Missouri Department of Natural Resources

FLAT CREEK WATERSHED

COMPUTER BASED EVALUATION OF THE AGNPS-SALT PROJECT

FAPRI-UMC Report #13-06

August, 2006

College of Agriculture Food and Natural Resources

FAPRI At the University of Missouri Food and Agricultural Policy Research Institute

Food & Agricultural Policy Research Institute (FAPRI)
University of Missouri

Published by the Food and Agricultural Policy Research Institute (FAPRI), University of Missouri-Columbia, 2006
http://www.fapri.missouri.edu

The Missouri Department of Natural Resources has provided funding for this project under a grant entitled "Development of Customized Watershed Simulation Tool". Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the Missouri Department of Natural Resources.

The Food and Agricultural Policy Research Institute at the University of Missouri (FAPRI) is charged with providing objective, quantitative analysis to decision makers. Since 1984, this service has been provided to Congress and national trade associations, and has focused on commodity policy issues.

In 1995, the unit was asked to expand its focus and begin to bring the same level of effort to environmental issues, that of providing objective, analytical support. The unit spent considerable time examining the problems and determined the area most lacking analysis was at the local level; the farm, the watershed, and the local community.

Similar to the extensive peer-review effort the unit goes through on national commodity policy issues, the environmental analysis effort recognizes the strong need for local involvement. If the local people who must live with the analysis have doubts about the way the analysis was developed, then the effort is wasted. Consequently, the process FAPRI brings to the table also incorporates extensive local input with respect to data sources and model calibration.

ACKNOWLEDGMENTS

The following participated and/or provided support for the Flat Creek AgNPS-SALT evaluation.

Food and Agricultural Policy Research Institute, University of Missouri-Columbia
Claire Baffaut, Walaiporn Intarapapong, Verel Benson

Missouri Department of Natural Resources
Gary Baclesse, Kenny Struemph, Dean Martin, Davin Althoff

U.S.D.A. Natural Resources Conservation Service
Robert Ball, Dan Philbrick, Tina Mills

University of Missouri
Stephen H. Anderson, Robert Broz, Patrick Guinan, William B. Kurtz

Barry County Soil and Water Board of Supervisors and Flat Creek watershed steering committee
Jeff Holder, Marie Liams, Voyd Brown, Jerry Yarnell, Toni Richard, Ron Black, Sally Ann Sparlock, Phillip Brooks, Bud Amos, Don Bowen, Garry Bartkoski

EXECUTIVE SUMMARY

The major concerns regarding water quality of the Flat Creek watershed are associated with nutrient and sediment. A total of 48 poultry operations produce 20 million birds annually in this watershed. These birds produce over 940,000 pounds of elemental phosphorus annually, which poses the biggest concern on water quality to this watershed. In addition, improper livestock management causes erosion and stream bank instability. To improve the water quality, the Agricultural Nonpoint Source-Special Area Land Treatment (AgNPS-SALT) program sponsored a number of conservation practices with technical and financial assistance through the Barry County Soil and Water Conservation District (SWCD). The AgNPS-SALT program focused on agricultural and land management activities that influence sediment and nutrient loading through agricultural conservation practices.

The purpose of this study was to assess the change in nutrient and sediment loads in the Flat Creek watershed due to the conservation practices proposed under the AgNPS-SALT program using watershed-scale computer modeling with the Soil and Water Assessment Tool (SWAT). The ability of the SWAT model to simulate the conservation practices associated with the AgNPS-SALT projected was evaluated.

Results showed a reduction in nutrients from implementing nutrient management, waste transport, grazing management, erosion control, woodland management, and riparian corridor management. Most of the conservation practices, except nutrient management and waste transport, showed sediment reductions. The reductions varied by practice. The reductions in sediment and nutrients at the outlet, which included the nutrient and sediment loads from the entire watershed, were similar to the reductions at the subbasin level, which accounted for nutrient and sediment runoff before reaching the stream. Due to the temporal variability, the average amount of nutrients and sediment simulated by the model might not be observed on a year-to-year basis.

Conservation practices whose effects are influenced by human factors could not be simulated, i.e., information and education, because the outcome is difficult to quantify. The model was able to simulate the practices that are implemented on the ground: nutrient management, waste transport, grazing management, erosion control, woodland management, and riparian corridor management.

The SWAT model can be used as an effective tool to quantify the amount of nutrient and sediment loads that varied due to agricultural management practices and physical characteristics, such as soil properties, topography, and hydrology. The information on pollutant load reductions from implementing conservation practices can be useful for the agencies in prioritizing the practices to achieve the optimal environmental impacts under the constrained resources.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Watershed Information

Flat Creek watershed is located in Barry County. Flat Creek flows through the watershed from south to north and eventually into the James River and Table Rock Lake. The watershed covers 72,990 acres and is included in the Ozark Highland-Major Land Resource Area 116A. The topography ranges from flat on the broad upland ridges to very steep in the breaks along the drainages. Soil types on flat slopes include the Tonti, Scholten, Nixa and Claiborne series. The Hailey and Clarksville series are found on the steeper slopes.

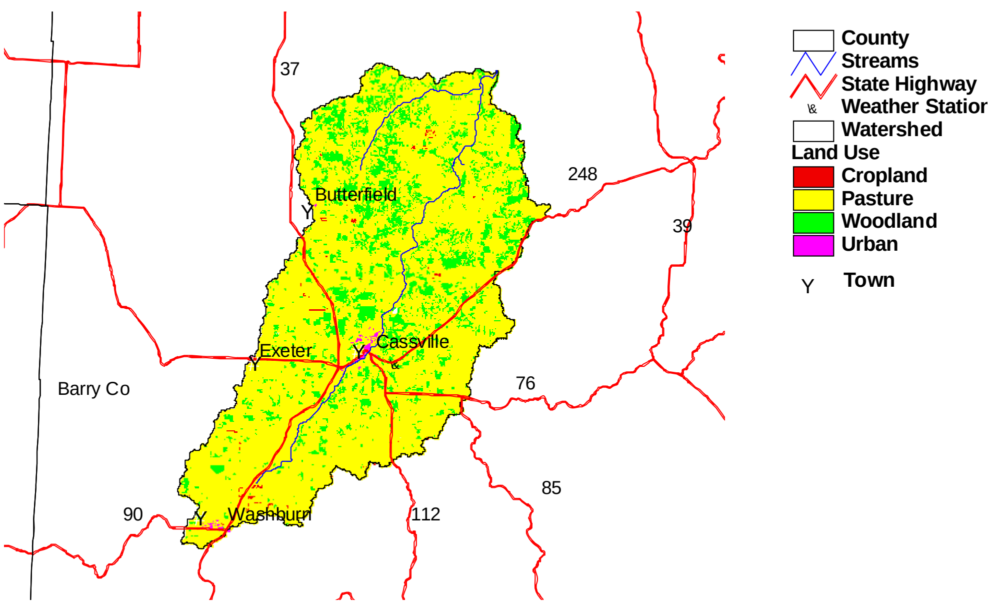

Figure 1. Flat Creek watershed location map and land use (1992 satellite image).

It is estimated that 38,166 acres out of 72,990 need some treatment. To improve acres that need treatment, the AgNPS-SALT project set the target acreage of land (16,835 acres) to be treated by conservation practices (Table 1). In addition, 12 streambank miles will be treated to reduce the sediment loads (Table 1).

Table 1. Land use data, AgNPS-SALT project proposal.

	Acres	**% of Total Land Use**	**Acres Needing Treatment**	**Acres Treated**
Cropland	2,190	3.00	1,700	250
Pasture/hayland	57,009	78.00	32,495	16,085
CRP Land	15	0.02	0	0
Urban	1,942	2.65	971	
Woodland	11,754	16.23	3,000	500
Publicly Owned	80	0.10	0	
Total	72,990	100.00	38, 166	16,835
Stream (miles)	79		15	12

The number of poultry growers continues to increase in this watershed. Some poultry farms have been sold to new poultry producers who have little experience. Extensive environmental education is required for the new poultry producers to properly manage their farms.

The major land use is pasture and hay lands that make up 78% (57,009 acres) of the entire watershed. Overgrazing causes the land to erode in excess of tolerable levels and 57% (32,495 acres) need treatment. Sixteen percent of this watershed is woodland and 25% of the total woodland need treatment (Table 1). In addition, unlimited access of cattle to rivers and streams through the woodland caused a decline in the stability of the stream banks and riparian corridors.

Analytical Tool

The baseline scenario was developed by recognizing the initial conditions of the watershed. The model input requirements were electronic land cover and soil maps, digital elevation model (DEM), soil database, climate data collected from nearby weather stations, and information about the management of the land. The SWAT version 2003 and the AVSWATX GIS interface were used in this study.

The AVSWATX interface was used to delineate the watershed and divide it into subbasins. The digital maps of land cover and DEM were obtained from the Missouri Spatial Data Information Service (http://msdisweb.missouri.edu), while soil information (STATSGO) was obtained from the National Resource and Conservation Service (NRCS; http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo). Daily precipitation and temperature data from 1971-2003 were obtained from the Cassville weather station (Figure 1) and provided by Dr. Patrick Guinan at the Missouri Climate Center at the University of Missouri Department of Soil, Environmental, and Atmospheric Sciences. Monthly rainfall and temperature were derived from a 32-year long series of daily values.

The information on typical agricultural land management for the baseline scenario was gathered during a meeting with the watershed steering committee. The committee consisted of landowners in the watershed who participated in the AgNPS-SALT program and members of the board of supervisors of the Barry County SWCD.

Approximations

To build a model with close approximation to reality, digital maps that contained land topography, streams, land use, and soils were incorporated. The heterogeneity of such information enabled the determination of 6 subbasins (Figure 2). The management practices developed for the simulation along with the current land use were applied to the watershed.

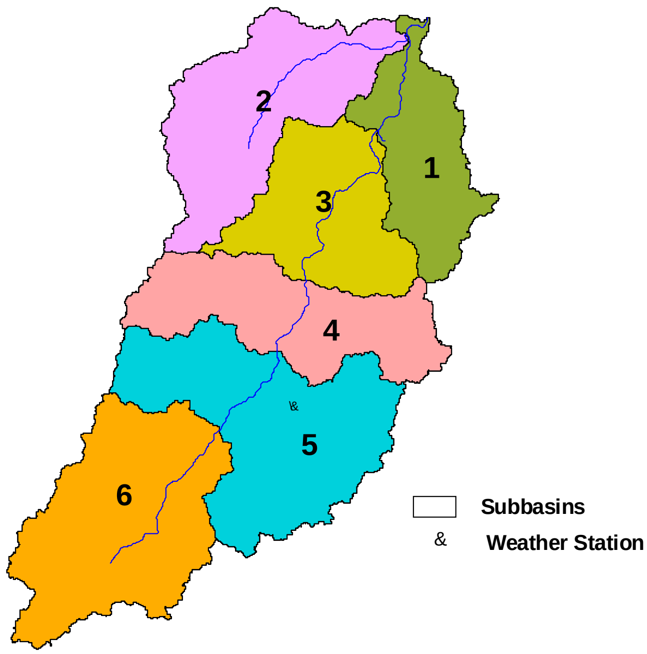

Figure 2. Subbasins of the Flat Creek watershed

The digital land use map used in this study was based upon 1992 satellite images and produced proportions of land use that are close to the land use distribution in the AgNPS-SALT proposal (Table 2). The differences can be explained by differences in interpretation of grassland:

- Forage crops such as alfalfa are included in the grassland category in the 1992 satellite image but in the cropland category by NRCS.

- The 30m resolution of the satellite image does not detect low intensity residential areas in and around Cassville and counted these areas as grassland. There may also be some growth of the town between 1992 and 2000.

Table 2. Percentage of land use distribution.

Land use	**AgNPS-SALT** (%)	**1992 satellite image** (%)
Cropland	3	<1
Pasture/hayland	78	84
Woodland	16	16
Urban	3	<1
Total	100	100

Limitations of the SWAT model

The alternative conservation practices under the AgNPS-SALT program included nutrient management, waste transport, grazing management, erosion control, woodland management, and riparian corridor management. These practices are all or partly simulated with the SWAT model. Due to limitations of the model, some proposed practices were not addressed. The SWAT model cannot estimate how education and training efforts affect the behavior of the producers and land managers. Therefore, an evaluation of the impact of meetings, education, training, and farm visits was not included in the study. Practices that affect groundwater quality (well decommission) were not addressed because the SWAT model does not currently completely track the quality of the groundwater.

The model could not be calibrated for flow or water quality because of a lack of data. No flow gauge exists in this watershed and no prior water quality monitoring program was operating to provide data against which to evaluate the results of the model.

Instead we used information obtained from the calibration of the SWAT model for two adjacent watersheds: Shoal Creek and the James River.

Scenarios

Scenarios presented in this study include the baseline and alternative scenarios. The baseline represented the conditions of agricultural practices before the AgNPS-SALT project was started. Pasture land was divided according to its condition. The SWAT2003 has capacity to partition each Hydrologic Response Unit (HRU) into smaller units. In the Flat Creek watershed, the pastures and hay land were partitioned into four parts. Pastures in poor condition (40% of total pasture land) were assumed to be those needing treatment; 23% and 7% were assumed to be in fair and good conditions, respectively. Hay land accounted for the remaining 30%. Woodland was classified into poor (26%) and fair conditions (74%).

Several alternative scenarios were defined: one for each best management practice (BMP) implemented on the target acreage of the AgNPS-SALT project, and one for each BMP implemented on all acres needing treatment. These scenarios evaluate the effectiveness of each BMP at the watershed level. The final scenario combined all the BMPs proposed in the project and enables evaluation of the impact of the AgNPS-SALT project as a whole. The nutrient and sediment loads from the baseline scenario were estimated and compared to the loads from the alternative scenarios.

In each scenario, the BMP was simulated on land or stream banks in poor condition that were part or all of the acres needing treatment. The numbers of acres needing treatment were obtained from the AgNPS-SALT proposal prepared by the Barry County SWCDs. The combined BMP scenario addressed the nutrient and sediment reductions when all the conservation practices were implemented on the target acreages simultaneously.

Baseline Scenario

The baseline scenario was developed to represent the typical land use, physical characteristics (topography and climate), and agricultural management practices in the watershed. Cropland and urban area were not included in the model because they represent a very small fraction of the watershed. The sediment, nitrogen, and phosphorus loadings generated in the baseline scenario were established.

In addition to topographic, soil, and land use information previously described, current representative agricultural management practices are key elements to determine the environmental outcomes. Under the baseline scenario, typical grazing management for the region was applied for the watershed. Cattle were rotated between two pastures. They grazed 60 days in each area during Spring and Fall, and 30 days in summer. During the winter, from mid December until the end of March, the cattle were moved to a wooded winter area where they were fed. Hay was harvested in May and September. Both summer pastures and the hay field were fertilized at the beginning of March. See Appendix A for a complete description of the management.

Some information which could be used in the baseline was not available. For instance, access to the stream by cattle implies that livestock spend some time in the streams and deposit some manure directly into the water. Excluding cattle from streams therefore not only contributes to a more stable and less erodible bank, it also decreases the nutrient load directly deposited in the stream. However, the number of animals having access to the streams was not known. Since we could not estimate the amount of manure directly deposited into the streams, we did not address that aspect. In addition, due to insufficient information about their number, size, and drainage area, ponds were not included in the baseline.

BMPs on Target Acres Scenario

Through the project, conservation practices are being introduced in the Flat Creek watershed on a certain number of acres (the target acres). However, these acreages did not include all acres needing treatment. For instance, 2,825 target acres are proposed for pasture improvement while the pasture and hay land needing treatment represents 32,500 acres. Only 5% of total pasture and hay land will be treated by implementing grazing management with cost share. To assess the environmental improvement due to the program, the “BMP on target acres” scenario was developed. This scenario carried the same physical characteristics and climate information as the baseline scenario. Replacement of the conventional practices by conservation practices caused some changes in the environmental parameters used in SWAT, and, consequently, impacted the nutrient and sediment runoff. Details about each simulated practice are given in Appendix B.

BMPs on All Acres Needing Treatment Scenario

Since the BMPs introduced under the AgNPS-SALT project covered only part of all acres needing treatment, this study further assessed the environmental impacts if conservation practices were applied to all the acres needing treatment. This is called the “all acres needing treatment” scenario. It evaluates the full potential benefit of each proposed practice in the watershed.

Combined BMPs Scenario

Under the combined BMPs scenario, the nutrient and sediment reduction of all the conservation practices proposed by the AgNPS-SALT program were assessed simultaneously. The sediment and nutrient loadings generated by this scenario were developed and compared to the loadings from the baseline scenario. This scenario estimates the total impact of the AgNPS-SALT project.

Results

The study focused on the outputs from the subbasins and at the outlet of the Flat Creek watershed. The nutrient and sediment loadings transported by the stream result from what is contributed to the stream by the land surrounding it and from the stream capacity, given its size and slope. Subbasin contributions are averaged over all the subbasins in the watershed. We call them yields and express them on a per-unit-area basis. Stream loadings are reported at the outlet of the watershed.

Baseline Scenario

Subbasin contributions

The estimated average annual sediment yield and nutrient runoff per acre (Table 3) were based on 30 year long simulated runs. Due to weather variability from year to year, these results are unlikely to be observed on a year-to-year basis. Table 3 also shows that the range of annual values obtained for each of the variables can vary by an order of 10.

Table 3. Estimated average annual sediment and nutrient yields in the baseline scenario.

	Annual Average	Range of annual values
Sediment Yield (tons/ac/yr)	0.11	0.03 – 0.3
Total Nitrogen (lbs/ac/yr)	1.7	0.5 – 4.6
Total Phosphorus (lbs/ac/yr)	1.3	0.2 – 2.7

The temporal variability was calculated as the minimum and maximum annual value obtained during the 30 simulated years. For sediment, for example, an annual variability indicates that the expected annual value of sediment could vary between 0.03 and 0.3 tons/ac/yr.

Stream loads

The outlet of the Flat Creek watershed is located at the outlet of subbasin 1. Sediment and nutrient loads transported by streams in the watershed go through this channel outlet and are total loads transported from the entire watershed (Table 4).

Table 4. Environmental impacts of the baseline scenario at the outlet.

	Sediment (tons/year)	**Nitrogen** (lbs/year)	**Phosphorus** (lbs/year)
Flat Creek watershed (Subbasin 1)	3,462	1,105,340	89,349

BMPs on Target Acres and Combined BMPs

Subbasin contributions

Reductions in sediment and nutrient yields that can be expected from each practice and from the combined BMPs are presented in Table 5. When the conservation practices were implemented simultaneously under the combined BMPs scenario, the reduction in the average annual sediment yields was 6%. This reduction was due in large part to better grazing management which improved pasture condition. Switching to a fertilization schedule adopted to the plant needs (nutrient management practice) resulted in a reduction in nutrients, and an increase in sediment.

Erosion control showed no change in the sediment because the target area was 140 acres compared with total acres of pasture and hay land needing treatment of 32,500 acres. Lack of information on the number, the nature, ant the location of the critical areas limited the capability to assess the full impact of the erosion control management. This is a major thrust of the U.S. Department of Agriculture Conservation Effects Assessment Program (CEAP) and research in that area is being undertaken.

Table 5. Expected impacts of the AgNPS SALT project at the subbasin level, percentage change in pollutant yields from the baseline.

	Sediment (% change)	**Surface Nitrogen** (% change)	**Groundwater Nitrogen** (% change)	**Phosphorus** (% change)
Nutrient Management	3	-4	-9	-8
Waste Transport	0	0	-3	- 4
Grazing Management	-8	-3	-1	-2
Erosion Control	0	0	0	0
Woodland Management	0	-3	0	0
Riparian Corridor Management	-1	-2	-1	-1
Combined BMPs	-6	-9	-11	-14

Nutrient yields, particularly nitrogen in groundwater were mostly reduced by nutrient management: fertilizing according to plant needs and transporting poultry litter out of the watershed. The low reductions in nutrient yields from riparian management were partly due to not taking into account the reduction of manure directly deposited in the streams when cattle did not have access to the streams any more, and the small amount of miles being treated. The combined BMPs resulted in nitrogen reductions of 9% and 11% from surface runoff and groundwater leaching, respectively (Table 5).

Applying the amount of phosphorus fertilizer according to the plants' nutrient need on nutrient management contributed to the highest phosphorus reduction rate compared with waste transport and grazing management. Total phosphorus reduces by 14% when all the conservation practices were conducted simultaneously under the combined BMPs scenario (Table 5).

Stream loads

Table 6 presents the reductions of stream loadings at the outlet of the watershed when BMP practices were implemented. Nutrient management showed the significant reductions in nitrogen and phosphorus compared with waste transport and riparian corridor management. Implementation of grazing management resulted in some reduction in sediments and phosphorus but showed an increase in nitrogen (Table 6). Reductions in surface nitrogen were simulated by the model, especially in organic nitrogen that adsorbs to soil particles and only moved if there was erosion. The model predicted an increase in leached nitrate which then returned to the stream with groundwater. This caused the total loadings of nitrate and total nitrogen in the stream to increase.

Table 6. Expected impacts of the AgNPS-SALT project at the outlet, percentage change in stream loads from the baseline

	Sediment (% change)	**Nitrogen** (% change)	**Phosphorus** (% change)
Nutrient Management	2	-7	-8
Waste Transport	0	-2	-4
Grazing Management	-5	3	-2
Erosion Control	0	0	0
Woodland Management	0	0	0
Riparian Corridor Management	-14	-1	-1
Combined BMPs	-17	-7	-14

Nutrient management and waste transport were among the BMPs that contributed to the high reduction in phosphorus in comparing with the others. The combined BMPs scenario represented a 14% reduction in the phosphorus stream loads (Table 6).

BMPs on all acres needing treatment

Subbasin contributions

Riparian corridor management would be the most effective approach to reduce nitrogen especially on surface runoff if it were to be implemented to the entire watershed (Table 7). Grazing management and erosion control would be the most effective approaches to reduce sediment (Table 7). Phosphorus would be reduced significantly by riparian corridor management, nutrient management, grazing management, and erosion control. It is noted that the sediment and nutrient reductions from grazing management and erosion were similar. In the SWAT simulation process, the same associated parameters to improve pasture condition were applied on both management practices. When applied on the same areas of all pasture needing treatment, it yielded the similar results.

Table 7. Expected impacts of BMPs implemented on all acreage needing treatment at the subbasin level, percent change from the baseline.

	Sediment Yields (% change)	**Surface Nitrogen** (% change)	**Groundwater Nitrogen** (% change)	**Phosphorus** (% change)
Nutrient Management	14	-23	-40	-47
Waste Transport	4	0	-7	-12
Grazing Management	-78	-23	0	-34
Erosion Control	-78	-23	0	-34
Woodland Management	-1	0	0	0
Riparian Corridor Management	-66	-62	-33	-62

Stream loads

The Riparian corridor management implemented along all streams needing treatment would cause a significant reduction in sediment and phosphorus. Grazing management and erosion control also would result in significant reductions in sediment and phosphorus while they would cause an increase in nitrogen (Table 8). Woodland management and waste transport showed the smaller reductions in sediment and nutrient relatively to other conservation practices (Table 8). The impact of these practices is limited by the current amount of poultry litter being spread and the relatively small acres of woodland that need improvement compared with the acres of grassland.

Table 8. Expected impacts of BMPs on all acreage needing treatment at the outlet, percentage change from the baseline.

	Sediment (% change)	**Nitrogen** (% change)	**Phosphorus** (% change)
Nutrient Management	7	-36	-47
Waste Transport	0	-7	-12
Grazing Management	-49	19	-33
Erosion Control	-49	19	-33
Woodland Management	-1	-1	0
Riparian Corridor Management	-66	-36	-62

Conclusions

Nutrient management and waste transport were among the most effective practices to reduce phosphorus and nitrogen, which are the main concerns associated with the water quality in the Flat Creek watershed. Nutrient management showed the highest reduction rates in the subbasin contributions and stream loads. The nutrient reduction rates from this practice were similar at the subbasin level and at the outlet.

Grazing management showed a higher reduction in sediment yields at the subbasin level compared with the watershed outlet. When was this practice extended to all acres needing treatment, sediment and phosphorus were significantly reduced, while there was a small nitrogen reduction at the subbasin level and increased nitrogen loads at the outlet.

When each application was extended to the entire acreage needing treatment, the reductions obtained with riparian corridor management resulted in high reduction rates for sediment and nutrient contributions to the streams and the stream loads. Riparian corridor management showed a higher reduction rate in sediment loads at the watershed outlet compared with the subbasin level, while the nutrient runoff at the subbasin and the outlet were the same. When extended to all stream miles needing treatment, it showed the highest reductions in sediment and nutrient at both the subbasin level and the outlet.

The conservation practice of erosion control and woodland management showed the smallest percentage of sediment and nutrient reductions when applied to the target scenario, which accounted for 5% and 0.3% of total woodland and pastureland, respectively. When extended to the total acres of woodland and pasture needing treatment, the reductions in sediment and nutrient loadings at the subbasin level increased significantly for erosion control compared with the loadings from woodland management.

The model was not able to address the sediment and nutrient reductions from erosion control because of the small acreage treated. The critical erosion conditions that are supposed to exist to justify applying this practice were not defined. This would have required either more information or an additional GIS-based process to identify these critical areas. In addition, SWAT2003 lacks the ability to simulate such specific areas. In this study, the associated parameters which contributed to an improvement in pasture conditions were used and applied to pasture land in general with no information on critical areas. For further study, another simulation program can be used at a smaller scale to capture the environmental contribution from critical areas. The results can be used as inputs to SWAT simulations.

When all of the conservation practices were implemented simultaneously on the target acres under the combined BMPs scenario, the sediment and nutrient reductions were significant. The comparisons were based on long-term (30 year) averages and the expected reductions may not be observed on a year-to-year basis due to weather variability. Therefore, short-term water quality measurements might not show any improvement. However, the results indicated reductions in sediment and nutrient loads when the conservation practices were implemented.

Appendix A. Baseline grazing management

Under the baseline scenario cattle were rotated across two pastures every two months in Spring and Fall, and one month in summer. Cows were left in the woodland for protection during the winter.

Table A1. Grazing periods of conventional grazing system on the Flat Creek watershed.

Date	**Operation**	**Amount**
Pasture 1		
March 11	Fertilizer 17-17-17	295 lbs/ac
March 26- May 15	Grazing	51 days, 1.5 acres/cow
July 16- August 15	Grazing	31 days, 1.5 acres/cow
October 16 – December 15	Grazing	61 days, 1.5 acres/cow
Pasture 2		
March 12	Fertilizer 17-17-17	295 lbs/ac
May 16- July 15	Grazing	61 days, 1.5 acres/cow
August 16- October 15	Grazing	61 days, 1.5 acres/cow
Hay		
March	Fertilizer 17-17-17	295 lbs/ac
May	Harvest	
September	Harvest	

Appendix B. BMP Simulation

Nutrient Management

The purpose of nutrient management is to optimize nutrient application rates while ensuring that the crops have the required nutrients to grow at their full potential and minimizing nutrient loadings to the streams. Nutrient management includes the determination of nutrient needs as a function of the soil chemical composition, the crop grown, and the expected yield. The target acres were 7,680 acres of grassland. The auto fertilization that attempted to match the nitrogen and phosphorus to plant nutrient need was applied on the simulation.

Waste Transport

The purpose of waste transport is to manage a large surplus of poultry litter which potentially causes water quality degradation due to nutrient runoff. Waste transport included manual transfer out of the watershed. The target amount proposed in AgNPS-SALT was 19,000 cubic yards. This amount was equivalent to 40% of total poultry litter application on pasture. In this scenario, 40% of pastures fertilized with poultry litter in the case were now fertilized with chemical fertilizer of 17-17-17 at the rate of 295 lbs/acre.

Grazing management

The goal of this practice (DSP-3, DSP-33 DSP-2, MDSP-2, WHIP) is to improve the ground cover, the quantity and quality of forage for cattle and of food for wildlife. Grazing areas and frequencies are based on the growth rates of forage, the season, and the livestock densities. Under the planned grazing system, shorter, more frequent grazing periods at higher grazing intensities were used on the area that required treatment to fertilize the soil and promote grass growth. The impacts were improved grass cover and reduced runoff. The target acres were 2,825 acres.

The planned grazing system was simulated by switching to more intensive grazing management – the number the pastures was four times instead of two, the duration of grazing on each was two weeks, and the grazing intensity was four times higher than the baseline level. Since the grass is of better quality and cattle are there for a shorter period of time, the grazing efficiency is better and there are less trampling losses.

Table B1 details the acreage of pasture in good, fair, and poor conditions in the baseline and the associated parameters. The condition of the pasture is characterized by the USLE cover factor (USLE_C), the curve number (CN), the minimum amount of biomass required for grazing to occur (BIO_MIN), and the Manning N coefficient. Poor conditions are characterized by a higher cover factor implying that soil erosion is more likely to occur due to poor ground cover, a higher curve number causes to less infiltration, the lower minimum amount of biomass required for grazing imply that cows are left in the pasture even though they should be moved to a different one (a characteristic of poor management). A lower Manning coefficient represents faster movement of surface runoff. Table B1 details these parameters for the different types of pasture.

Table B1**.** Input parameter values to describe pasture condition in the Flat Creek watershed

	USLE_C	CN Soil class B	CN Soil class C	BIO_MIN	Manning N	Baseline Acres
Good condition	0.003	63	76	700	0.20	3,990
Fair condition	0.003	71	81	450	0.15	13,112
Poor condition	0.011	81	88	250	0.10	22,804

Prescribed grazing was applied to pastures in poor condition and we assumed it would improve their condition to the "good" level.

Erosion Control

Erosion control included permanent vegetative cover establishment/improvement (DSL-1, DSL-2). The target acreages according to AgNPS-SALT were 140 acres. The model was not able to capture the sediment and nutrient reductions from erosion control because of the small acreage treated and the critical areas are not identified. To address the erosion control management in the simulation, pasture in poor condition was reduced by 0.3% (140 acres), while pasture in good condition increased by 0.3%. This may not simulate the impact of critical areas being treated.

Woodland Management

To protect the woodland acres that are susceptible to erosion, cattle usually left in the forest during the winter would be permanently removed from the woodland. The target acres of the woodland exclusion were 500 acres. The USLE_C were set at 0.003 and 0.011 for fair and poor conditions, respectively. The CN values of non-grazing woodland in fair condition were set at 62 and 75 for soil classes B and C, respectively. Where cows were left in the woodland and grazing was allowed, The CN of soil classes B and C was set to the poor condition: 66 and 77, respectively.

Riparian Corridor Management

The stream riparian corridor management included a forest buffer (N391, CCRP). The 129 target acres were converted into length based on 80 foot buffer width; the calculated total length of the buffers was 12 miles as proposed by the AgNPS-SALT.

The main purpose of this management practice is to reduce sediment and nutrient runoff from surface water, and reduce nutrient in shallow ground water flow. The sediment reduction due to stream exclusion was simulated by decreasing the bank erodibility (CH_EROD) and increasing its vegetation cover (CH_COV).

To estimate the overall CH_COV and CH_EROD, the 12 target stream miles in AgNPS-SALT were taken into account. The initial values of good and poor conditions of CH_COV used in this study were 0.1 and 0.5, respectively. For CH_EROD, the initial values used for good and poor conditions were 0.1 and 0.4, respectively. The overall CH_COV and CH_EROD were 0.12 and 0.11 compared with the baseline of 0.18 and 0.17. Details of the calculations appear in Appendix C. On filter strip, one acre-buffer was estimated to protect 8.3 acres. The target acre of 129 acres was equivalent to 1,071 buffer-acres. The filter strip of 80 feet wide was applied on an HRU which had the pasture area closed to the estimated buffet-acres of 1,071.

Combined BMPs Scenario

All of the BMPs mentioned above were included in the combined BMP scenario. The parameter specifications of this scenario were as follows.

1. The overall CH_COV and CH_EROD were 0.12 and 0.11, respectively.
2. The USLE_C factors for pasture in good, fair, and poor conditions were 0.003, 0.003, and 0.01. The USLE_C for woodland in fair and poor condition were 0.003 and 0.01, respectively.
3. The CN of soil B and C for the pasture under good, fair, and bad condition were 63 and 76, 71 and 81, and 81 and 88, respectively. The CN of soil B and C for the

woodland under fair and poor conditions were 62 and 75, and 66 and 77, respectively.

4. Pasture land in good condition increased 5%, while pasture land in poor condition decreased by 5% compared to the baseline. Woodland in fair condition increased 5%, while the poor condition woodland decrease by 5% compared to the baseline.
5. Auto fertilization was applied in some acres of pasture land.
6. Poultry litter application was taken out on some acres of pasture land in fair condition.
7. Grazing was not allowed in some acres of woodland.

Appendix C. Calculation of weighted average

Channel cover factor (CH_COV)

- The overall CH_COV was estimated according to the length of the treated stream. The initial values of 0.1 and 0.5 represented good and poor conditions, respectively.

$CH\_COV^{base} = [SNT*0.5+(STL-SNT)*0.1]/STL$

$CH\_COV^{BMP} = [(SNT-SAgT)*0.5+(STL-SNT+SAgT)*0.1]/STL$

Where: STL = total stream length;

SNT = stream length needing treatment; and

SAgT = target stream length to get treatment under AgNPS-SALT.

Channel erodibility factor (CH_EROD)

- The overall CH_EROD was calculated using a similar approach as CH_COV. The initial values of CH_EROD for good and poor conditions were 0.1 and 0.4, respectively.