Missouri Department of Natural Resources

MIAMI CREEK WATERSHED

COMPUTER BASED EVALUATION OF THE AgNPS-SALT PROJECT

FAPRI-UMC Report #18-06

September 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 Big Maries 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
Diane Bradley

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

Bates County Soil and Water District
Brad Powell

Board of Supervisors of Bates County Soil and Water District
Darrell Stevener, Rod Morris, Al Decker, Doug Cox, Mark Nelson

EXECUTIVE SUMMARY

Major water quality symptoms in Miami Creek are excessive sediment, nutrient, and pesticide loads, and stream bank instability. To improve the water quality, an Agricultural Nonpoint Source-Special Land Area Treatment (AgNPS-SALT) project was approved in 1998 to cost-share conservation practices and to provide technical assistance through the Bates County Soil and Water Conservation District (SWCD).

The purpose of this study was to assess the changes in nutrient, sediment, and chemical loads in the Miami Creek River due to the implementation of 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 as a tool to simulate the conservation practices associated with the AgNPS-SALT project was evaluated.

Results showed that implementing the conservation practices caused a reduction in sediments, nutrients, and chemicals. The reductions varied by practice. The load reductions at the outlet of the watershed were less than the reductions in nutrient, sediment, and chemical runoff before reaching the stream. The difference in reduction rates in what is reaching the stream and at the watershed outlet were influenced by the stream sediment, nutrient, and chemical transport processes. Due to spatial and temporal variability, the average amount of nutrients, sediment, and chemical 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: pesticide management, nutrient management, residue management, pasture management, tillage management, buffers and filter strips, grazing management, and conservation rotation.

The SWAT model can be used as an effective tool to quantify how the sediment and agrichemical loadings vary 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 CONTENT

LIST OF FIGURES

LIST OF TABLES

Watershed Information

The Miami Creek watershed is located above the USGS gauge (06916675 Miami Creek below Butler) in the northwest corner of Bates County in western central Missouri. It covers 133 square miles (84 240 acres) and is approximately 17 miles long. The U.S. Highway 71 and Missouri Highways 18 and 52 provide access to the watershed. Miami Creek and its tributaries flow in a southeasterly direction to the Marais des Cygnes River, Osage River and eventually into the Truman reservoir.

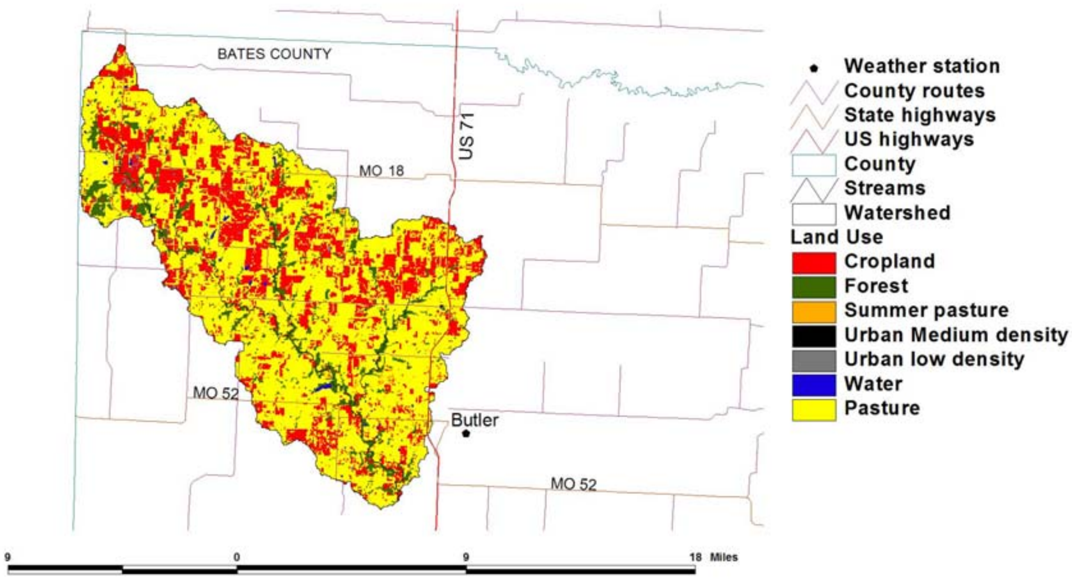

Figure 1. Miami Creek location map and land use (1992 satellite image).

The watershed is primarily agricultural with 56% of cropland, 36% of grassland, and 8% of forest. Some confinement operations are located in the watershed. To improve the land use condition on the acreages needing treatment, the AgNPS-SALT project set the target acres of land that needed to be improved. Table 1 reproduces the land use distribution provided in the AgNPS-SALT proposal.

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

Land use	Percent of watershed area (%)	acres
Crop land	53	44,647
Pasture	28	23,587
Forest	8	6,739
Other	11	9,266
Total	100	84,239

When the AgNPS-SALT proposal was developed, the cropland lacked sufficient conservation measures to ensure that pesticides and nutrients did not flow into the streams. Similarly, pasture land was not being managed to protect streams from bank erosion and high nutrient loadings.

The water quality problems in the Miami Creek watershed were excessive chemical and nutrient loadings in the stream. Specific problems were identified as:

- Improper storage and excessive application of animal manure,
- Transport of agricultural amendment into surface waters,
- Inadequate facilities for mixing pesticides,
- Disposal of pesticide containers,
- Inadequate protection of stream riparian zones,
- Bank erosion along gullies and stream channels,
- Poorly managed and overly grazed pastures,
- Sheet and rill erosion on some cropland,
- High pesticide runoff, and
- Excessive sedimentation in the lakes.

The AgNPS-SALT program focuses on agricultural and land management practices that are expected to reduce sediment, nutrient, and pesticide loadings. The conservation practices, goal acreages, and perceived importance are presented in Table 2. Several of these practices were implemented on the same field. The proposal did not report how many acres in the watershed were in need of treatment when the project started.

Table 2. Miami Creek AgNPS-SALT project goals.

Type of activity	Project Goals	Importance
Pesticide management	13,700 ac	19%
Nutrient management	13,700 ac	16%
Filter strips	50 ac	8%
Field borders	50 ac	4%
Stream & water body protection	50 ac	4%
Pasture and hay land management	5,400 ac	6%
Planned grazing systems	3,500 ac	8%
Waste treatment lagoon	5	4%
Conservation tillage – No-till	3,425 ac	5%
Residue Management	10,275 ac	6%
Cover and Green manure crop	1,370 ac	3%
Conservation Crop Rotation	1,000 ac	3%
Newsletter	28	3%
Fact sheet	7	1%
Workshop	12	3%
Watershed Tour	5	3%
Slide presentation	11	0%
Enviroscape presentation	42	0%
Poster exhibit	24	0%
Steering committee meeting	7	0%
Pasture and hay land planting	1000 ac	1%
Waterways	52.5 ac	1%
Terraces	77,000 ft	1%
Ponds	49	1%

Analytical Tool

Baseline Scenario

The baseline scenario was developed to represent the typical land use, physical characteristics (topography, soil, and climate), and agricultural practices of the watershed.

The baseline scenario was used as a base case to compare with other scenarios where alternative managements or land uses were introduced. The comparison was based on sediment, nutrient, and pesticide loadings and yields.

The baseline scenario was developed by recognizing the initial conditions of the watershed. The model input requirements are electronic land cover and soil maps, digital elevation model (DEM), soil characteristics, climate data, and information about land management. The ArcView® interface AVSWATX was used to delineate the watershed, overlay land use and soil maps, enter the required inputs, and run the model.

In this study, the electronic maps of land cover and DEM were obtained from Missouri Spatial Data Information Service (http://msdisweb.missouri.edu), while soils (SSURGO) and obtained from National Resource and Conservation Service. Information on climate which include daily precipitation and temperature data from 1977-2003 were obtained for the Butler weather station (Figure 1). This data was provided by Dr. Patrick Guinan at the Missouri Climate Center at the University of Missouri Department of Soil, Environmental, and atmospheric Sciences. Monthly characteristics of rainfall and temperature were derived from this 27-year long series of daily values. Daily flow data from October 2001 to September 2004 were obtained for water balance calibration from flow gauge at the outlet of the watershed, near Butler (Figure 1). Information on the current agricultural land management was gathered from meetings with Diane Bradley (Bates County Conservationist) and with Brad Powell (Bates County SWCD).

General input parameters were set to the values that have shown to produce reasonable results in Missouri. The model was run using the Penman-Monteith evapotranspiration method and the Muskingum channel flow routing method; channel degradation was turned off (the channel dimensions remain the same through the simulation); and the stream water quality was turned off. The model was calibrated using daily flow information. Details of model calibration appear in Appendix A.

Approximations

To build a model with close approximation to reality, data and information need to represent the watershed, be readily available, and be in a form that can be directly used in the AVSWATX ArcView® interface. To develop the model, digital maps that contain land topography, streams, land use and soils were used. The heterogeneity of such data along with information on management practices enabled the model to sub-divide the watershed into 7 subbasins (Figure 2). These subbasins match the subbasins used in the 2000 study of the Miami Creek watershed (Baffaut et al, 2001).

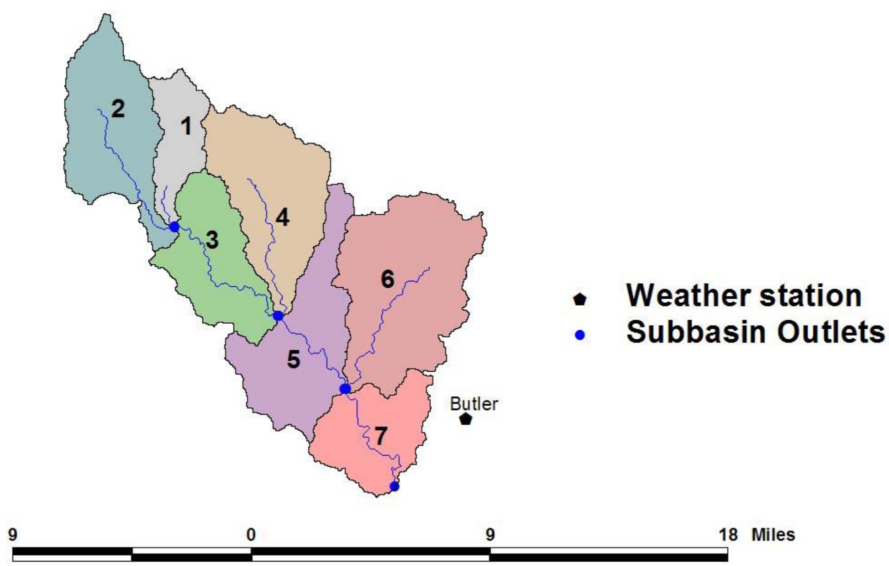

Figure 2. Delineation of the Miami creek watershed.

The digital land use map used in this study was based upon 1992 satellite images. The proportions of the agricultural land uses obtained from the digital land use map and AgNPS-SALT proposal are stated in Table 3. The proportions of each type of land use to the total acreage are very closed, except for the pasture (Table 3). The discrepancy was partially because hayed land and land enrolled in the Conservation Reserve Program are classified as cropland by NRCS. On the other hand, on the digital land use map, they are classified as grassland.

In addition, the corresponding percentages were estimated from the 1997 farm history records (Baffaut et al., 2001). It seems that some of the land classified as others in the SWCD document is interpreted as grassland on the satellite image. This may include all the residential areas. We used the 1992 map because it was readily available in a GIS format, which is necessary for the AVSWATX interface. Differences in the land use or land cover between 1992 and 1998, date at which the AgNPS-SALT project started, may be present. According to Missouri agricultural statistics, some grassland were converted to soybeans acreages during that period (Baffaut et al, 2001).

Land uses and soils which make up for very small percentages were eliminated according to the procedure implemented in the AVSWATX interface (Di Luzio, 2001). The thresholds for land use and soils were 5% and 21%, respectively. Three land uses (grassland, cropland, and forest) and four soils (Kenoma silt loam, Hartwell silt loam, Verdigris silt loam, Eram-Balltown complex) were retained. The major soil for cropland and pasture land was the Kenoma silt loam; the major soil for forest was the Verdigris silt loam.

Table 3: Differences in land use distribution.

Land use	AgNPS-SALT proposal		1992 satellite image	
Row Crops	23	Total cropland: 53	23	23
Hay	15		15	Total grassland: 66
CRP	15		15	
Pastures	28	28	36	
Forest	8	8	11	11
Other	11	11	<1	<1
Total	100	100	100	100

The required management information for cropland includes the crop rotations, the timing and rates of fertilizer applications, and the tillage management. Several cropping rotations were used in the watershed and each one was distributed throughout the watershed. However, to make the model manageable, two baseline cropping rotations were considered. These rotations were a corn-soybeans rotation and a corn-soybeans-winter wheat-double cropped soybeans rotation. To evaluate the impact of a conservation rotation, a corn-winter wheat-double cropped soybeans rotation was introduced. Information on the rotation combination (corn-soybeans rotation versus soybeans-corn for example) was required and tillage management used on each crop field must be specified. If we were to address all the combinations of rotations (5), nutrient managements (2), and tillage managements (3) in each subbasin, it would result in a large number of individual units (30 for each cropland soil simulated in a subbasin). To limit the number of individual units to the level that would allow an assessment of the AgNPS-SALT project, the following criteria were considered.

- One row crop rotation was assigned to each subbasin in a way that balances the acreage of corn, soybeans, and wheat in the whole watershed.

- Three types of tillage were used in each subbasin: no-till, conservation tillage, and conventional tillage. Data obtained from the Conservation Technology Information Center through the Bates SWCD were used to estimate the relative proportions of cropland under each tillage system in 1998.

- The amount of terraces present in 1998 was estimated by the Bates SWCD at our request. The acreage protected by the terraces (terrace acreage), not the linear footage was crucial information. Because the terrace acreage matched best the acreage under conservation tillage, terraces were associated to that tillage system.

- One baseline nutrient management system was used. Alternative nutrient management plans were introduced afterward.

- Three types of grassland conditions (poor, fair, and good) were considered in each subbasin. The hay and CRP fields were assumed to be in fair conditions. Estimates of hay and CRP acreages were obtained from farm records consulted during our previous study of the Miami Creek Watershed (Baffaut et al., 2001). Because the AgNPS-SALT proposal does not detail how much pasture land require better management, we assumed the following proportions:

    - Hay, fair condition: 24%
    - CRP, fair condition: 24%
    - Pasture, fair condition: 31%
    - Pasture, poor condition: 20%
    - Pasture, good condition: 1%

- Cattle were distributed among the pastures in each subbasin so that an approximately equal number of animals were in the watershed at all times during the year. Hay land was assumed to be grazed after the hay harvest.

- No filter strips, riparian buffers, or ponds were assumed in the baseline condition.

- One baseline pesticide management was applied to all the cropland. Since SWAT can simulate the overall loading for one pesticide only, we selected to route atrazine through the whole system.

Limitations of the SWAT model

The alternative conservation practices under the AgNPS-SALT program included nutrient and pesticide management, field borders and buffers, pasture management and planned grazing systems, erosion control, no-till systems, residue management, conservation rotations, and terraces and waterways. Due to limitations of the SWAT 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. Waste treatment lagoons were not evaluated because we do not have any description of the pre-project management of the waste.

Scenarios

The Project has provided incentive payments to encourage the adoption of Best Management Practices (BMPs) and the application of Resource Management Systems

(See Table 2). The project did not list how many acres were in need of treatment. Information on those acreages was obtained from other sources or some assumptions were made.

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. A final scenario combined all the BMPs proposed in the project in the amounts proposed. This final scenario evaluates the effectiveness of the AgNPS-SALT project as a whole. In each scenario, the model was run over a 30-year long period to estimate annual sediment, nutrient, and pesticides loadings to the stream and out of the watershed. The nutrient, sediment and pesticide loads from the alternative scenarios were compared to the loads from the baseline.

Since there was no estimate of the acreage needing treatment and where the practices have been implemented, the BMPs were simulated on land or stream banks in poor condition unless there was a reason to associate the practice with a different land condition. Terraces, for example, are associated with land in conservation tillage (See section on approximations). Sensitivity analysis was performed for some BMPs to estimate the impact of the practice on land that needed treatment and on land that was already managed with best management practices.

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. Urban land was not included in the model because it represents only a very small fraction of the Miami Creek watershed. The sediment, nutrient, and chemical loadings generated in the baseline scenario were compared with the loadings obtained with the alternative BMP scenarios.

Some information was not directly available for the simulation. For instance, the number of acres already protected by terraces, the acres that the terraces proposed in the project would protect, the existing number of ponds with their drainage area, the proportions of crop land under the different tillage systems, the acres that the proposed field borders and buffer strips would protect were not available. Since this information is critical and influenced the estimated impact of terraces, conversion to no-till, or construction of new ponds, we either made some assumptions or did not address those aspects.

Some assumptions on terraces were that 2,115 acres of cropland in the watershed are equipped with working terraces (Brad Powell, personal communication). During the project 43 additional acres were equipped with terraces at an average terrace length of 265 feet per acre of cropland.

Filter strips and field borders were applied to cropland. For every acre of filter strip, about 5 acres of cropland are protected. On average, a 40 acre large crop field would be protected by 3.6 acres of field borders. Riparian buffers were applied to pasture and Brad Powell estimated that 95 acres of riparian buffers were established on approximately 294 acres of pasture, an average 3.1 acre of protected pasture per acre of riparian buffer.

Assumptions on tillage systems were derived from information from the Conservation Technology Information Center (CTIC) for Bates County. The proportions of different tillage practices are detailed in Table 4.

Table 4. Proportions of tillage systems in the Miami Creek watershed in 1998 and 2003.

	Conventional tillage	Conservation tillage	No-till
1998 (pre-SALT project)	58%	10%	32%
2003 (post SALT project)	38%	15%	47%

BMPs on Target Acres Scenario

The ultimate goal of the AgNPS-SALT project is to reduce non-point source pollution associated with agricultural practices. Through the project, a number of conservation practices are being introduced in the watershed. To assess the environmental improvement due to the project, 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, sediment, and chemical runoff. Appendix B reviews how each management practice was simulated in the model.

BMPs on All Acres Needing Treatment Scenario

The BMPs introduced under the AgNPS-SALT project covered part of all acres needing treatment. For instance, 5,400 target acres were proposed for pasture and hayland management in the watershed, while the pastures in poor condition were 11,076 acres. Only 49% of pastureland in poor condition was treated by implementing grassland management. This study further assessed the environmental impacts if the grassland management were applied to all the acres in poor condition. Similar procedures were applied to other conservation practices.

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.

Results

The study focused on the outputs from the subbasins and at the outlets of the Miami Creek watershed. The nutrient, sediment, and chemical loadings transported by the stream result from what is contributed to the stream by the land around 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 (outlet of subbasin 7).

Baseline Scenario

Subbasin contributions

The average annual sediment yield, and nutrient and atrazine runoff per acre are stated in Table 5. The simulation was run for a period of 30 years. Due to temporal variability, these results are unlikely to be observed on a year-to-year basis. The time variability is caused by the climatic changes from year to year.

Table 5. Variability of the subbasin contributions in the baseline scenario.

	Amount	Temporal Variability*	70% Range
Sediment Yield (tons/ac/yr)	0.7	0.3 (48%)	0.4 - 1.0
Total Nitrogen (lbs/ac/yr)	13.6	8.5 (63%)	5.1 - 22.1
Total Phosphorus (lbs/ac/yr)	2.5	1.2 (48%)	1.3 - 3.7

*Temporal variability is the standard deviation among the 30 years of simulation.

The temporal variability is calculated as the standard deviation of the annual values obtained for each of the 30 simulated years. It corresponds to a 70% confidence interval. For sediment, for example, a temporal variability of 0.3 tons/acre/year indicates a 70% chance to observe an annual yield of 0.7 ± 0.3 tons/acre/year.

Stream loads

The outlet of the watershed is located at the boundary of subbasin 7. The nutrient, sediment, and chemical loads at the outlet of that subbasin are loads transported from the entire watershed (Table 6).

Table 6. Environmental impacts of the baseline scenario at the outlet.

	Sediment (tons/year)	**Nitrogen** (lbs/year)	**Phosphorus** (lbs/year)	**Atrazine** (lbs/year)
Miami Creek Watershed (Subbasin 7)	2, 812	1,107,920	204,292	4.88E+08

BMPs on Target Acres and Combined BMPs

Subbasin contributions

The largest reduction in sediment yields was provided by no-till practices (25%). The reduction of the sediment yields from nutrient management was 4%. For residue management, the reduction was 5% when applied to crop land under conventional tillage.

When applied to land that was under reduced tillage, the expected reduction was nil. Pasture management was expected to provide a small reduction in sediment yields (2%). Buffers and filter strips provided some reduction (7%) when applied to land in conventional tillage. Again, the reduction is smaller when applied to land under reduced or conservation tillage. Grazing management was expected to provide a 4% reduction in sediment yields.

Switching to a conservation rotation by incorporating a winter crop, did not produce significant results because the target acreage was very small. However, the results at the field level showed 62% and 22% reductions in sediment and phosphorus yields, respectively. This practice could be a viable approach to reduce the sediment and phosphorus, in spite of a small increase of nitrogen losses (3%). This loss occurs because nitrogen is added to fertilize the winter wheat; a more conservative approach would be to plant a winter crop and not fertilize it to let it use the excess nitrogen in the soil.

When the conservation practices were implemented simultaneously under the combined BMPs scenario, the reduction in the average annual sediment yields was 39% (Table 7). It is due in large part to implementation of no-till practices.

The nitrate reductions from no-till practices and nutrient management were among the highest. Other practices may lead to a decrease in surface runoff nitrogen but to an increase of nitrogen leaching, which resulted in no change in total nitrogen (pasture management) or an increase of total nitrogen (rotational grazing). Buffers and filter strips provided some reductions in surface nitrogen and no change in nitrogen leaching, which resulted in a smaller reduction of total nitrogen. The combined BMPs indicated a total reduction in nitrogen of 4% (Table 7).

Table 7. Expected impacts of the AgNPS SALT project at the subbasin level, percentage change in pollutant yields from the baseline.

	Sediment (% change)	**Nitrogen** (% change)	**Phosphorus** (% change)	**Atrazine** (% change)
Reduced atrazine	NA	NA	NA	-15%
Nutrient Management	0%	-1%	-4%	0%
Residue Management	-5%	0%	-1%	0%
Pasture Management	-2%	0%	-11%	0%
Tillage Management	-25%	-6%	-7%	6%
Buffers and filter strips	-7%	-2%	-2%	-4%
Grazing Management	-4%	15%	-13%	0%
Conservation rotation	0%	0%	0%	0%
Combined BMPs	-39%	-4%	-25%	-10%

Phosphorus reductions from the pasture and grazing management practices proposed in the AgNPS-SALT project were 11% and 13%, respectively. This is largely due to ground cover enhancement and reduction in phosphorus associated with sediment. Tillage management (no-till practices) resulted in a 7% reduction, mostly through the reduction of organic phosphorus losses associated with sediment. Nutrient management and buffers provided smaller reductions of 4% and 2%, respectively. Total phosphorus reduction was 25% when all the conservation practices were conducted simultaneously (Table 7). No-till increased atrazine losses compared to conservation tillage. Possible reasons included a difference in canopy cover, interception of the herbicide, and atrazine decay. Atrazine reductions were smaller when all practices were implemented than when tested on its own because the proportion of corn in no-till was greater.

Some practices were not presented in this study. Although terraces were proposed and have been constructed during the project, the area protected is very small relative to the acreage of crop land. The impact was not visible at the watershed level. Similarly, grade stabilization structures (pond) were proposed and constructed during the project. Previous work (See Big Maries River Watershed report) showed that the impact from ponds can be simulated with the model. However, the erosion conditions that were supposed to exist in a small, critical area to justify the construction of a pond were not defined and could not be simulated using SWAT. This prevented the model to predict any benefits from the construction of ponds. To define and identify the critical areas, more information, or an additional GIS-based process are required.

Stream loads

The reductions in sediment achieved at the subbasin level were not visible at the outlet of the watershed because of sediment deposition in the stream. The stream loads are controlled by the stream capacity and a reduction of incoming sediment did not result in a reduction of stream loads. The combined BMPs scenario resulted in an 8% sediment load reduction for the entire watershed (Table 8). The results showed no differences in nitrogen, phosphorus, and atrazine load reductions because we left the stream water quality processes inactive. The lack of water quality data in Miami Creek did not allow us to adjust the parameters for these processes with any accuracy. In the absence of data, the best approximation was to let nitrogen, phosphorus, and atrazine be transported through the streams of this small watershed without any transformation.

Table 8. Expected impacts of the AgNPS-SALT project at the outlet, percentage change in stream loads from the baseline.

	Sediment (% change)	**Nitrogen** (% change)	**Phosphorus** (% change)	**Atrazine** (% change)
Reduced atrazine	0%	0%	0%	-15%
Nutrient Management	0%	-1%	-4%	0%
Residue Management	0%	0%	-1%	0%
Pasture Management	-4%	0%	-11%	0%
Tillage Management	-2%	-6%	-7%	6%
Buffers and filter strips	-1%	-2%	-2%	-4%
Grazing Management	-3%	15%	-13%	0%
Conservation rotation	0%	0%	0%	0%
Combined BMPs	-8%	-4%	-25%	-11%

Stream loading of nitrogen at the outlet of the entire watershed were reduced by small amounts when nutrient management, tillage management, and buffer and filter strips were implemented. However, when grazing management was applied, the amount of nitrogen was increased due to an increase in leached nitrogen. The combined BMPs were expected to produce a 4% reduction of nitrogen, and an 11% reduction of atrazine in the stream loads (Table 8).

The total phosphorus stream loads at the outlet of the entire watershed could be reduced if nutrient management, pasture management, grazing management, or no-till practices were implemented. The combined BMPs scenario represented a substantial decrease of 25% in the phosphorus stream load (Table 8).

BMPs on all acres needing treatment

Subbasin contributions

As previously mentioned, the proposal did not specify the acreage that needed to be improved. The scenario was developed in the following way: reduced atrazine rates were applied to all corn acreage; the nutrient management plan was applied to all crop land and grassland land; filter strips were installed on all agricultural land; and pasture management was applied to all pasture in poor condition resulting in all pastures being either in fair or good condition. No-till was applied on all conventional tillage fields. Residue management was not examined because small benefits were expected and there was a lack of interest in this practice. Rotational grazing was not examined due to the difficulty in defining a representative baseline scenario. Results presented in Table 9 showed that the contributions of all pollutants to the stream could be considerably reduced by tillage management, buffers, and field borders. Again these results were compared to the baseline scenario which assumed no filter strips, no nutrient management plan, and a full application of atrazine on all corn fields. An additional benefit of the riparian buffers that was not simulated in this study was the reduction of channel erosion due to the protection of the banks by vegetation and the reduced bank erodibility due to tree roots. Nutrient management and pasture management showed significant impact on phosphorus loadings. A reduction of atrazine rates on all crop land could reduce atrazine losses by 29% (Table 9).

Table 9. Potential impacts of BMPs implemented on all acreage at the subbasin level, percent change from the baseline.

	Sediment Yields (% change)	**Nitrogen** (% change)	**Phosphorus** (% change)	**Atrazine** (% change)
Reduced atrazine	0%	0%	0%	-29%
Nutrient Management	-0%	-0%	-23%	0%
Pasture Management	-3%	0%	-16%	0%
Tillage Management	-79%	-27%	-45%	0%
Buffers and filter strips	-79%	-42%	-75%	-74%

Stream loads

The sediment loads at the outlet of the watershed would reduce by 21% and 25% through the implementation of conservation tillage on all fields that were currently conventionally tilled, and the implementation of buffers and filter strips (Table 10). Other pollutant reduction rates were similar to what were obtained at the subbasin level.

Table 10. Potential impacts of BMPs implemented on all acreage at the outlet, percent change from the baseline.

	Sediment Yields (% change)	**Nitrogen** (% change)	**Phosphorus** (% change)	**Atrazine** (% change)
Reduced atrazine	0%	0%	0%	-29%
Nutrient Management	-0%	-1%	-23%	0%
Pasture Management	-3%	0%	-16%	0%
Tillage Management	-21%	-28%	-46%	0%
Buffers and filter strips	-25%	-42%	-75%	-74%

Conclusions

This analysis estimated the individual and combined impacts of the practices proposed in the AgNPS-SALT project in Miami Creek, using the acreage of what has been realized since 1998 when the project started. The model was calibrated using flow data collected at the USGS near Butler. More than 40 runs were then performed to determine the environmental impacts of proposed conservation practices. The comparisons were based on long-term (30 years) averages. 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, nutrient, and chemical loads when the conservation practices were implemented.

Tillage management and the implementation of buffers and filter strips appeared to be the most efficient practices to reduce the sediment loadings. Residue management reduced sediment contributions by leaving a good ground cover of residues from harvest until shortly before planting. Buffers and filter strips also reduced nutrient and chemical loadings. Tillage management (a conversion from conventional to no-till practices) reduced nutrient loadings but increased atrazine loadings. A possible alternative to complete no-till would be either to adopt conservation tillage instead of no-till or to allow a shallow incorporation of atrazine after it was applied.

Pasture and grazing management contributed to significant reductions in phosphorus loadings even though the reductions in nitrogen and sediment were minimal. The adoption of a conservation rotation did not result in significant impacts because the acreage was very small. However, the field-level results showed that sediment and phosphorus yields decreased significantly, along with a small increase in nitrogen losses.

The model was not able to adequately estimate the sediment and nutrient reductions from rotational grazing because the distribution of the cows in a traditional pasture was not known. When we assumed uniformly distributed across the pastures, the model predicted a decrease in sediment and phosphorus from an improvement of pasture condition. However, the results indicated an increase in nitrogen leaching.

The model was not able to address the sediment and nutrient reductions from gully erosion control because of the small acreage treated. Previous work (See Big Maries River watershed report) showed that grade stabilization structures (ponds) could be simulated in the watershed but not the critical erosion conditions that were supposed to exist to justify the construction of a pond. This prevented the model to predict any benefits from the construction of ponds. Such definition of critical areas required either more information or an additional GIS-based process to identify them. For further study, another simulation program could be used at a smaller scale to capture the environmental contribution from critical areas. The results can be used as inputs to SWAT simulations.

Terraces were simulated with SWAT. However, the small target acreage of terraces proposed under the AgNPS-SALT project did not produce a beneficial impact at the watershed level. Since terraces are expensive a viable strategy might be to cost-share them through various programs to obtain the required amount in the watershed.

When all of the conservation practices were implemented simultaneously on the target acres under the combined BMPs scenario, the sediment, nitrogen, phosphorus, and atrazine reductions were 8%, 4%, 25%, and 11%, respectively.

Appendix A: Model Calibration

Flow, sediment, and water quality parameters are estimated using the SWAT model. When data are available, one strategy is to compare the simulated values obtained during a time period to measured data, and adjust the model parameters so that measured and simulated values match. This process is known as calibration. Simulated values and measured data are then compared for a period of time not used for the model calibration; this is called model validation. Ideally, several years of measured data on flow, sediment, and water quality are required for model calibration and validation. However, in practice, the data do not always exist, and the model is calibrated, validated, or simply verified with what is available.

Weather and flow data were available for the Miami Creek watershed from October 2001 to September 2004. Although the first year was characterized by a marked drought, we used these years to calibrate the model. No validation was performed because of the lack of additional data. The flow gauge is located at the watershed outlet; the weather station where daily precipitation and temperature were measured is located in Butler. No sediment or nutrient data were available but quarterly atrazine concentration measurements were available since 1998.

The base flow separation program described in Arnold et al.(1995) and Arnold and Allen (1999) was used. The result indicated that the base flow represented 13% to 29% of the total flow. The alpha factor used by the SWAT model to control return flow was estimated to be 0.138. This value was used for the model.

Several calibration indicators were used to quantify how well the model reproduces the measured flows. The relative deviations in annual surface and groundwater flow indicate the overall over- or under-prediction of the model. For flow, these should be within 10%. Average crop yields obtained with the model fitted well the crop goals in the watershed, although simulated soybeans yields were low. Table A1 presents the values of these indicators after calibration of the model based on these 3 years of data.

Table A1. Calibration criteria for the Miami Creek Watershed.

Criteria	Goals	Value
Surface runoff deviation	[-10%, 10%]	3%
Base flow deviation	[-10%, 10%]	11%
Total flow deviation	[-10%, 10%]	2%
Base flow proportion	[13%, 29%]	16%
Corn yield (bu/ac)	[120-150]	123
Spring soybeans yield (bu/ac)	[45-65]	39
Double cropped soybeans (bu/ac)	[20-50]	32
Winter wheat (bu/ac)	[65]	68

Appendix B: BMP Simulation

Pesticide Management

The purpose of pesticide management is to reduce pesticide application rates, modify their timing, and filtering the runoff so that the dissolved pesticide does not enter the streams. The filter strips and field borders are usually counted as a practice unto themselves and we did not incorporate them in this practice. In this case, the April 12 application rate was reduced by 20% from 1.4 to 1.1 kg/ha, the second application was delayed from May 1 to May 20 and its rate was reduced by 40% from 0.84 to 0.5 kg/ha.

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. On grassland, it is determined as a function of the soil chemical composition, the hay harvest, and the number of animals grazing. Nutrient management plans can include a split application of nutrients but this was almost never implemented in the Miami Creek watershed.

The phosphorus application dates and rates for the different crops under conventional practices and under a nutrient management plan are shown in Table B1. These application rates were calculated by considering the average annual amount of phosphorus removed by crops and adding an extra 10% of phosphorus to account for losses and increased yield. The average amount of phosphorus removed by crops was estimated from the baseline SWAT model results. Phosphorus was applied either in the spring before corn was planted or in the fall before wheat was planted; the application rate was based on the phosphorus needs of corn or wheat and the following soybean crop.

Table B1. P application rates with and without a nutrient management plan

Crop	Date	Conventional (kg/ha/)	Nutrient management plan (kg/ha)
Corn	Spring P	84	52
Wheat	Fall P	78	29
Pasture	Spring P	45	31

Similar to the phosphorus, nitrogen rates were based on crop requirements and an extra amount to account for losses and potential increased yields. The resulting rates were lower but very close to those used in the baseline scenario. This explains why there is almost no reduction in nitrogen losses when the nutrient management plan was implemented.

Residue management

Residue management (Code 344) consists in leaving residues on the ground surface during the winter. No tillage is allowed from harvest until 3 days before planting. The project acreage goal for this practice was 1573 acres. Some sensitivity analyses were performed to determine the impact of the practice location and of the tillage systems. The results indicated that it was most efficient to apply this practice to conventionally tilled agricultural systems.

Pasture management

Pasture management includes the practices of permanent vegetation establishment (DSL-1), permanent vegetation improvement (DSL-2), permanent vegetation cover establishment (DSP-2), and permanent vegetation cover-critical areas (DSL-11). The acreage of treated pasture was 5,400 acres out of 23,587 acres of pastures in the watershed. In this analysis, pasture management was only applied to pastures in poor condition and it was assumed that the treatment would improve them to a good condition.

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 biological mixing factor (BIOMIX). Poor conditions are characterized by a higher cover factor implying that soil erosion is more likely to occur because the ground cover is poor; a higher curve number because of less infiltration; a lower minimum amount of biomass required for grazing implying that cows are left in the pasture even though they should be moved to other pasture (a characteristic of poor management); a lower Manning coefficient (N) that represents faster movement of surface runoff; and a lower biological mixing index that implies less biological activity in the soil to mix residues and nutrients. Table B5 details these parameters for the different types of pasture.

Table B2. Input parameter values to describe pasture condition in the Miami Creek watershed.

	USLE_C	CN	BIO_MIN	Manning N	BIOMIX
Good condition	0.003	76	500	0.20	0.4
Fair condition	0.003	79	500	0.15	0.3
Poor condition	0.011	84	200	0.10	0.2

Tillage management

In this analysis, three types of tillage were included: conventional tillage, conservation tillage, and no-till. The tillage operations for each tillage system are detailed in Appendix C. Tillage management goals for the Miami Creek AgNPS-SALT project included switching 3,425 acres from conventional tillage to no-till practices. The no-till system still included some fall tillage when followed by corn planting in the spring because it represented what farmers were more likely to do. No fall tillage occurred when the following crop was soybeans or winter wheat. A spring tillage that disturbed less than 25% of the residues may be performed in the spring before planting soybeans, and to incorporate fertilizer before planting corn. Using the CTIC data from 1998 and 2002 for Bates County, we concluded that additional acres had been switched: 1,100 acres from conventional tillage to conservation tillage and 3,300 acres from conventional to no-till. These acres were proportionally distributed throughout the watershed.

Buffers and filter strips

Buffers (Code 391) and filter strips (Code 393) were modeled in SWAT by a band of grass that filters sediment, nutrient, and pesticides out of the runoff. Similarly, grassed waterways (Code 412) were simulated as a filter strip along with a shortening of the slope length. Without any additional information about these waterways, we assumed it was divided in half. A reduction coefficient is calculated by the SWAT model for each pollutant as a function of the buffer or filter strip width. This representation simulates a filter strip or waterway better than a riparian buffer. The interaction of the groundwater with surface runoff in a riparian buffer is not modeled in SWAT.

Since we had no estimation of how many buffers and filter strips already existed in the watershed when the project started, we assumed there were none, which consequently maximized the effect of newly implemented buffers.

The project proposed to install 50 acres of filter strips, 50 acres of buffers, and 50 acres of waterways. These quantities needed to be translated into the protected acreages. We first estimated the length of these filter strips and buffers, assuming a width of *40 ft*. We then estimated the acres protected. Since the estimated protected acres were fairly small, we assigned them to one HRU in the watershed. To test the sensitivity of the location of these filter strips, we made seven runs:

1. filter strip associated with crop land in conventional tillage in subbasin 7,
2. filter strip associated with crop land in conventional tillage in subbasin 1,
3. filter strip associated with crop land in conservation tillage in subbasins 2 and 3,
4. filter strip associated with crop land in conservation tillage in subbasins 6 and 7,
5. filter strip associated with crop land in no-till in subbasin 5
6. riparian buffers associated with pasture in fair condition in subbasin 1,
7. riparian buffers associated with pasture in fair condition in subbasin 7.

The largest gains were obtained from the filter strips associated with crop land under conventional tillage. The reductions were mostly in terms of organic nutrients attached to sediment and filtered by the grass. No gains were predicted when filter strips were applied to crop land in conservation tillage or no-till, or when riparian buffers were applied to pastures.

Grazing management

The goal of grazing management (Code 528) 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 grazing management scenario, 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 3,500 acres; 3,560 acres were achieved.

While each prescribed grazing system is unique and depends on many factors, including soils, topography, herd size, and drinking sources, a typical scenario needed to be designed for the purpose of model simulation. The prescribed grazing system was simulated by switching to more intensive grazing management - the number of pastures used was doubled, the duration of grazing on each of them was only 10 days, and the grazing intensity was adjusted accordingly. This resulted in higher values of manure deposited and forage being eaten by cattle. However, since the grass was of better quality and cattle were there for a shorter period of time, the grazing efficiency was better and there were less trampling losses. This was simulated by assuming good condition pasture for a prescribed grazing system (Table B2). To simulate the rotation of cattle between pasture, grazing periods were different in each subbasin. Table B3 and B4 detail these grazing periods for conventional and prescribed grazing systems in one subbasin.

Table B3. Grazing periods in a conventional grazing system for Miami Creek watershed.

Year	Operation	Date
Year 1	Fertilization	March 10, 50 lbs/a N, 40 lbs/a P
	Grazing	March 20 – May 20, 61 days
	Hay harvest	July 1
	Grazing	Aug 1 – Sep 30, 46 days

Table B4. Grazing periods in a prescribed grazing system for Miami Creek watershed.

Year	Operation	Date
Year 1	Fertilization	March 10, 50 lbs/a N, 40 lbs/a P
	Grazing	March 21 – March 30, 10 days
	Grazing	May 16 – May 25, 10 days
	Grazing	July 14 – July 20, 7 days
	Grazing	Sep 1 – Sep 10, 10 days
	Grazing	Oct 30 – Nov 8, 10 days

Conservation rotation

This practice (Code 328) includes growing crops in a recurring sequence to reduce sheet and rill erosion, reduce wind erosion, take advantage of nutrient fixing from one crop to the next, and improve water use efficiency. Other goals are relative to wildlife and forage production for livestock. A cover crop (Code 340) may be included to minimize erosion during the winter. This practice was implemented on 427 acres during the project, less than the 1000 acre goal stated in the proposal. Since we did not have crops grown in a continuous manner in the model because it represented a small percentage of cropland in the watershed, we selected to replace 420 acres of land in a corn-soybean rotation by a corn-winter wheat-double cropped soybeans rotation. The impact was minimal at the subbasin level, and could not be detected at the watershed level.

Appendix C: Baseline management scenarios

Corn – soybeans rotation

Date	Operation	Conventional	Conservation	No-till
March 10	N fertilizer	189 kg/ha	189 kg/ha	189 kg/ha
March 10	P fertilizer	84 kg/ha	84 kg/ha	84 kg/ha
March 12	Tillage	Disk chisel	Generic conservation	Generic conservation
March 31		**Corn planting**		
April 12	Atrazine	1.4 kg/ha	1.4 kg/ha	1.4 kg/ha
May 1	Atrazine	0.84 kg/ha	0.84 kg/ha	0.84 kg/ha
September 15		**Corn harvest**		
November 6	Fall tillage	Disk	Generic conservation	None
April 28	Spring tillage	Chisel/cultivator	Generic conservation	No-till mixing
May 2		**Soybeans planting**		
October 1		**Soybeans harvest**		
October 25	Fall tillage	Cultivator	Generic conservation	Generic conservation

Corn – soybeans – wheat – double cropped soybeans rotation

Date	Operation	Conventional	Conservation	No-till
March 10	N fertilizer	189 kg/ha	189 kg/ha	189 kg/ha
March 10	P fertilizer	84 kg/ha	84 kg/ha	84 kg/ha
March 12	Tillage	Disk chisel	Generic conservation	Generic conservation
March 31			**Corn planting**	
April 12	Atrazine	1.4 kg/ha	1.4 kg/ha	1.4 kg/ha
May 1	Atrazine	0.84 kg/ha	0.84 kg/ha	0.84 kg/ha
September 15			**Corn harvest**	
November 6	Fall tillage	Disk	Generic conservation	None
April 28	Spring tillage	Chisel/cultivator	Generic conservation	No-till mixing
May 2			**Soybeans planting**	
October 1			**Soybeans harvest**	
October 5	N fertilizer	56 kg/ha	56 kg/ha	56 kg/ha
October 5	P fertilizer	78 kg/ha	78 kg/ha	78 kg/ha
October 5	Incorporation	Disk chisel	Generic conservation	None
October 10			**Wheat planting**	
March 5	N fertilizer	50 kg/ha	50 kg/ha	50 kg/ha
June 20			**Wheat harvest**	
July 1			**Soybeans planting**	
October 1			**Soybeans harvest**	
November 1	Fall tillage	General fall plowing	Generic conservation	Generic conservation

Corn –wheat – double cropped soybeans rotation on conservation tillage

Date	Operation	Type
March 10	N fertilizer	189 kg/ha
March 10	P fertilizer	84 kg/ha
March 12	Tillage	Generic conservation
March 31	**Corn planting**	
April 12	Atrazine	1.4 kg/ha
May 1	Atrazine	0.84 kg/ha
September 15	**Corn harvest**	
October 5	N fertilizer	56 kg/ha
October 5	P fertilizer	78 kg/ha
October 5	Incorporation	Generic conservation
October 10	**Wheat planting**	
March 5	N fertilizer	50 kg/ha
June 20	**Wheat harvest**	
July 1	**Soybeans planting**	
October 1	**Soybeans harvest**	
November 1	Fall tillage	Generic conservation