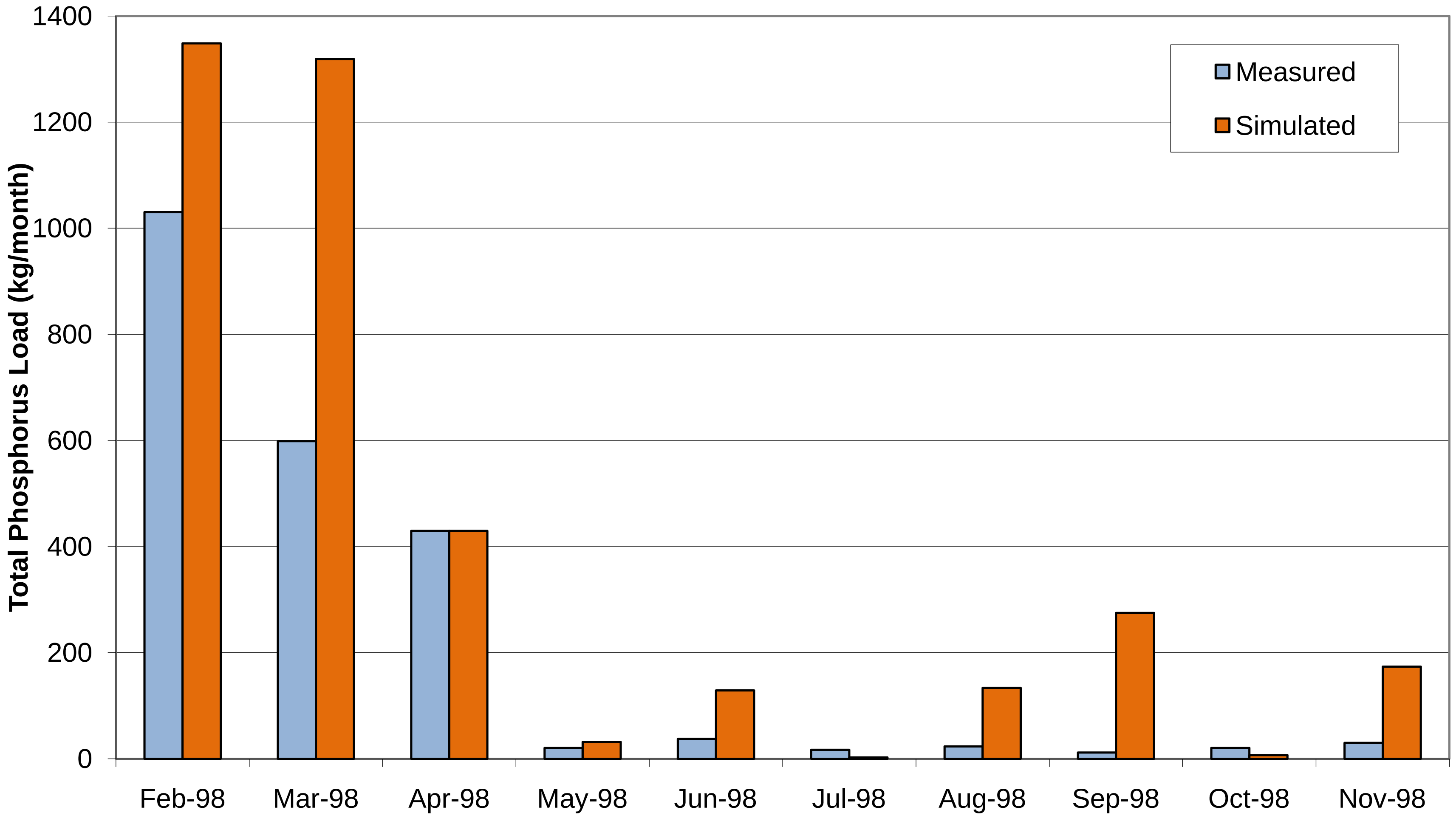

Figure 21- Muskrat Creek Subwatershed Phosphorus Calibration

3.2 Eau Claire River Watershed Calibration

The SWAT model for the entire watershed that contributes to Lake Eau Claire and Lake Altoona was calibrated by combining parameter values obtained during the subbasin calibrations with adjustments to match the observations at the larger stream sites. The calibration of the entire watershed was based on a trial and error approach that relied on reducing the difference between observed and simulated flow, sediment and nutrients at the Eau Claire River stations at Fall Creek, Highway G and Highway MM. The calibration sought to minimize subwatershed-specific changes, and emphasized global changes across the watershed to minimize the number of adjustable parameters and provide a more defensible calibration. The final adjustments to the model were based on a visual comparison of monthly totals at the Eau Claire River at Fall Creek because that site was monitored during a relatively wet summer (2000) and is the furthest downstream station.

In addition to the land management sources of phosphorus that were included in the subwatershed calibrations, the watershed calibration also included point sources. Information on wastewater treatment plant discharges was obtained through the Wisconsin Department of Natural Resources. The wastewater treatment facilities included were: Boyd, Stanley, Thorp, Augusta, Fairchild and Fall Creek. The average daily phosphorus loading from all of these facilities combined is approximately 7 kilograms/day. The point sources were included in the model using the average daily phosphorus mass loading rate for each facility added to the stream in the appropriate subwatershed.

The final Eau Claire River Watershed calibration also included Lake Eau Claire as a reservoir in the model. Lake Eau Claire has been shown to be a source of phosphorus through release from the sediments. The final simulations did not try to mimic this release of phosphorus beyond using a negative sedimentation during the summer months (-10 m/d).

3.2.1 Hydrology

The hydrology calibration relied on changes to several parameters. The RCN were maintained at the ratio similar to that in NRCS TR-55 (NRCS, 1985) with a uniform 10% reduction to all curve numbers. The lateral flow was adjusted by changing the slope length for lateral subsurface flow (SLSOIL) parameter in the HRU files so that the ratio of surface layer hydraulic conductivity to SLSOIL was 8 for all HRUs. This led to SLSOIL values that ranged from 0.4 to 175 but it prevented very high lateral flow in the more permeable soils. The calibration adjustments for other hydrologic parameters are shown in Appendix . Figures 22 and 23 show the measured and simulated flows at the two principal Eau Claire River monitoring locations: 1) the Eau Claire River at CTH G (Site 8); and, 2) the Eau Claire River at Fall Creek (Site 11). Overall, the agreement between measured and observed is acceptable and suggests that the calibrated model is able to successfully simulate the streamflow in the Eau Claire River watershed. The model does not simulate all storms equally well. That is consistent with variations in precipitation across the watershed leading to variations in runoff generation that are not captured in the SWAT simulation.

An overall water budget for the Eau Claire River watershed was described by Young and Hindall (1972). They reported an average annual water yield (the difference between precipitation and evapotranspiration) between 9 and 11 inches for this portion of the Eau Claire River basin. The six year simulation (with six years of warm-up) that was used for calibration and for evaluating management impacts had an average, watershed-wide runoff of 10.25 inches/calendar year with 6.60 inches of groundwater and 3.75 inches of surface runoff.

3.2.2 Sediment

The SWAT simulated suspended sediment delivery in the Eau Claire River watershed was approximately 4,150 metric tons per year. Figures 24 and 25 show the comparison between simulated and observed monthly sediment exported at the two primary stream sites. Sediment loss is very sensitive to precipitation and the largest differences between the predicted and observed was often when runoff volumes were poorly predicted. Overall there is general agreement between the total sediment measured and predicted, but the variations can be fairly large from month to month.

The simulated sediment loss was attributed almost entirely (>95%) to agricultural land. One factor contributing to this sediment loss is the relatively high soil loss predicted during periods with little crop cover. Figure 26 shows how the cover crop factor in the erosion prediction varied over time in one of the agricultural response units. This figure shows simulation results from the most common agricultural rotation, two years of corn and four years of alfalfa (CCAAAA). The three winters with the very high cover crop factors are those following fall plowing. The erosion simulation below shows how daily sediment loss often occurs during those periods.

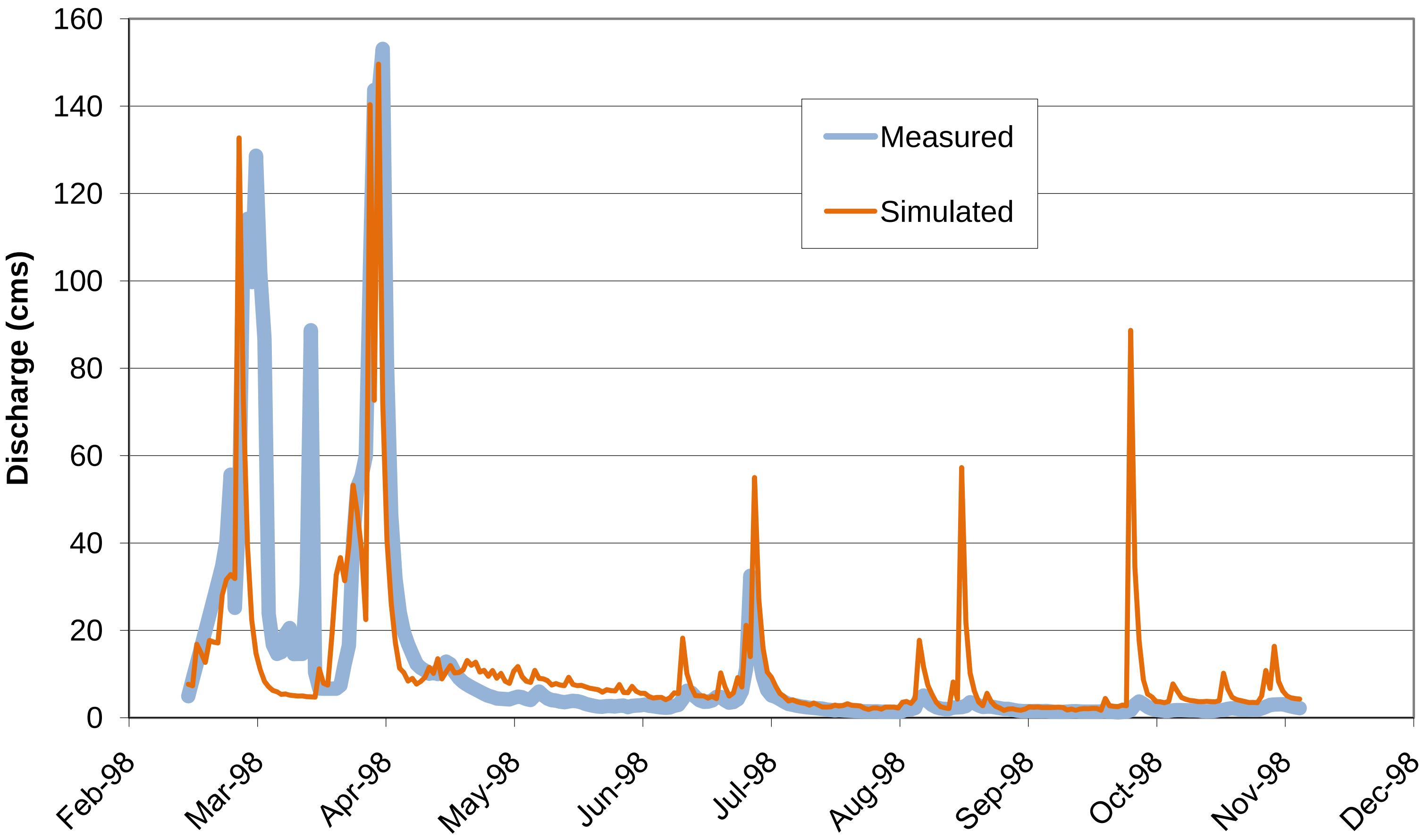

Figure 22 – Eau Claire River at Highway G (Site 8) Discharge Calibration

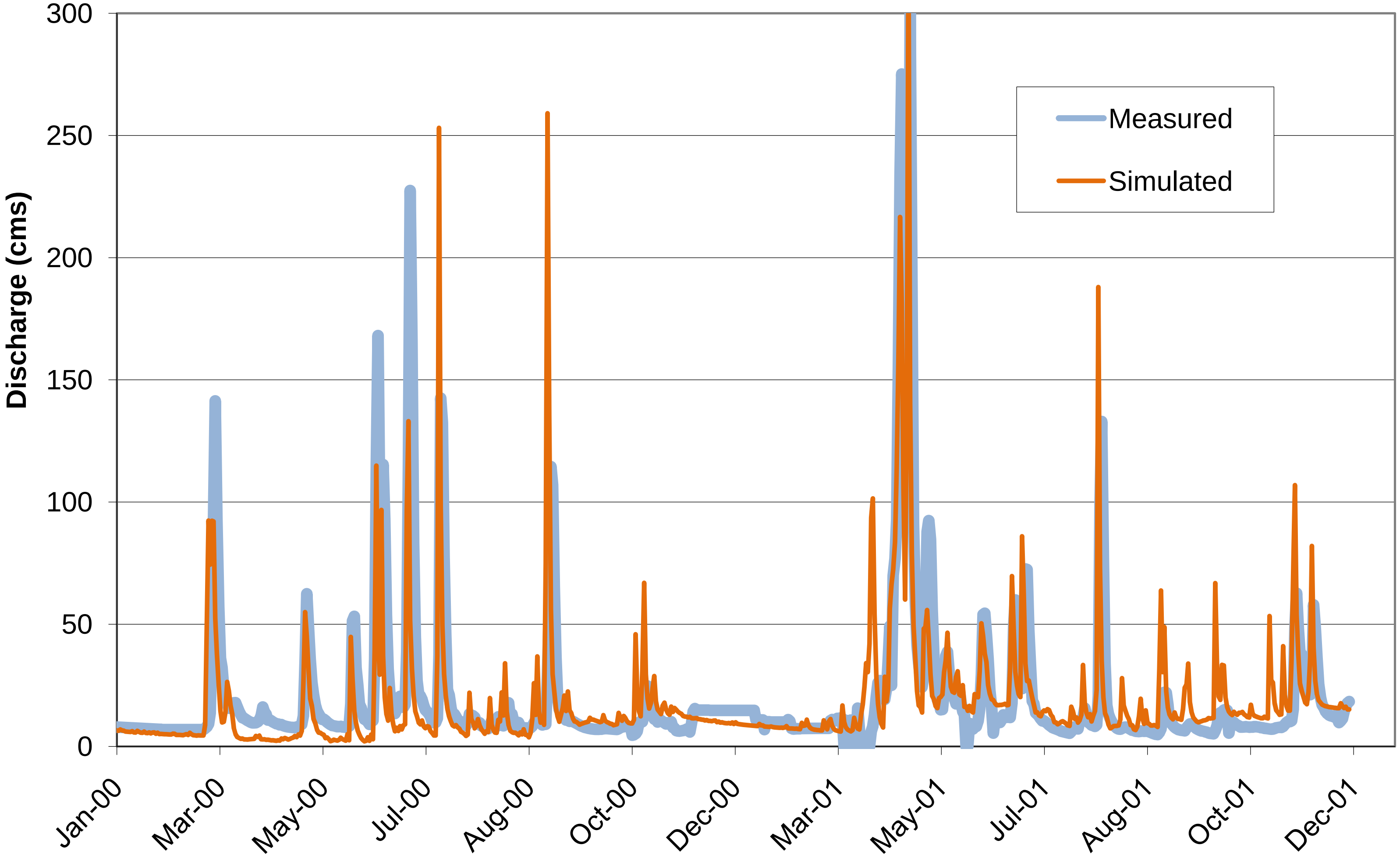

Figure 23 - Eau Claire River at Fall Creek (Site 11) Discharge Calibration

The sediment loss per land area varies with agricultural rotation, soil and subbasin characteristics. The average delivered sediment loss in the Eau Claire River watershed is 2.0 metric ton/square kilometer/year (2,000 kg/square kilometer/year), but as Figure 27 shows, the yield can vary substantially between subbasin. The highest subbasin sediment yield is predicted from those subbasins with a large percentage of row crop agriculture and more erosive soils. While local erosion rates may be large, the watershed wide average is within the 25th percentile of watersheds in the suspended sediment range according to Robertson et al. (2006).

3.2.3 Phosphorus

The phosphorus export from the Eau Claire River watershed reflects the movement of water through surface runoff pathways, movement of phosphorus associated with sediment, and the availability of soluble phosphorus to runoff. SWAT simulates the surface runoff, sediment erosion and availability of soluble phosphorus.

The phosphorus calibration sought to match both: 1) the monthly total phosphorus export of the monitoring studies; and, 2) the distribution of phosphorus between particulate and dissolved forms. The SWAT model was used in a "passive channel" mode (Almendinger and Murphy, 2007) where HRU-level modifications were used to adjust the sediment and phosphorus acquired during runoff generation and altered during delivery. To match the reductions in sediment and phosphorus that occur throughout the watershed, HRU-level parameter adjustments were made uniformly across the watershed to account for delivery (FILTERW, PHOSKD, USLEP, ERORGP). The result was a calibration that matched monthly measured values, was approximately 30% soluble P (groundwater and soluble P), and had a particulate P content more than 6000 mg/kg for the agricultural rotations.

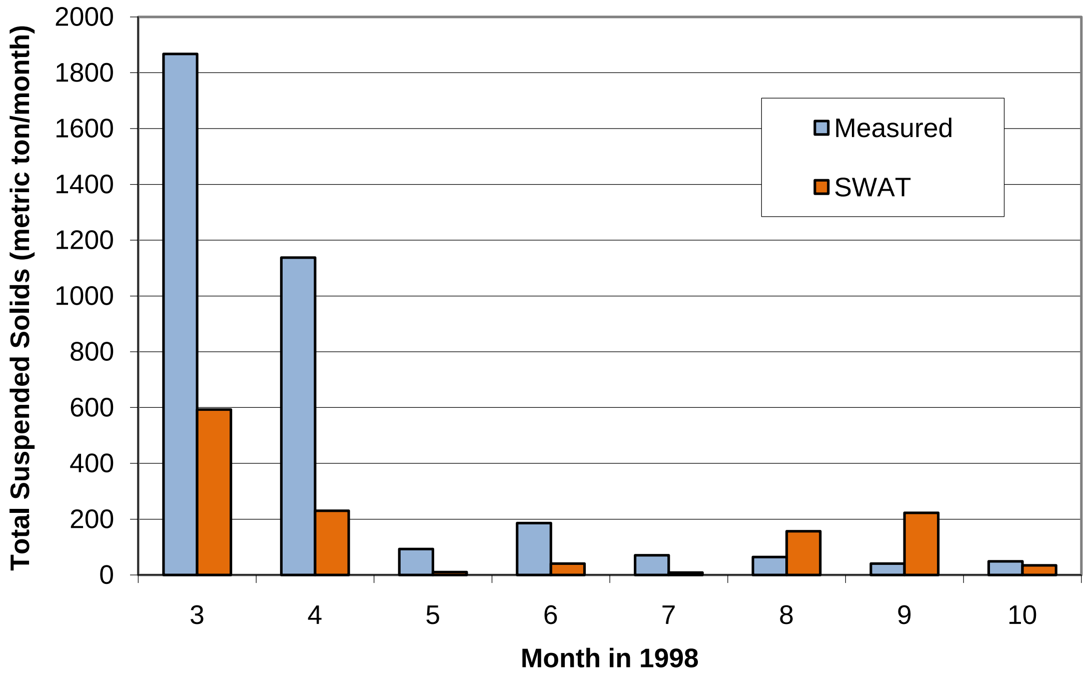

Figure 24 - Eau Claire River at Highway G (Site 8) Sediment Calibration

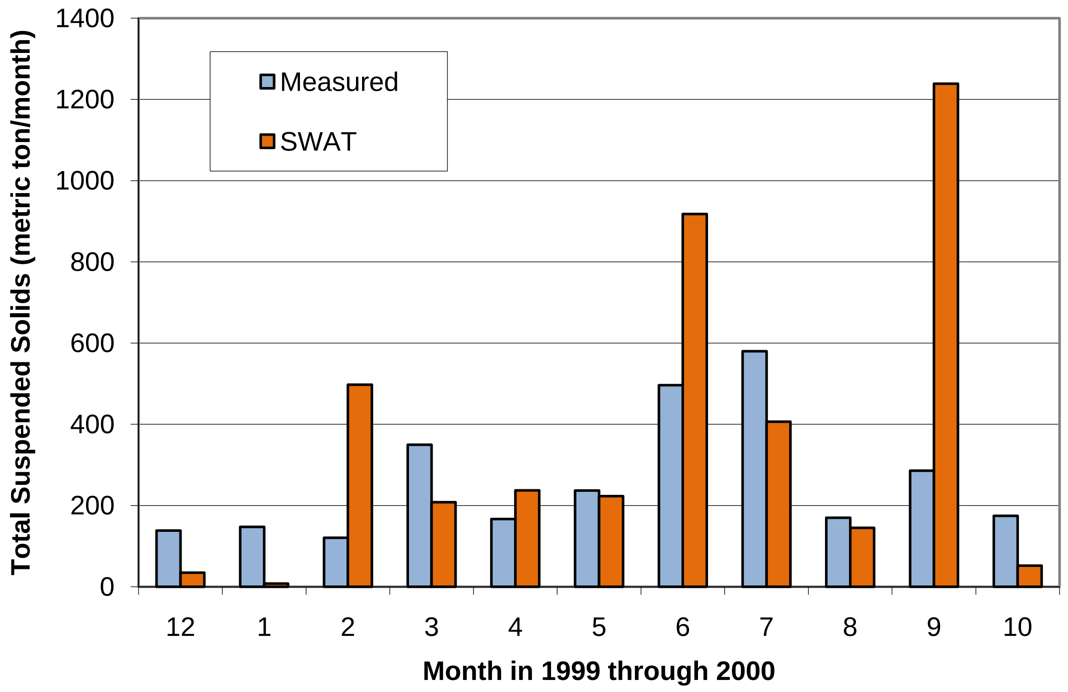

Figure 25 - Eau Claire River at Fall Creek (Site 11) Sediment Calibration

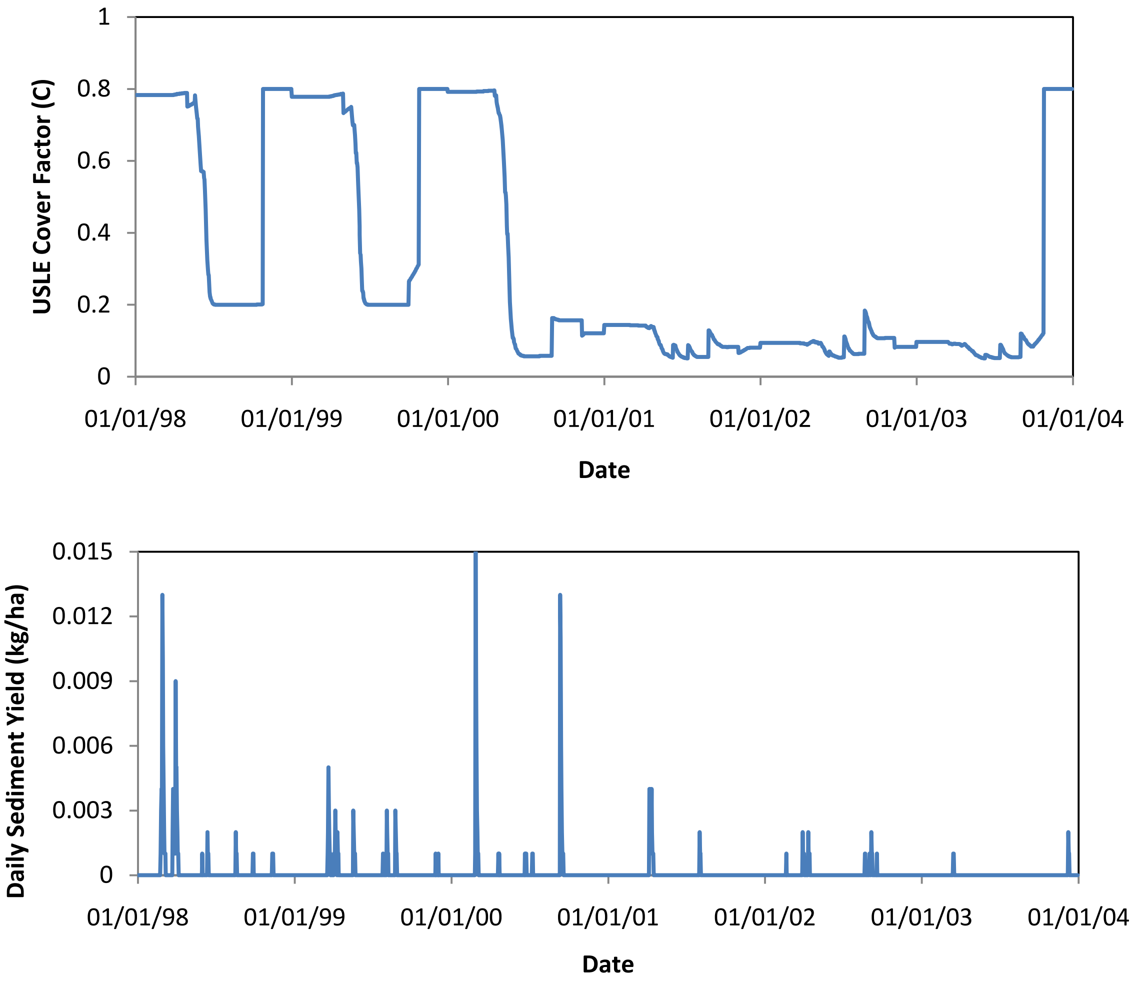

Figure 26 - Comparison of soil erosion cover factor (above) and daily sediment loss (below) for a typical agricultural rotation (116 or CCAAAA) (Subbasin 25)

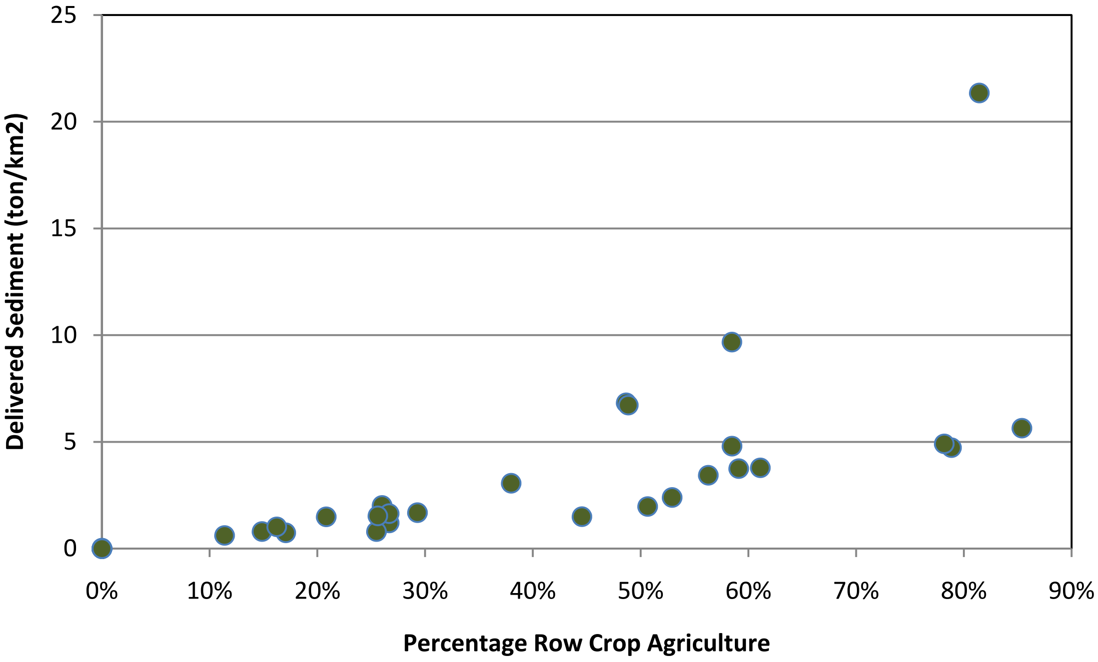

Figure 27 - Variation in delivered sediment yield (ton/km^2) with changes in row crop agriculture in the different subbasins

Figures 28 and 29 show the monthly total phosphorus at Site 2 and Site 4 during the calibration years. In both cases there is a general agreement between the measured and simulated phosphorus loads, but the difference between them is highly variable. Some of the variability can be attributed to variations in the distribution of rainfall across the watershed and variation in rainfall intensity during the day. As was observed during the hydrology calibration, not all of the storms are simulated similarly. Because only several weather stations were available, there was likely to be considerable variation in precipitation patterns between monitoring stations. Overall, however, the calibration seemed to provide a satisfactory match between observed and measured phosphorus concentrations.

The calibrated SWAT model was used to simulate phosphorus loading to Lake Altoona and Lake Eau Claire over time. The six year simulation results (following a six year warm-up period) are shown in Figure 30 for Lake Altoona and Figure 31 for Lake Eau Claire. They are shown as totals for both the calendar year (annual) and the growing season (May-September). The average annual total phosphorus load to Lake Altoona was simulated to be approximately 62,000 kilograms per year (136,000 pounds/year). This compares to the annual phosphorus load during the one year (2000) of monitoring of 55,000 kilograms. A little less than half of the phosphorus is predicted to be delivered during the growing season (May-September) where approximately 24,000 kilograms/growing season (53,000 pounds/growing season) were simulated with SWAT. The annual phosphorus loading to Lake Eau Claire during the one year (1998) of monitoring was estimated to be 44,233 kilograms. The SWAT model predicts an average annual phosphorus loading of 40,000 kilograms (88,000 pounds) with almost half coming during the growing season. The growing season phosphorus load was simulated to be approximately 15,000 kilograms/growing season (33,000 pounds/growing season).

The phosphorus export from the subwatershed is linked to agricultural land use within the subwatershed. Figure 32 shows the variation in unit area phosphorus with changes in percentage row crop agriculture in each subwatershed. The modeling suggests phosphorus export rates are between 0.8 to 1.2 kilogram/ha/year (0.7-1.1 pound/acre/year) when there is a very high percentage of row crop agriculture within the subwatershed. That is similar to the “most likely” value of 1.0 kg/ha/year (0.9 lb/acre/year) reported by Panuska and Lillie (1995) from 16 Wisconsin watersheds with more than 95% of the land in agriculture. The link between nutrient loss and agricultural lands is also shown in a subwatershed evaluation of phosphorus load and yield (Figures 33 and 34). The subwatersheds with greater acreage of agriculturally managed lands are simulated as having a greater P load and yield.

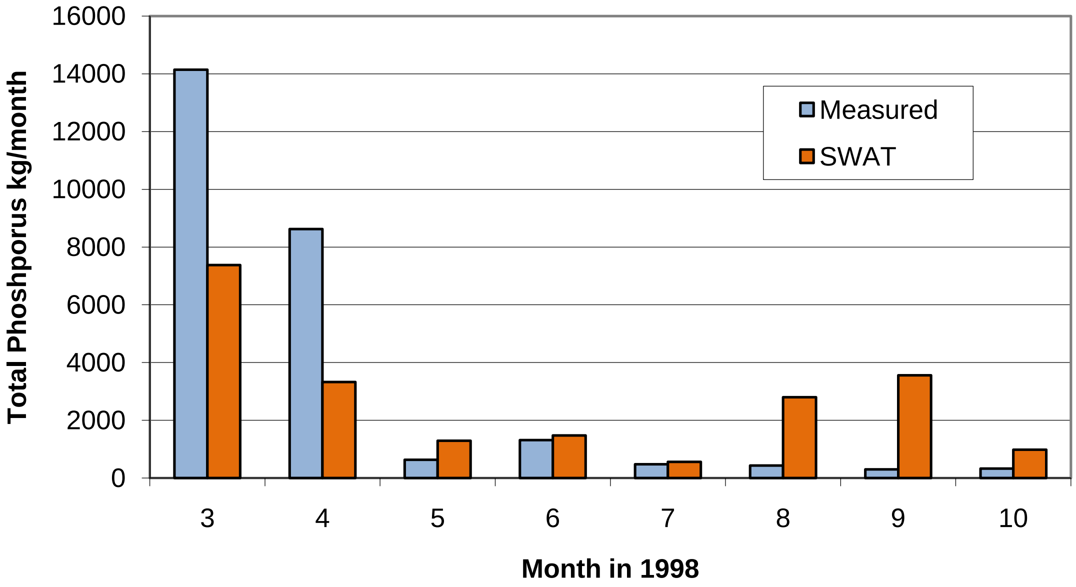

Figure 28 - Eau Claire River at Highway G (Site 8) Phosphorus Calibration

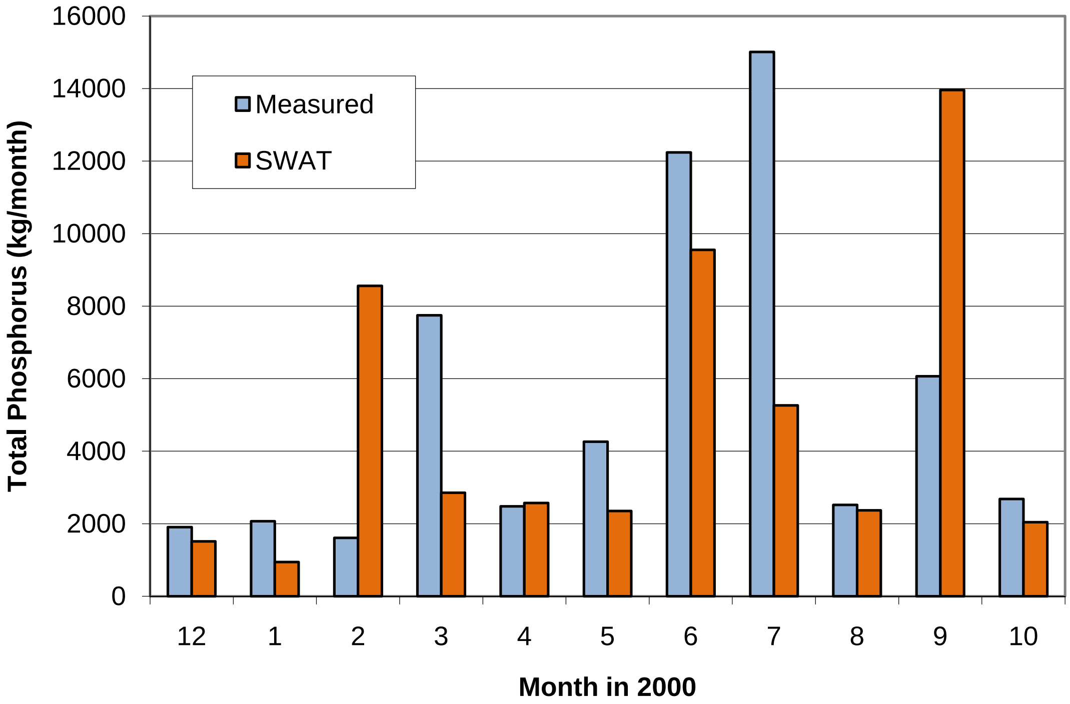

Figure 29 - Eau Claire River at Fall Creek (Site 11) Phosphorus Calibration

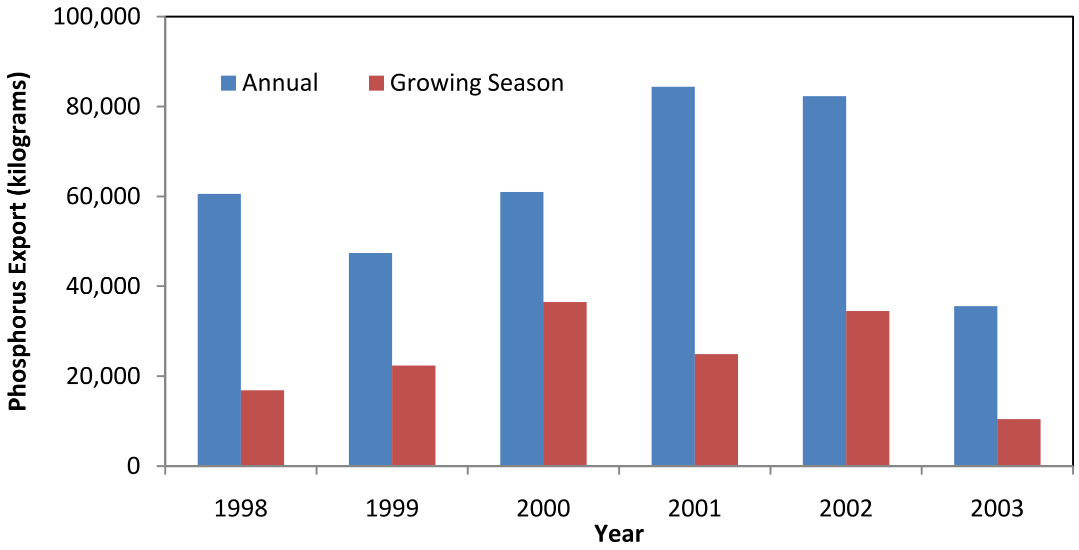

Figure 30 - SWAT simulated phosphorus export to Lake Altoona shown for the calendar year (annual) and growing season (May-September).

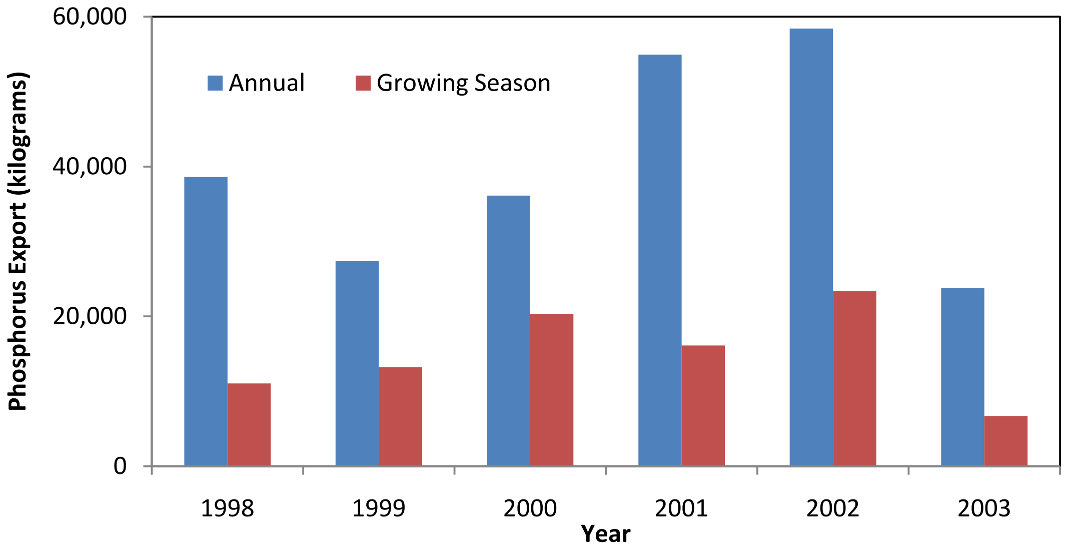

Figure 31 - SWAT simulated phosphorus export to Lake Eau Claire shown for the calendar year (annual) and growing season (May-September)

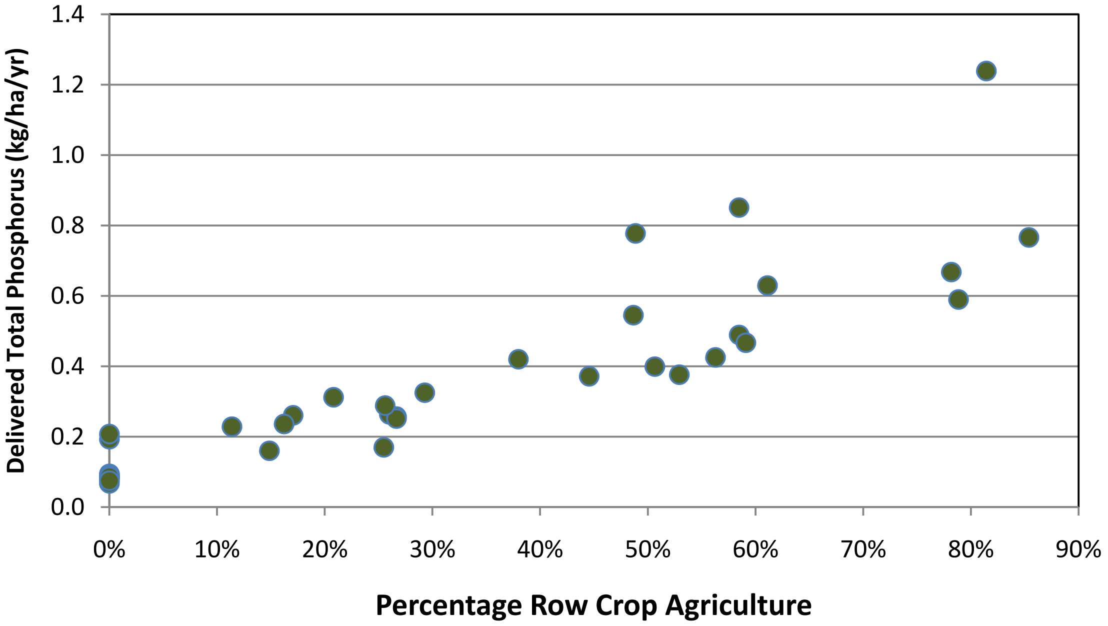

Figure 32 - Unit-area phosphorus export with changes in percent row-crop agriculture in the different subbasins

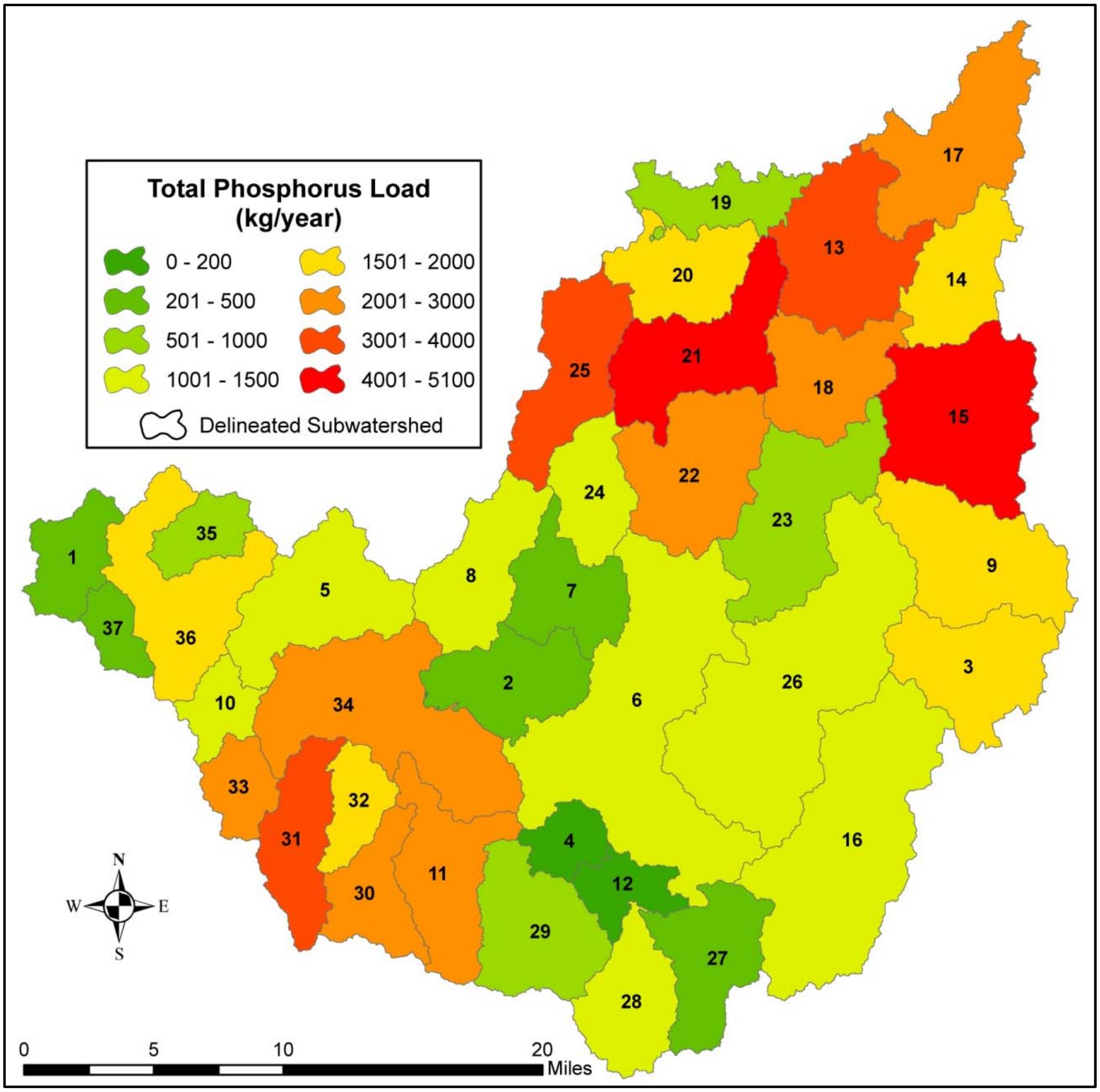

Figure 33 - SWAT Simulated TP Load (kg/yr) per Subwatershed

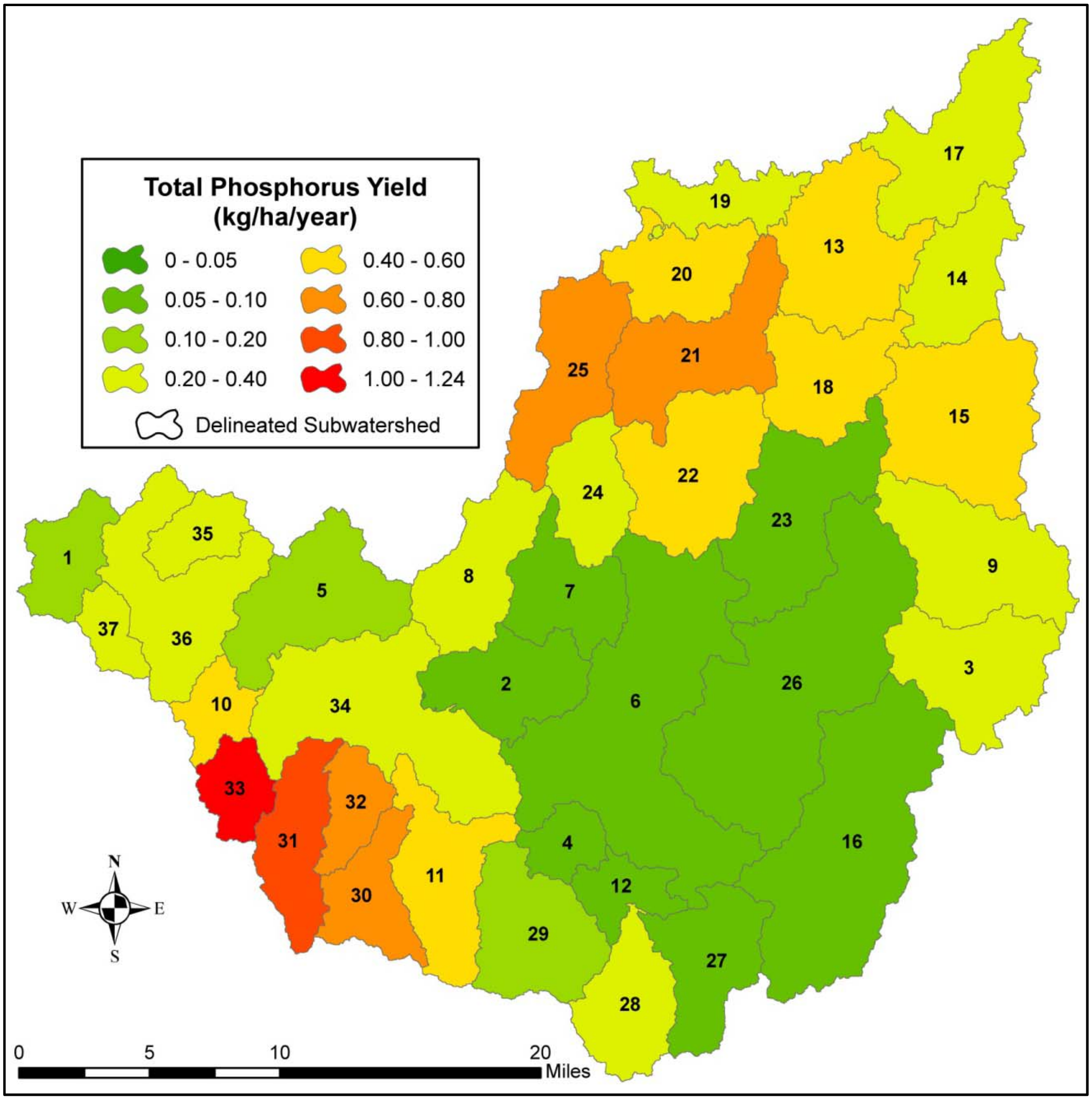

Figure 34 - SWAT Simulated TP Yield (kg/ha/yr) per Subwatershed

4.0 Phosphorus Management

The results of the SWAT simulation can be used to examine the principle sources of phosphorus to the lakes and explore management options to reduce phosphorus loading to the lake. For example, the overall phosphorus loading from the watershed can be divided on the basis of different land use to help target management activities. Figure 32 below shows that approximately seventy-five percent of the phosphorus export in the watershed is associated with land that is currently under agricultural management.

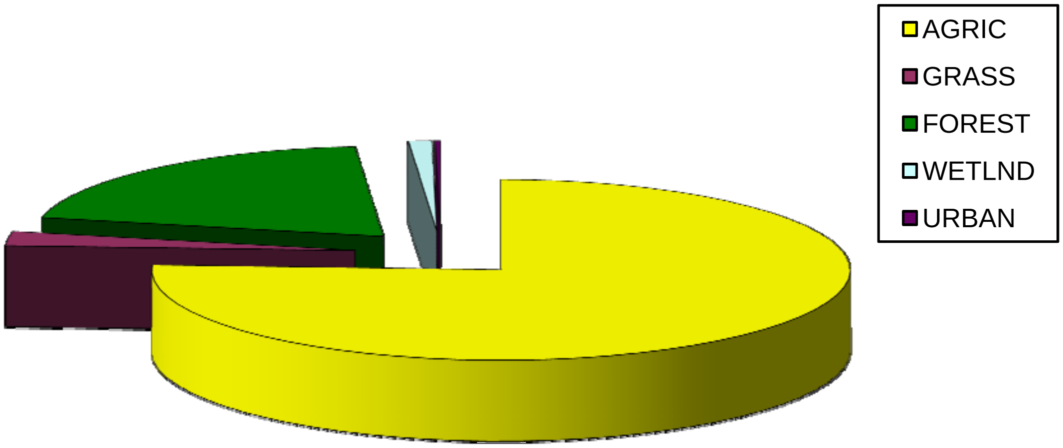

Figure 35 - SWAT simulation distribution of phosphorus export by land use category

The portion of the phosphorus export that is potentially controllable was estimated by separating the simulated groundwater contributions from the phosphorus attributed to each land use. Figure 33 shows that after excluding the phosphorus associated with groundwater, that the phosphorus from agricultural land uses is approximately 65% of the total phosphorus. This likely establishes an upper boundary on the extent of phosphorus reduction that is possible. In other words, there is no way to control approximately thirty-five percent of the phosphorus from the watershed.

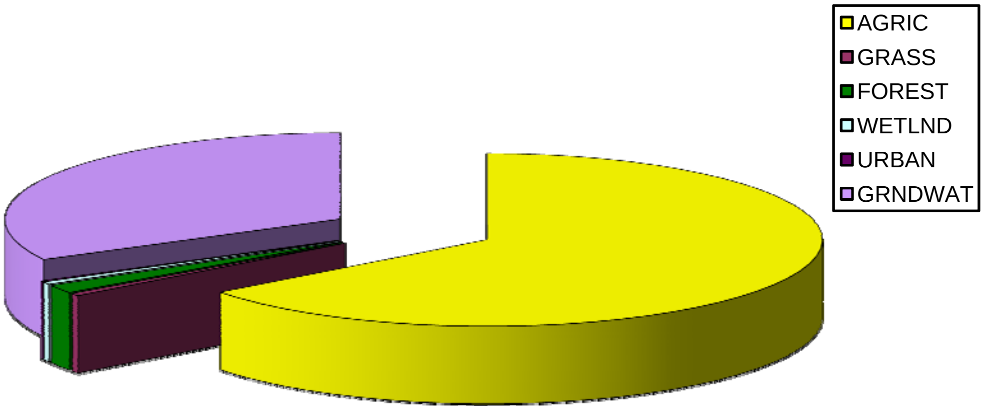

Figure 36 - Distribution of phosphorus export between agricultural phosphorus that might be controllable (AGRIC), other land uses and groundwater (GRNDWAT)

A variety of management scenarios were examined to determine how they might impact agricultural phosphorus export from the watershed. Table 6 lists the management scenarios that were examined and discusses the adjustments that were made to the model to simulate those changes. The changes were evaluated as the average across a six year rotation after a six year warm-up period.

The impact of management changes on phosphorus export to Lake Eau Claire and Lake Altoona in Table 7 and Table 8, respectively. The phosphorus reductions shown in these Tables assume that the management actions are fully implemented across the watershed. The results in these Tables show how some management alternatives can be combined to achieve an almost additive reduction. For example, addressing soil phosphorus levels and manure application rates is likely to reduce the soluble phosphorus exported. Improvements in erosion control would principally reduce particulate phosphorus export. Combining those strategies can lead to a reduction in both soluble and particulate phosphorus. The results of the combination options show that addressing both soluble and particulate phosphorus through reductions in phosphorus availability, surface runoff volume reduction and reducing sediment loss could lead to phosphorus reductions of 20%-30%.

Table 5 – Summary of Management Scenarios Evaluated with SWAT

Simulation ID	Management Practice	Conceptual Description and SWAT Model Representation
Baseline	Calibration period management	Deep (6") fall tillage (eg moldboard plow), spring disk cultivator, runoff curve numbers -10% from default, USLE P (practice factor) 0.20, Filterw 22 meter, sediment P enrichment (erorgP) 50, overland flow n 0.1, biomix 0.2
Soil Phosphorus Reduction	Reduce soil phosphorus and also reduce nutrient inputs	Reduce the labile phosphorus concentration (sol_labp) from current county-wide averages to 20 ppm, reduce manure application rates by 20%
Contour Strip Cropping	Decrease erosion through management practices	35% reduction in USLE P
Decrease Dietary Phosphorus	Reduce nutrient inputs by reducing manure P content	Reduce fraction of phosphorus in dairy manure (FMINP and FORGP both reduced by 25%).
Reduce Tillage	Increase soil cover by increasing residue on soil surface	Shallow (3") fall tillage (eg., coulter chisel) and spring cultivator. Increasing Manning's n for overland flow to 0.2 and decrease runoff curve numbers by 2.
No-Till	Increase soil cover and residue on surface	No tillage, increase Manning's n for overland flow to 0.3 and reduce curve numbers by 6 for agricultural rotations, biomix increased to 0.6.
Combination Options	Reduce Soil P and Soil Erosion (eg increased contouring)	Initial soil P at 20 ppm, reduce manure by 20%, and reduce USLE P by 35%
	Reduce Soil P and reduced tillage, increased contouring, and reduce dietary P	Initial soil P 20 ppm, USLE P reduced by 35%, reduce manure P content by 25% for both mineral and organic, reduce manure application rates by 20%, shallow fall tillage, increase Manning's n for overland flow to 0.2, decrease runoff curve numbers by 2.

Table 6 – SWAT Simulated P Export to Lake Eau Claire and the Projected Impact of Management Changes

Simulation ID	**Management Practice**	**Annual Sediment (Metric Ton)**	**Annual Total P (Kg)**	**Growing Season Total P (Kg)**	**% Change in Growing Season P From Baseline**
Baseline	*Calibration period management*	**2,284**	**39,875**	**15,142**	**--**
Soil Phosphorus Reduction	*Reduce soil phosphorus to 20 mg/kg and reduce manure inputs by 20%*	**2,281**	**37,067**	**14,145**	**7%**
Contour & Strip Cropping	*Decrease erosion through management practices*	**1,485**	**34,780**	**13,353**	**12%**
Decrease Dietary Phosphorus	*Reduce nutrient inputs by reducing manure P content*	**2,354**	**38,384**	**14,560**	**4%**
Reduce Tillage	*Increase soil cover by increasing residue on soil surface*	**1,358**	**34,225**	**13,926**	**8%**
No-Till	*Increase soil cover and residue on surface*	**1,014**	**31,889**	**12,552**	**17%**
Combination Options	*Reduced Soil P and manure by 20%, Reduce erosion*	**1,483**	**32,583**	**12,560**	**17%**
	Reduce Soil P / Reduce tillage / Reduce dietary P/ Reduce erosion	**927**	**27,961**	**11,191**	**26%**
*Based on an average of simulations from 1998-2003					

Table 7 – SWAT Simulated P Export to Lake Altoona and the Projected Impact of Management Changes

Simulation ID	Management Practice	Annual Sediment (Metric Ton)	Annual Total P (Kg)	Growing Season Total P (Kg)	% Change in Growing Season P From Baseline
Baseline	*Calibration period management*	**4,150**	**61,854**	**24,273**	**--**
Soil Phosphorus Reduction	*Reduce soil phosphorus to 20 mg/kg and reduce manure inputs by 20%*	**4,150**	**56,289**	**22,219**	**8%**
Contour & Strip Cropping	*Decrease erosion through management practices*	**2,689**	**54,492**	**21,641**	**11%**
Decrease Dietary Phosphorus	*Reduce nutrient inputs by reducing manure P content*	**4,246**	**57,432**	**22,654**	**7%**
Reduce Tillage	*Increase soil cover by increasing residue on soil surface*	**2,600**	**53,722**	**22,881**	**6%**
No-Till	*Increase soil cover and residue on surface*	**1,931**	**50,063**	**21,000**	**8%**
Combination Options	*Reduced Soil P and manure by 20%, Reduce erosion*	**2,698**	**49,923**	**19,923**	**18%**
	Reduce Soil P / Reduce tillage / Reduce dietary P/ Reduce erosion	**1,747**	**41,500**	**17,445**	**28%**
*Based on an average of simulations from 1998-2003					

5.0 Conclusions and Recommendations

A SWAT model of the Eau Claire River Watershed draining to Lake Eau Claire and Lake Altoona was developed using topography, historical weather, soil types, and land management in the watershed. The SWAT model was calibrated using previous monitoring studies and was able to simulate the observed flow, sediment and phosphorus exported from the watershed.

The SWAT model was used to improve the estimate of the long-term average annual phosphorus export from the watershed. This model estimated an average phosphorus loading to Lake Eau Claire of approximately 40,000 kilograms (88,000 pounds) with 15,000 kilograms (33,000 pounds) during the summer (May-Sept) months. Lake Altoona has an annual phosphorus loading of 62,000 kilograms (136,000 pounds) with a summer loading of 24,000 kilograms (53,000 pounds). Approximately two-thirds of this annual phosphorus load was attributed to agricultural land management.

The SWAT model was used to better understand the sources of phosphorus and opportunities that are available for reducing phosphorus export. Model results indicate that much of the phosphorus export from the watershed was linked to agricultural land uses. This is consistent with a transfer of phosphorus from surface runoff that is generated during periods of low vegetative cover and with high available phosphorus levels. Unit-area phosphorus from the watershed varies with soils and land management, but overall, the agricultural land management leads to phosphorus export rates of approximately 1 kilogram/ha/year (0.9 lb/acre/year) which is similar to the state-wide average for phosphorus export from agricultural watersheds.

The SWAT model was used to explore how changes in agricultural management could be used to reduce the transfer of phosphorus. The results of these simulations show there are opportunities for reducing phosphorus export from the watershed. The simulations show that implementing strategies to reduce phosphorus availability (e.g., soil test phosphorus), runoff generation (e.g., reduced tillage) and reduced soil erosion (e.g., contour and strip cropping) could provide phosphorus export reductions up to 20 to 30 percent from the watershed.

The ECRW phosphorus export study provides the initial step in locating and mitigating non-point source pollution. The completion of the project revealed areas requiring additional investigation to improve the conceptualization of phosphorus loss throughout the ECRW.

The use of a water quality simulation model provides land managers with a tool to evaluate the watershed response to various land conditions and management. The tool's predictive ability can be improved with quality input data. Large areas of the ECRW have limited or no data. It is recommended that additional multi-year localized monitoring occur in areas identified as being the largest contributors of sediment and nutrients.

In addition to multi-year water quality monitoring within various target subwatersheds, it is recommended that the Eau Claire and Altoona lake associations work with the county conservationists to develop a management priority list. The SWAT model isolated the most likely subwatersheds to contribute high phosphorus concentrations. The next step is to prioritize the action taken within those subwatersheds. Locating point sources such as barnyards and cattle crossings, and locating the confluences of agricultural field runoff to the stream network could be some of the next steps.

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Appendix A

Land Cover Acreage and Percentage

LANDCOVER BY TYPE PER SUBWATERSHED
(Refer to Figure 5 for Subwatershed Locations)

		Urban	Agriculture	Grassland	Forest	Water	Wetland
North Fork Eau Claire River	Acres	1,871	15,020	1,858	10,398	163	2,628
	Percentage (%)	6	47	6	33	1	8
Mead Lake	Acres	3,780	27,615	6,656	20,226	410	5,990
	Percentage (%)	6	43	10	31	1	9
Upper Eau Claire River	Acres	5,033	39,821	11,211	104,246	880	34,405
	Percentage (%)	3	20	6	53	0	18
Hay Creek	Acres	197	10,358	2,367	8,752	92	3,607
	Percentage (%)	1	41	9	34	0	14
Muskrat Creek	Acres	0	4,168	1,582	9,148	35	3,964
	Percentage (%)	0	22	8	48	0	21
Coon Fork	Acres	658	6,726	1,753	15,774	267	6,915
	Percentage (%)	2	21	5	49	1	22
Lake Eau Claire	Acres	0	182	200	8,961	1,067	1,453
	Percentage (%)	0	2	2	76	9	12
Bridge Creek	Acres	369	18,284	3,645	9,871	141	4,013
	Percentage (%)	1	50	10	27	0	11
Fall Creek	Acres	128	6,675	1,181	1,853	32	486
	Percentage (%)	1	64	11	18	0	5
Lower Eau Claire River	Acres	65	24,065	4,916	24,773	365	4,516
	Percentage (%)	0	41	8	42	1	8
Lake Altoona	Acres	760	8,858	4,305	17,538	1,090	1,269
	Percentage (%)	2	26	13	52	3	4

Appendix B

Agricultural Management Rotations

Dairy (CG-CG-CS-S-A-A) (Manure Storage) (Gridcode 111)

Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	4/25	Manure	Dairy	5,380	kg/ha
2000	5/1	Tillage	Disk Plow		
2000	5/5	Plant	Corn Grain		
2000	5/5	Fertilizer	09-23-30	224	kg/ha
2000	6/15	Herbicide	Round-Up		
2000	10/15	Harvest/Kill	Corn Grain		
2000	10/20	Manure	Dairy	1,345	kg/ha
2000	10/25	Tillage	Moldboard Plow		
2001	4/25	Manure	Dairy	5,380	kg/ha
2001	5/1	Tillage	Disk Plow		
2001	5/5	Plant	Corn Grain		
2001	5/5	Fertilizer	09-23-30	224	kg/ha
2001	6/15	Herbicide	Round-Up		
2001	10/15	Harvest/Kill	Corn Grain		
2001	10/20	Manure	Dairy	1,345	kg/ha
2001	10/25	Tillage	Moldboard Plow		
2002	4/25	Manure	Dairy	2,119	kg/ha
2002	5/1	Tillage	Disk Plow		
2002	5/5	Plant	Corn Grain		
2002	5/5	Fertilizer	09-23-30	224	kg/ha
2002	6/15	Herbicide	Round-Up		
2002	10/15	Harvest/Kill	Corn Grain		
2002	10/20	Manure	Dairy	1,345	kg/ha
2002	10/25	Tillage	Moldboard Plow		
2003	4/25	Manure	Dairy	1,345	kg/ha
2003	5/10	Tillage	Disk Plow		
2003	5/15	Plant	Soybeans		
2003	10/1	Harvest/Kill	Soybeans		
2003	10/25	Tillage	Disk Plow		
2004	4/25	Plant	Alfalfa		
2004	4/25	Fertilizer	05-14-42	224	kg/ha
2004	9/5	Harvest	Alfalfa		
2004	9/5	Fertilizer	00-00-60	224	kg/ha
2005	6/10	Harvest	Alfalfa		
2005	7/15	Harvest	Alfalfa		
2005	9/1	Harvest	Alfalfa		
2005	10/1	Kill Alfalfa	Alfalfa		
2005	10/15	Manure	Dairy	5,380	kg/ha
2005	10/25	Tillage	Moldboard Plow		

Cash (CG-CG-CG-A-A-A) (No Storage/No Manure) (Gridcode 113)

Year	*Date*	*Operation*	*Crop / Type*	*Rate*	*Units*
2000	5/1	Tillage	Disk Plow		
2000	5/5	Plant	Corn Grain		
2000	5/5	Fertilizer	09-23-30	280	kg/ha
2000	6/15	Herbicide	Round-Up		
2000	10/15	Harvest/Kill	Corn Grain		
2000	10/25	Tillage	Moldboard Plow		
2001	4/25	Fertilizer	46-00-00	336	kg/ha
2001	5/1	Tillage	Disk Plow		
2001	5/5	Plant	Corn Grain		
2001	5/5	Fertilizer	9/23/1930	280	kg/ha
2001	6/15	Herbicide	Round-Up		
2001	9/25	Harvest/Kill	Corn Grain		
2001	10/25	Tillage	Moldboard Plow		
2002	4/25	Fertilizer	46-00-00	336	kg/ha
2002	5/1	Tillage	Disk Plow		
2002	5/5	Plant	Corn Grain		
2002	5/5	Fertilizer	09-23-30	224	kg/ha
2002	6/15	Herbicide	Round-Up		
2002	9/25	Harvest/Kill	Corn Grain		
2002	10/25	Tillage	Moldboard Plow		
2003	4/25	Plant	Alfalfa		
2003	9/5	Harvest	Alfalfa		
2003	9/15	Fertilizer	00-00-60	336	kg/ha
2004	6/10	Harvest	Alfalfa		
2004	7/15	Harvest	Alfalfa		
2004	9/1	Harvest	Alfalfa		
2004	9/15	Fertilizer	00-00-60	336	kg/ha
2005	6/10	Harvest	Alfalfa		
2005	7/15	Harvest	Alfalfa		
2005	9/1	Harvest	Alfalfa		
2005	10/1	Kill	Alfalfa		
2005	10/1	Herbicide	Round-Up		
2005	10/25	Tillage	Moldboard Plow		

Dairy (CG-S-A-A-A-A) (Manure Storage) (Gridcode 114)

Year	*Date*	*Operation*	*Crop / Type*	*Rate*	*Units*
2000	4/25	Manure	Dairy	5,380	kg/ha
2000	5/1	Tillage	Disk Plow		
2000	5/5	Plant	Corn Grain		
2000	5/5	Fertilizer	09-23-30	224	kg/ha
2000	6/15	Herbicide	Round-Up		
2000	10/15	Harvest/Kill	Corn Grain		
2000	10/20	Manure	Dairy	5,380	kg/ha
2000	10/25	Tillage	Moldboard Plow		
2001	5/1	Tillage	Disk Plow		
2001	5/15	Plant	Soybeans		
2001	5/15	Fertilizer	05-14-42	224	kg/ha
2001	6/25	Herbicide	Round-Up		
2001	10/1	Harvest/Kill	Soybeans		
2001	10/25	Tillage	Disk Plow		
2002	4/10	Manure	Dairy	1,345	kg/ha
2002	4/15	Tillage	Disk Plow		
2002	4/25	Plant	Alfalfa		
2002	4/25	Fertilizer	05-14-42	224	kg/ha
2002	9/1	Harvest	Alfalfa		
2002	9/15	Fertilizer	00-00-60	224	kg/ha
2003	6/10	Harvest	Alfalfa		
2003	7/15	Harvest	Alfalfa		
2003	9/1	Harvest	Alfalfa		
2003	9/15	Fertilizer	00-00-60	224	kg/ha
2004	6/10	Harvest	Alfalfa		
2004	7/15	Harvest	Alfalfa		
2004	9/1	Harvest	Alfalfa		
2004	9/15	Fertilizer	00-00-60	224	kg/ha
2005	6/10	Harvest	Alfalfa		
2005	7/15	Harvest	Alfalfa		
2005	9/1	Harvest	Alfalfa		
2005	10/1	Kill	Alfalfa		
2005	10/15	Manure	Dairy	1,345	kg/ha
2005	10/25	Tillage	Moldboard Plow		

Dairy/Amish (CS-A-A-A-CS-A) (No Manure Storage) (Gridcode 115)

Year	*Date*	*Operation*	*Crop / Type*	*Rate*	*Units*
2000	4/1	Manure	Dairy	1,009	kg/ha
2000	5/1	Tillage	Disk Plow		
2000	5/1	Manure	Dairy	1,009	kg/ha
2000	5/20	Plant	Corn Silage		
2000	5/20	Fertilizer	09-23-30	224	kg/ha
2000	9/1	Manure	Dairy	505	kg/ha
2000	10/1	Harvest/Kill	Corn Silage		
2000	10/1	Manure	Dairy	505	kg/ha
2000	10/25	Tillage	Moldboard Plow		
2000	11/1	Manure	Dairy	505	kg/ha
2000	12/1	Manure	Dairy	505	kg/ha
2001	4/20	Tillage	Disk Plow		
2001	4/25	Plant	Alfalfa		
2001	9/5	Harvest	Alfalfa		
2002	6/10	Harvest	Alfalfa		
2002	7/15	Harvest	Alfalfa		
2002	9/1	Harvest	Alfalfa		
2003	6/10	Harvest	Alfalfa		
2003	7/15	Harvest	Alfalfa		
2003	9/1	Harvest	Alfalfa		
2003	10/1	Kill	Alfalfa		
2003	10/1	Manure	Dairy	1,009	kg/ha
2003	10/25	Tillage	Moldboard Plow		
2004	4/1	Manure	Dairy	1,009	kg/ha
2004	5/1	Tillage	Disk Plow		
2004	5/1	Manure	Dairy	1,009	kg/ha
2004	5/20	Plant	Corn Silage		
2004	5/20	Fertilizer	09-23-30	224	kg/ha
2004	9/1	Manure	Dairy	505	kg/ha
2004	10/1	Harvest/Kill	Corn Silage		
2004	10/1	Manure	Dairy	505	kg/ha
2004	10/25	Tillage	Moldboard Plow		
2004	11/1	Manure	Dairy	505	kg/ha
2005	4/20	Tillage	Disk Plow		
2005	4/25	Plant	Alfalfa		
2005	4/25	Plant	Alfalfa		
2005	9/5	Harvest	Alfalfa		
2005	10/1	Kill	Alfalfa		
2005	10/1	Manure	Dairy	1,009	kg/ha
2005	10/25	Tillage	Moldboard Plow		

Dairy (CS-CS-A-A-A-A) (No Manure Storage) (Gridcode 116)

Year	*Date*	*Operation*	*Crop / Type*	*Rate*	*Units*
2000	4/1	Manure	Dairy	1,681	kg/ha
2000	5/1	Tillage	Disk Plow		
2000	5/1	Manure	Dairy	1,681	kg/ha
2000	5/20	Plant	Corn Silage		
2000	5/20	Fertilizer	09-23-30	224	kg/ha
2000	9/1	Manure	Dairy	841	kg/ha
2000	10/1	Harvest/Kill	Corn Silage		
2000	10/1	Manure	Dairy	841	kg/ha
2000	10/25	Tillage	Moldboard Plow		
2000	11/1	Manure	Dairy	841	kg/ha
2000	12/1	Manure	Dairy	841	kg/ha
2001	4/1	Manure	Dairy	1,681	kg/ha
2001	5/1	Tillage	Disk Plow		
2001	5/1	Manure	Dairy	1,681	kg/ha
2001	5/20	Plant	Corn Silage		
2001	5/20	Fertilizer	09-23-30	224	kg/ha
2001	9/1	Manure	Dairy	841	kg/ha
2001	10/1	Harvest/Kill	Corn Silage		
2001	10/1	Manure	Dairy	841	kg/ha
2001	10/25	Tillage	Moldboard Plow		
2001	11/1	Manure	Dairy	841	kg/ha
2001	12/1	Manure	Dairy	841	kg/ha
2002	4/20	Tillage	Disk Plow		
2002	4/25	Plant	Alfalfa		
2002	9/1	Harvest	Alfalfa		
2003	6/10	Harvest	Alfalfa		
2003	7/15	Harvest	Alfalfa		
2003	9/1	Harvest	Alfalfa		
2004	6/10	Harvest	Alfalfa		
2004	7/15	Harvest	Alfalfa		
2004	9/1	Harvest	Alfalfa		
2005	6/10	Harvest	Alfalfa		
2005	7/15	Harvest	Alfalfa		
2005	9/1	Harvest	Alfalfa		
2005	10/1	Kill	Alfalfa		
2005	10/1	Manure	Dairy	1,009	kg/ha
2005	10/25	Tillage	Moldboard Plow		

Beef (CG-A-A-A-CG-A) (No Manure Storage) (Gridcode 119)

Year	*Date*	*Operation*	*Crop / Type*	*Rate*	*Units*
2000	4/1	Manure	Beef	1,882	kg/ha
2000	5/1	Tillage	Disk Plow		
2000	5/1	Manure	Beef	1,882	kg/ha
2000	5/20	Plant	Corn Grain		
2000	5/20	Fertilizer	09-23-30	224	kg/ha
2000	9/1	Manure	Beef	471	kg/ha
2000	10/1	Harvest/Kill	Corn Grain		
2000	10/1	Manure	Beef	471	kg/ha
2000	10/25	Tillage	Moldboard Plow		
2000	11/1	Manure	Beef	471	kg/ha
2000	12/1	Manure	Beef	471	kg/ha
2001	4/20	Tillage	Disk Plow		
2001	4/25	Plant	Alfalfa		
2001	9/5	Harvest	Alfalfa		
2002	6/10	Harvest	Alfalfa		
2002	7/15	Harvest	Alfalfa		
2002	9/1	Harvest	Alfalfa		
2003	6/10	Harvest	Alfalfa		
2003	7/15	Harvest	Alfalfa		
2003	9/1	Harvest	Alfalfa		
2003	10/1	Kill	Alfalfa		
2003	10/1	Manure	Beef	1,882	kg/ha
2003	10/25	Tillage	Moldboard Plow		
2004	4/1	Manure	Beef	1,882	kg/ha
2004	5/1	Tillage	Disk Plow		
2004	5/1	Manure	Beef	1,882	kg/ha
2004	5/20	Plant	Corn Grain		
2004	5/20	Fertilizer	09-23-30	224	kg/ha
2004	9/1	Manure	Beef	471	kg/ha
2004	10/1	Harvest/Kill	Corn Grain		
2004	10/1	Manure	Beef	471	kg/ha
2004	10/25	Tillage	Moldboard Plow		
2004	11/1	Manure	Beef	471	kg/ha
2005	4/20	Tillage	Disk Plow		
2005	4/25	Plant	Alfalfa		
2005	4/25	Plant	Alfalfa		
2005	9/5	Harvest	Alfalfa		
2005	10/1	Kill	Alfalfa		
2005	10/1	Manure	Beef	471	kg/ha
2005	10/25	Tillage	Moldboard Plow		

Continous Hay Pasture with Grazing (Gridcode 120)					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	4/1	Plant	Pasture		
2000	4/1	Manure	Dairy	420	kg/ha
2000	5/1	Manure	Dairy	420	kg/ha
2000	6/1	Manure	Dairy	420	kg/ha
2000	7/1	Manure	Dairy	420	kg/ha
2000	8/1	Manure	Dairy	420	kg/ha
2000	9/1	Manure	Dairy	420	kg/ha
2000	10/1	Manure	Dairy	420	kg/ha
2000	11/1	Manure	Dairy	420	kg/ha
2000	11/15	Kill	Pasture		
2001	4/1	Plant	Pasture		
2001	4/1	Manure	Dairy	420	kg/ha
2001	5/1	Manure	Dairy	420	kg/ha
2001	6/1	Manure	Dairy	420	kg/ha
2001	7/1	Manure	Dairy	420	kg/ha
2001	8/1	Manure	Dairy	420	kg/ha
2001	9/1	Manure	Dairy	420	kg/ha
2001	10/1	Manure	Dairy	420	kg/ha
2001	11/1	Manure	Dairy	420	kg/ha
2001	11/15	Kill	Pasture		
2002	4/1	Plant	Pasture		
2002	4/1	Manure	Dairy	420	kg/ha
2002	5/1	Manure	Dairy	420	kg/ha
2002	6/1	Manure	Dairy	420	kg/ha
2002	7/1	Manure	Dairy	420	kg/ha
2002	8/1	Manure	Dairy	420	kg/ha
2002	9/1	Manure	Dairy	420	kg/ha
2002	10/1	Manure	Dairy	420	kg/ha
2002	11/1	Manure	Dairy	420	kg/ha
2002	11/15	Kill	Pasture		
2003	4/1	Plant	Pasture		
2003	4/1	Manure	Dairy	420	kg/ha
2003	5/1	Manure	Dairy	420	kg/ha
2003	6/1	Manure	Dairy	420	kg/ha
2003	7/1	Manure	Dairy	420	kg/ha
2003	8/1	Manure	Dairy	420	kg/ha
2003	9/1	Manure	Dairy	420	kg/ha
2003	10/1	Manure	Dairy	420	kg/ha
2003	11/1	Manure	Dairy	420	kg/ha
2003	11/15	Kill	Pasture		
2004	4/1	Plant	Pasture		
2004	4/1	Manure	Dairy	420	kg/ha
2004	5/1	Manure	Dairy	420	kg/ha
2004	6/1	Manure	Dairy	420	kg/ha
2004	7/1	Manure	Dairy	420	kg/ha
2004	8/1	Manure	Dairy	420	kg/ha
2004	9/1	Manure	Dairy	420	kg/ha
2004	10/1	Manure	Dairy	420	kg/ha
2004	11/1	Manure	Dairy	420	kg/ha
2004	11/15	Kill	Pasture		
2005	4/1	Plant	Pasture		
2005	4/1	Manure	Dairy	420	kg/ha
2005	5/1	Manure	Dairy	420	kg/ha
2005	6/1	Manure	Dairy	420	kg/ha
2005	7/1	Manure	Dairy	420	kg/ha
2005	8/1	Manure	Dairy	420	kg/ha
2005	9/1	Manure	Dairy	420	kg/ha
2005	10/1	Manure	Dairy	420	kg/ha
2005	11/1	Manure	Dairy	420	kg/ha
2005	11/15	Kill	Pasture		

Appendix C

Subwatershed and ECRW Model Calibration Parameter Summary

SWAT HYDROLOGY SUBWATERSHED CALIBRATION PARAMETERS

Basin ID	North Fork Eau Claire River (Soil Type 13, 20, 25)	North Fork Eau Claire River (Soil Type 15, 26)	Mead Lake (Soil Type 15,26,58	Mead Lake (Soil Type 20)	Mead Lake (Soil Type 43)	Mead Lake (Soil Type 56)	Muskrat Creek (Soil Type 43)	Muskrat Creek (Soil Type 48)	Muskrat Creek (Soil Type 56)	Muskrat Creek (Soil Type 58)	Coon Fork (Soil Type 48, 54)	Coon Fork (Soil Type 56, 62)	Hay Creek (Soil Type 15,26,58	Hay Creek (Soil Type 43)	Hay Creek (Soil Type 50)	Hay Creek (Soil Type 56)	Hay Creek (Soil Type 48)
EC Final Basin #	13,17	13,17	3,9,14,15	3,9,14,15	3,9,14,15	3,9,14,15	2,7,24	7,24	7,24	7,24	4,12,27,28	4,12,27,28	2,8,25	2,8,25	2,8,25	2,8,25	2,8,25
Calibration Points (Days)	6484	6484	180	180	180	180	365	365	365	365	120	120	365	365	365	365	365
CN - Alf	59	72	71	64	64	64	59	35	---	72	54	55	65	50	50	---	37
CN - Soy	78	85	85	78	78	78	78	---	---	85	60	69	72	78	---	---	---
CN - Corn	77	83	83	77	77	77	77	67	---	83	60	69	71	76	76	---	67
CN - CSIL	---	83	83	77	77	77	77	67	---	83	60	69	71	76	76	---	67
CN - PAST	---	79	---	---	---	---	69	---	---	---	31.5	47	---	---	56	56	49
CN - SF Till	76	74	84	69	69	69	76	75	---	74	51	59	63	65	65	---	75
CN - Wetl	69	79	64	52	52	52	69	49	69	79	31.5	48.6	76	62	62	62	44
CN - Grass	---	72	66	54	54	54	59	31	59	72	38.5	46.8	67	53	---	---	39
CN - FRST	60	73	64	52	52	52	60	36	60	73	38.5	45	67	54	54	54	35
CN - URB	---	85	80	66	66	66	---	---	---	---	---	---	85	---	---	---	---
SOL_BD	1.67	1.75	1.8	1.92	1.74	1.8	1.73	1.73	1.28	1.73	1.27	1.27	1.73	1.28	1.18	1.34	1.34
SOL_AWC	0.12	0.19	0.18	60	61.2	60	0.14	0.04	0.7	0.18	0.19	0.2	0.17	0.14	0.24	0.05	0.06
SOL_K	143.63	11.96	11.32	0.1	0.14	0.08	59	510	884.7	15.34	30	53.59	11.05	42.63	1.28	60	60
ESCO	0.975	0.975	0.516	0.516	0.516	0.516	0.5	0.5	0.5	0.5	0.95	0.95	0.40	0.40	0.40	0.40	0.40
GW_Delay	221.779	221.779	255	255	255	255	223	223	223	223	291.97	291.97	150.73	150.73	150.73	150.73	150.73
ALPHA_BF	0.002	0.002	0.0095	0.0095	0.0095	0.0095	0.0001	0.0001	0.0001	0.0001	0.01529	0.01529	0.0001	0.0001	0.0001	0.0001	0.0001
GWQMN	0.036	0.036	---	---	---	---	0.0605	0.0605	0.0605	0.0605	0.0376	0.0376	0.0388	0.0388	0.0388	0.0388	0.0388
GW_REVAP (Other HRUs)	0.048	0.048	0.10	0.10	0.10	0.10	0.12	0.12	0.12	0.12	0.2	0.2	0.1353	0.1353	0.1353	0.1353	0.1353
GW_REVAP (Wetlands)	---	---	0.20	0.20	0.20	0.20					0.2	0.2	0.1353	0.1353	0.1353	0.1353	0.1353
REVAPMN (Other HRUs)	0.190	0.190	0.08	0.08	0.08	0.08	0.1491	0.1491	0.1491	0.1491	0.269	0.269	59.239	59.239	59.239	59.239	59.239
REVAPMN (Wetlands)	---	---	0.00	0.00	0.00	0.00					0	0	59.239	59.239	59.239	59.239	59.239
SFTMP	1.000	1.000	---	---	---	---	1	1	1	1	---	---	1	1	1	1	1
SMTMP	-1.494	-1.494	---	---	---	---	-1.115	-1.115	-1.115	-1.115	---	---	-1.439	-1.439	-1.439	-1.439	-1.439
SMFMX	6.358	6.358	---	---	---	---	0.385	0.385	0.385	0.385	---	---	0.563	0.563	0.563	0.563	0.563
SMFMN	0.141	0.141	---	---	---	---	1.488	1.488	1.488	1.488	---	---	1.926	1.926	1.926	1.926	1.926
COVMX	3.189	3.189	---	---	---	---	0.279	0.279	0.279	0.279	---	---	2.263	2.263	2.263	2.263	2.263
50COV	0.018	0.018	---	---	---	---	0.411	0.411	0.411	0.411	---	---	0.0354	0.0354	0.0354	0.0354	0.0354
TIMP	0.063	0.063	---	---	---	---	0.315	0.315	0.315	0.315	---	---	0.128	0.128	0.128	0.128	0.128
SURLAG	1.000	1.000	1	1	1	1	1	1	1	1	4	4	1	1	1	1	1
CANMX (Cropped HRUs)	---	---	10.00	10.00	10.00	10.00	---	---	---	---	---	---	---	---	---	---	---
CANMX (Other HRUs)	---	---	20.00	20.00	20.00	20.00	---	---	---	---	---	---	---	---	---	---	---

SWAT SEDIMENT AND PHOSPHORUS SUBWATERSHED CALIBRATION PARAMETERS

Basin ID	**North Fork Eau Claire River**	**Mead Lake**	**Muskrat Creek**	**Coon Fork**	**Hay Creek**
EC Final Basin #	13,17	3,9,14,15	7,24	4,12,27,28	2,8,25
Calibration Points (Months)	---	11	10	6	10
USLE_P (Cropped HRUs)	---	0.5	0.5	0.5	0.5
SLSUBBSN (Cropped HRUs)	---	50	---	---	---
SLOPE (Cropped HRUs)	---	30% Reduction	30% Reduction	30% Reduction	30% Reduction
FILTERW (All HRUs)	---	24.25	---	2.00	---
APM	---	0.640	0.50	0.80	0.60
SOL_LABP (Cropped HRUs)	---	21 - 44	54 - 58	40 - 58	54-58
PHOSKD	---	20.00	175.00	75.00	125.00
UBP	---	5.00	60.00	20.00	20.00
ERORGP	---	10.00	0.00	10.00	0.00
GWSOLP	---	0.08	0.000	0.08	0.00
PSP	---	0.300	0.65	0.65	0.5

SWAT HYDROLOGY, SEDIMENT, AND PHOSPHORUS WATERSHED CALIBRATION PARAMETERS

	Soil Number 56,54,48,64,46	Soil Number 13,20,62,43	Soil Number 49,58,15,25,26	Soil Number 50
CN – Alf	45	58.5	72	76.5
CN-Soy	58.5	64.8	72.9	76.5
CN-Corn	58.5	64.8	72.9	76.5
CN-Pasture	36	49.5	61.2	67.5
CN-Forest	40.5	49.5	56.7	65.7
CN-Grassland	40.5	49.5	56.7	65.7
CN-Wetland	54	54	54	54
CN-Urban	70	75	80	85
OV-N	0.1 Ag Row Crop 0.2 Forest/Grass, 0.15 Pasture 0.05 Wetland	0.1 Ag Row Crop 0.2 Forest/Grass, 0.15 Pasture 0.05 Wetland	0.1 Ag Row Crop 0.2 Forest/Grass, 0.15 Pasture 0.05 Wetland	0.1 Ag Row Crop 0.2 Forest/Grass 0.15 Pasture 0.05 Wetland
Soil BD	Default	Default	Default	Default
Soil AWC	Default	Default	Default	Default
Soil K	Default	Default	Default	Default
ESCO	0.9	0.9	0.9	0.9
GW Delay	130	130	130	130
Alpha BF	0.1	0.1	0.1	0.1
GW QMin	50 Wetland 20 Other	50 Wetland 20 Other	50 Wetland 20 Other	50 Wetland 20 Other
GW Revap	0.5 Wetland 0.1 Other	0.5 Wetland 0.1 Other	0.5 Wetland 0.1 Other	0.5 Wetland 0.1 Other
GW RevapMn	0.0 Wetland 0.05 Other	0.0 Wetland 0.05 Other	0.0 Wetland 0.05 Other	0.0 Wetland 0.05 Other
SFTMP	1.0	1.0	1.0	1.0
SMTMP	0.5	0.5	0.5	0.5
SMFMX	4.5	4.5	4.5	4.5
SMFMN	1.5	1.5	1.5	1.5
COVMX	1.0	1.0	1.0	1.0
50COV	0.5	0.5	0.5	0.5
TIMP	0.5	0.5	0.5	0.5
SURLAG	1.0	1.0	1.0	1.0
CANMX	50	50	50	50
USLEP	0.20	0.20	0.20	0.20
SLSUBBSN	70% Default	70% Default	70% Default	70% Default
SLOPE	70% Default	70% Default	70% Default	70% Default
FILTERW	22	22	22	22
APM	0.60	0.60	0.60	0.60
PHOSKD	10	10	10	10
ERORGP	20	20	20	20
UBP	10	10	10	10
GWP	0.07	0.07	0.07	0.07
PSP	0.40	0.40	0.40	0.40

Appendix D

ECRW Model Datasets CD