Missouri Department of Natural Resources

LONG BRANCH LAKE WATERSHED

COMPUTER BASED EVALUATION OF THE AgNPS-SALT PROJECT

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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.

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EXECUTIVE SUMMARY

The purpose of this study was to assess the change in nutrient, pesticide, and sediment loads in the Long Branch Lake watershed due to the conservation practices proposed under the AgNPS-SALT project 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.

The study focused on the outputs from the subbasins and the inputs to Long Branch Lake. The model predicts that most of the conservation practices proposed for implementation under the AgNPS –SALT grant will reduce sediment, nutrient, and/or chemical yields. Implementation of erosion control practices (modeled as filter strips in this analysis) appears to be the most efficient method to reduce the sediment and nutrient yields. This scenario also provided a substantial reduction in atrazine yields; nearly equivalent to the pesticide management scenario (50% reduction in application).

The AgNPS-SALT project seeks to implement a variety of conservation practices simultaneously, which may yield synergistic effects and increase the benefits of the project. When all of the conservation practices were implemented simultaneously on the target acres under the Combined BMPs Scenario, the sediment, nutrient and pesticide reductions in the stream and reservoir were significant.

The AgNPS-SALT project does not attempt to treat all acreage in need of treatment. If this were to occur, model results indicated that reductions in stream and reservoir loadings of sediment and nutrients could be more than doubled. However, reductions in atrazine loadings would only be increased by about one-third if all acreage in need were treated with pesticide management and buffers. Thus, it appears that full implementation of conservation practices on targeted acreage under the AgNPS-SALT project will achieve near maximal reductions in pesticide loading but leave lots of work to be done on sediment and nutrients. This scenario also shows that pollutant loads could be minimized but not eliminated.

This analysis estimated the individual and combined impact of practices proposed in the AgNPS-SALT project in the Long Branch Lake watershed using target acreages provided in the grant proposal. Thus, results are predicated on the assumption that the practices will be fully implemented. Further, the predicted 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 in water quality parameters. However, results indicated reductions in sediment, nutrient, and chemical yields and loads when the conservation practices were fully implemented. SWAT is an effective tool for analyzing some conservation efforts in the AgNPS-SALT project, but some efforts cannot be evaluated (e.g., well decommissioning, educational efforts, practices effecting small acreages).

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Introduction

Major water quality symptoms in the Long Branch Lake watershed are excessive sediment and pesticide loads, but nutrient loads are also of concern because the lake serves as a drinking water supply for the cities of Atlanta, Bevier, Clarence, and Macon and intervening rural areas. To improve the water quality, the Agricultural Nonpoint Source-Special Land Area Treatment (AgNPS-SALT) program, begun in July 2003, sponsored a number of conservation practices through technical and financial assistance through the Macon County and Adair County Soil and Water Conservation Districts (SWCDs). 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, pesticide, and sediment loads in the Long Branch Lake watershed due to the conservation practices proposed under the AgNPS-SALT project 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 the environmental improvement due to a reduction in sediments, nutrients, and pesticides that could be expected from implementing the conservation practices. The reductions varied by practice. The reductions in sediment, nutrients, and pesticides delivered to the reservoir, which included the loads from the entire watershed, were less than the reductions at the subbasin level, which accounted for nutrient, pesticide, and sediment runoff reaching the stream. The differences in reduction rates at the reservoir and the subbasins were influenced by the stream transport processes. Due to the spatial and temporal variability of weather patterns, the average amount of pollutants predicted 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. Well decommissioning was not simulated because the model does not fully track groundwater quality and the contamination potential of a well is more a risk than a fact. The model was able to simulate the practices that are implemented on the ground: grassland improvement, rotational grazing, woodland exclusion, erosion control, and management of nutrient and pesticide applications.

The SWAT model can be used as an effective tool to quantify the amount of nutrient, pesticide, 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.

Watershed Information

The Long Branch Lake watershed encompasses some 66,683 acres (as calculated by the Geographic Information System used in this analysis) of north-central Missouri in Macon and Adair counties (Figure 1). The East Fork of the Little Chariton River and Long Branch Creek drain the basin and feed Long Branch Lake, which lies just west of the city of Macon. Reservoir storage began in 1978. The 2,763-acre lake provides fishing and other recreational opportunities in addition to supplying drinking water.

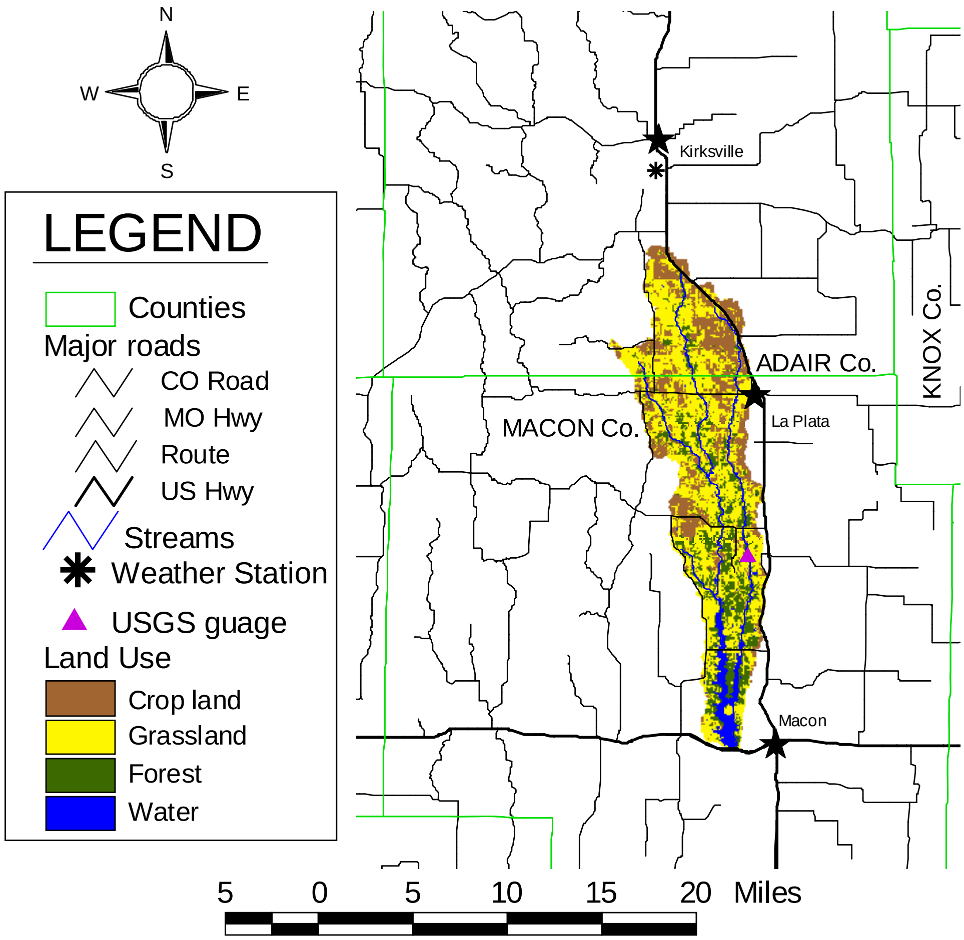

Figure 1. Long Branch Lake watershed location map and land use (1992 satellite image).

The watershed is primarily agricultural with 25% of cropland, 39% of grassland and 24% of forest. To improve acres that need treatment, the AgNPS-SALT project set acreage targets based on the number of acres needing treatment and the available funds. Table 1 reproduces the land use distribution provided in the AgNPS Special Area Land Treatment (SALT) proposal.

Table 1: Land use data according to the AgNPS-SALT project proposal.

Land use	Percent of watershed area (%)	Total acres	Acres needing treatment	Acres to be treated
Crop land	25	16,029	11,450	9,475
Pasture/Hay	24	15,498	3,210	3,210
CRP	15	9,525	300	0
Forest	24	15,239	4,000	940
Water	4	2,763	0	0
Urban/Public	8	4,721	0	0
Total	100	63,775	22,100	13,625

The water quality problems in the Long Branch Lake Watershed were excessive sediment, nutrient, and pesticide loadings in the reservoir. Long Branch Lake was included on the 1998 303d List of Impaired Waters for the presence of the herbicide cyanazine used on corn and sorghum. Cyanazine was discontinued in 1999 and levels decreased. Long Branch Lake was de-listed for cyanazine on the 2002 303d list, but added for mercury from atmospheric deposition. Specific problems identified in the AgNPS-SALT proposal were:

- Turbidity and suspended solids from sheet and rill erosion of croplands and streambank sloughing,
- Eutrophic conditions resulting from fertilizer runoff,
- Presence of agricultural chemicals,
- Presence of fecal coliform bacteria,

The AgNPS SALT program focuses on agricultural and land management practices that are thought to impact sediment, nutrient, and pesticide loadings. These practices and their acreage goals are presented in Table 2. Several of these practices can, be implemented on the same field. Project managers expected nutrient and pesticide management practices to be applied simultaneously to the same fields.

Table 2. Long Branch Lake Watershed AgNPS-SALT project goals.

Category	Type of activity	Project Goals	Unit
Public awareness		**60**	**each**
	Newsletter	20	
	Media Information	21	
	Workshops/Training/Education	12	
	Field Days/Tour	7	
Pasture management		**3210**	**acres**
	Permanent vegetative cover enhancement	1500	
	Planned grazing systems	1150	
	Planned grazing system with pond	560	
Critical area treatment		**62**	**each**
	Permanent vegetative cover	10	
	Water impoundment	35	
	Water control structure	5	
	Sod waterways	12	
Erosion control		**395**	**acres**
	Permanent vegetative cover establishment	280	
	Terrace systems	15	
	Terrace systems with tile	90	
	Diversions	10	
Stream corridor protection		**23,490**	**feet**
	Alternative watering system	17,424	
	Stream bank stabilization	6,066	
Buffers		**230**	**acres**
	Contour buffer strips	40	
	Filter strips	120	
	Riparian forest buffer	70	
Woodland protection		**940**	**acres**
	Woodland protection	800	
	Use exclusion	140	
Nutrient & pest management		**8,360**	**acres**
	Pesticide management	4,180	
	Nutrient management	4,180	
Water protection		**7**	**each**
	Well decommissioning	7	

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 standard to compare against other scenarios where alternative managements or land uses were introduced. This 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 the management of the land. 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 (STATSGO) were obtained from National Resource and Conservation Service (NRCS). Information on climate, which include daily precipitation and temperature data from 1977-2003, were obtained for the Kirksville 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 January 1996 to December 2003 were obtained from the flow gauge on Long Branch Creek, near Atlanta (Figure 1) for water balance calibration and validation. Information on the current agricultural land management was gathered during a meeting with a panel of local producers gathered by Mark Collins (Macon County SWCD).

General input parameters were set to values that have shown to produce reasonable results in Missouri. The model was run using the Hargreaves evapo-transpiration method; the channel flow routing method was selected to be the Variable Storage 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

Some information had to be approximated in order to build a model that is realistic, yet uses data that is readily available and in a form that can be directly used by the interface. These approximations are detailed below.

In order to represent, the spatial variability of the land topography, streams, land use, soils, and management practices, the watershed is sub-divided in subbasins. The heterogeneity of such information enabled the determination of 6 subbasins (Figure 2). These match the subbasins used in the 2004 study of the impacts of the Conservation Reserve Enhancement Program (CREP) in the Long Branch Lake Watershed (Farrand, 2004).

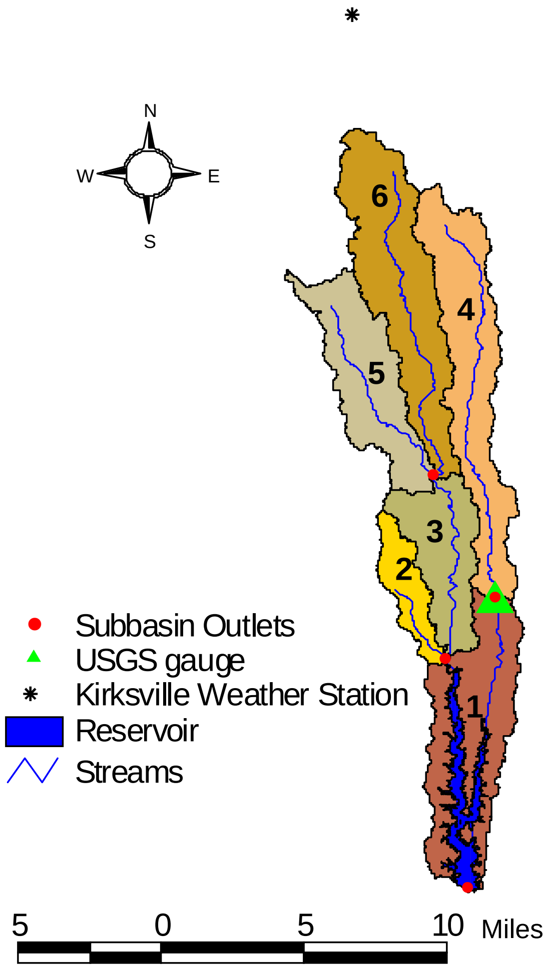

Figure 2. Delineation of the Long Branch Lake watershed.

In contrast to previous models, we used the NRCS STATSGO database for soil inputs instead of SSURGO data. This decision was made for 3 reasons. First, we want to keep the model manageable in terms of the numbers of units (land use – soil combinations) within each subbasin. There are more than 45 soil types in the SSURGO database for the Long Branch Lake Watershed and only 2 soil types in the STATSGO database. Second, using STATSGO greatly simplified building input files because STATSGO soils tables for each state can be downloaded with the AVSWATX interface (Di Luzio, 2001). Finally, soils information for any unit can be modified if necessary to aid the calibration process. The 2 soils in the STATSGO database for this watershed were the Armstrong-Gara-Adco complex in the lower-relief northern portion of the watershed and the Lindley Keswick-Goss complex in the higher-relief southern portion. Based on the previous studies in this watershed, we selected soil parameters from Armstrong loam as representative of the Armstrong-Gara-Adco complex, and Keswick clay-loam parameters as representative of the Lindley-Keswick-Goss complex.

The digital land use map used in this study was based upon 1992 satellite images (Table 3). Minor land uses and soils were eliminated according to the procedure implemented in the AVSWATX interface (Di Luzio, 2001). The thresholds for land use and soils were 3% and 10%, respectively. Four land uses (grassland, cropland, forest, and water) and two soils were retained. The dominant soil under cropland was Armstrong loam. Grassland and forest lands were split almost evenly between both soils.

There may be some differences in the land use or land cover between 1992 and July 2003, the date at which the AgNPS-SALT project was started. The AgNPS-SALT proposal noted that the quantity of cropland and grassland in the watershed varies with livestock prices. The proposal also identified replacement of cropland, pasture and forest with rural residential development as a continuing trend.

There are also some differences between the 1992 land use map and the land use described in the project proposal. Table 3 shows the differences in watershed percentages covered by each category. Hay land and land enrolled in the Conservation Reserve Program are included in the cropland category by NRCS but they are classified as grassland on the land use map. Apparently, some of the land classified as Urban or Public in the SWCD document is interpreted as grassland on the satellite image. This may include rural residential areas. We used the 1992 map because it was readily available in a GIS form, which is necessary for the AVSWATX interface.

Table 3: Differences in percent land use distribution.

Land use	AgNPS-SALT proposal	1992 satellite image
Row Crops	25	25
Pasture/Hay	24	Total grassland: 51
CRP	15	
Forest	24	19
Water	4	4
Urban/Public	8	<1
Total	100	100

The required management information for cropland includes the rotation of crops, the timing and amount of fertilizer and pesticide applications, and the tillage management. Multiple rotations are used in the watershed and each type is distributed throughout the watershed. Cropland in the Long Branch watershed is primarily planted to corn (24%), soybeans (66%) and wheat (10%). The producer panel indicated that the most common crop rotations in the watershed were corn-bean, corn-bean-bean-bean, and bean-wheat. To build a manageable model and keep it consistent with previous modeling efforts (Heidenreich and Farrand, 2000; Farrand, 2004), the corn-bean-bean-bean rotation was reduced to continuous soybeans.

We had no information regarding which fields were under which crop rotation. Thus, each rotation was allocated in each subbasin such that the proportion of each crop in each subbasin matched that of previous models (Heidenreich and Farrand, 2000; Farrand, 2004). Further, the allocation of crop rotations kept annual crop proportions in the watershed (corn-24%, soybeans-66%, and wheat-10%) constant by modeling 2-crop rotations as different phases in different subbasins (i.e., corn-bean and bean-wheat in subbasins 1, 3, and 4, and bean-corn and wheat-bean in subbasins 2, 5, and 6).

Previous models of the watershed assumed most of the cropland was no-tilled. The producer panel indicated that conservation tillage was the dominant tillage practice for all crops (72% of bean fields, 67% of corn fields, and 89% of wheat fields), with the remainder of ground in conventional till. They also indicated that minimum tillage (e.g., field cultivator) was becoming more common for soybeans and that no-till corn was more common in the northern portion of the watershed. Because tillage practices were not a focus of the AgNPS-SALT project, all cropland was modeled as conservation till. Thus, tillage occurs more often than in previous models, but still classifies as conservation till (i.e. > 30% surface remains covered with residues).

Grassland in the Long Branch watershed is primarily managed as pasture or hay (62%) or left idle (38%). Previous models and the producer panel indicated that hay management comprised a small proportion of managed grasslands and was not incorporated as a separate land use in this model. Idle grasslands were primarily enrolled in the Conservation Reserve Program (CRP) or other similar federal program. Although these lands can come back under management at the end of their contract cycle (generally 10-15 years), most fields are re-enrolled due to high erodibility of the underlying soils. Further, enrollment levels have remained at fairly stable levels since the early-1990's (date of digital land cover information) with the exception of the Conservation Reserve Enhancement Program (CREP). CREP added just over 4,000 acres of grassland to the watershed by late 2004. Because CREP was separate from the AgNPS-SALT project, no changes in the proportion of idle grasslands were incorporated into this model.

We had to make additional choices to limit the number of individual units in each subbasin to a minimum that would allow the assessment of the AgNPS-SALT project. The following factors were considered.

- One baseline nutrient management system was used for each crop. Alternative nutrient management plans were introduced afterward to be assessed.
- SWAT calculates the overall loading for only one pesticide. Thus, we selected to route atrazine through the whole system, because it is the primary concern in the lake.
- The producer panel indicated that approximately 75% of pastures were fertilized. Thus, we assumed that 75% of the grassland within each subbasin was fertilized, and that the unfertilized pasture was in poorer condition.
- Per the panel's recommendation, cattle were distributed among the pastures in each subbasin so that an approximately equal number of animals were grazing in the watershed from April 15th to December 15th, and move between pastures every month. Cattle were assumed to have supplemental feed in the winter months, but still hang out in grazed forests.
- No filter strips, riparian buffers, ponds, terraces or other conservation practice implemented under the AgNPS-SALT project were assumed in the baseline condition.

- Approximately, 26% (4,000/15,239 acres) of forests were grazed under the baseline scenario and these were distributed proportionally among the subbasins.

Limitations of the SWAT model

The conservation practices to be implemented under the AgNPS-SALT program included nutrient and pesticide management, buffers, pasture management and planned grazing systems, erosion control plantings, and streambank protection (Table 2). 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. Further, we omitted some practices due to a lack of sufficient information about pre-project conditions (e.g., alternative watering systems and well decommissioning) or because they were deemed too small to have a measurable effect at the watershed scale (i.e., approximately 1 mile of streambank stabilization).

Scenarios

The AgNPS-SALT project provides incentive payments to encourage the adoption of Best Management Practices (BMPs) (See Table 2). After building a baseline representation of the Long Branch Lake watershed and calibrating the model to USGS flow guage information, we modeled the effects of most BMPs offered under the project. Each selected practice or group of practices was implemented as an alternative model run (i.e. scenario) such that outputs from the alternative model could be compared to the baseline model to yield a before and after comparison of the expected impact of the BMP. Likewise, the synergistic effect of implementing multiple BMPs was modeled by incorporating all the proposed practices at once in a separate alternative model. This scenario enables evaluation of the impact of the AgNPS-SALT project as a whole. Finally, we ran an additional alternative scenario that applied the suite of BMPs to all acreage in the watershed needing treatment according to the AgNPS-SALT proposal. This scenario enables an evaluation of the maximum benefit that could be obtained from implementing the BMPs. 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 to the lake.

Because few practices had been implemented when this study began and there were no intentions on the part of project managers to target any of the practices, each BMP, with the exception of planned grazing, was simulated in all subbasins proportional to the land use available in each subbasin. Planned grazing was applied to a fixed acreage in each subbasin to facilitate the movement of cattle among fields.

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 a very small fraction (<1%) of the Long Branch Lake watershed. The sediment, nutrient, and chemical loadings generated in the baseline scenario were compared with the loadings obtained with the alternative BMP scenarios.

Nutrient & Pesticide Management Scenario (Alternative 1)

The AgNPS-SALT proposal listed 16,029 acres of row crop ground in the watershed and proposed to treat 9,475 acres (59.1%). Whereas, nutrient management practices could be applied to pastureland, project managers expected that nutrient and pesticide management practices will likely be applied to the same crop fields. This is reflected in the decision to equally divide target acreages for nutrient and pesticide management practices (4,180 acres each). Because the primary nutrient and pesticide concerns in the watershed deal with corn management (i.e., nitrogen and atrazine applications), this scenario was structured such that these management practices were applied simultaneously to areas modeled as a corn-soybean rotation in each subbasin. Thus, nutrient and pesticide managements affected approximately 26% (4,180/16,029) of crop land in the watershed.

Some assumptions used in this scenario were that:

- Nitrogen applications were reduced from 150 lbs/acre to 120 lbs/acre,
- Atrazine applications were reduced from 2.25 lbs/acre to 1.125 lb/acre.

Buffers & Other Erosion Control Practice Scenario (Alternative 2)

Other crop land conservation practices offered under the AgNPS-SALT project in this watershed were focused on erosion control (i.e., the Critical Area Treatment, Erosion Control, and Buffers categories of practices in Table 2). We lumped most of these practices together within the model because they have similar environmental impacts (trapping sediments, impeding overland flow, and increasing infiltration), funds were allotted to treat only relatively small acreages with each practice, and critical area treatments were allotted by number of sites rather than acres. Grouped erosion control practices were implemented within the model as grass filter strips applied across all crop rotations in each subbasin. Thus, erosion control practices affected approximately 4% (669/16,029) of crop land in the watershed. This is less than the 7% proposed under the SALT grant because we did not model water impoundment and control structures, given that we had no information on numbers of existing impoundments and structures or how much acreage an average impoundment or structure would protect.

Some assumptions used in this scenario were that:

- Critical area cover plantings and sod waterways would average 2 acres in size,
- Acreages given in the AgNPS-SALT proposal or assumed for all practices grouped in this scenario represented the actual acreage of the installed practice rather than the area protected by the practice,
- The acreage protected by each practice would approximate 10 acres for every acre installed. This ratio was arrived at after examining the number of acres treated, the number of acres needing treatment, and the total acreage of cropland in the watershed.

Planned Grazing Scenario (Alternative 3)

The AgNPS-SALT grant listed 15,498 acres of pasture/hay in the watershed and proposed to treat 3,210 acres (20.7% of pasture land). Planned (i.e., rotational) grazing targeted 11% (1,710/15,498) of pasture/hay acres in the watershed. This practice involved using shorter grazing periods on each field and moving cattle among fields more frequently. Planned grazing was applied to a constant acreage to facilitate the movement of cattle in the model.

Some assumptions used in this scenario were that:

- Cattle were moved between subbasins to simulate moves between fields,
- Cattle stopped grazing (i.e., received supplemental feeding) when grass biomass in the field dropped to 358 pounds per acre (400 kg/ha or approximately 1 inch tall),
- Cattle moved to a new pasture every week,
- Rotational grazing would only be implemented on good quality pastures, thus only occurred on a subset of fertilized pastures.

Cover Enhancement Scenario (Alternative 4)

In addition to planned grazing, the AgNPS-SALT proposal targeted 9.7% (1,500/15,498) of pasture/hay acres in the watershed for cover enhancement. This practice involved overseeding and fertilizing pastures. Cover enhancement was applied proportionally to pasture acreage in all subbasins.

Some assumptions used in this scenario were that:

- Cover enhancement would be necessary only on pastures in poor condition, thus it was applied to unfertilized pastures in each subbasin.

Woodland Protection Scenario (Alternative 5)

Forests comprise approximately 24% of the Long Branch watershed and typically are composed of deciduous species. The producer panel indicated that some producers allow their livestock to graze freely in woodlots, especially in wooded draws. The AgNPS-SALT proposal listed 15,239 acres of forests in the watershed, 4,000 acres (26.2%) of which needed treatment (i.e, were presumably affected by grazing). The proposal targeted 940 acres (6.2%) through woodland protection and use exclusion. Thus, this scenario was structured such that 23.5% (940/4,000) of grazed forests received treatment under the woodland protection scenario. Woodland practices were applied proportionately to all subbasins.

Some assumptions used in this scenario were that:

- Woodland protection and use exclusion are environmentally equivalent practices.

Combined BMPs Scenario (Alternative 6)

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 “Combined BMPs” 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 (Alternative 7)

The BMPs introduced under the AgNPS-SALT project covered only part of all acres needing treatment. For instance, 3,210 target acres were proposed for pasture management in the watershed, while 6,350 acres were identified as in need of treatment. Only 51% 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 needing treatment. This was implemented in the model by assuming that the proportion of acreage allotted between planned grazing and cover enhancement remained constant. Therefore, on the 6,350 acres needing treatment, planned grazing was applied to 53% (1,710/3,210) and cover enhancement was applied to 47% (1,500/3,200). Similar logic was applied to other conservation practices, and all BMPs were simulated simultaneously as in the Combined BMPs scenario. There was enough acreage available that practices from more than 1 scenario were not applied to the same ground.

Results

The study focused on the outputs from the subbasins and the inputs to Long Branch Lake. 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. These are referred to as yields and are expressed on a per unit area basis. Reservoir loadings are reported at the input to the lake (outlet of the stream reach in subbasin 1).

Baseline Scenario

Subbasin contributions

The average annual sediment yield and nutrient and atrazine runoff per acre are stated in Table 4. 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 climatic changes from year to year.

Table 4. Variability of the subbasin contributions in the baseline scenario.

	Amount	**Temporal Variability***	**70% range**
Sediment Yield (tons/ac/yr)	2.4	1.3 (53%)	1.1 – 3.7
Total Nitrogen (lbs/ac/yr)	10.2	4.2 (42%)	6.0 – 14.4
Total Phosphorus (lbs/ac/yr)	1.7	0.8 (45%)	0.9 – 2.5
Total Atrazine (lbs/ac/yr)	0.005	0.003 (66%)	0.002 – 0.008

*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 1.3 t/a/yr indicates a 70% chance to observe an annual yield of 2.4 ± 1.3 tons/acre/year.

Reservoir loads

The reservoir is located in subbasin 1. The nutrient, sediment, and chemical loads delivered to the reservoir are loads transported from the entire watershed (Table 5).

Table 5. Environmental impacts of the baseline scenario at the reservoir.

	Sediment (tons/year)	**Nitrogen** (lbs/year)	**Phosphorus** (lbs/year)	**Atrazine** (lbs/year)
Long Branch Lake	10,348	671,157	191,346	322

Alternative Management Scenarios

Subbasin contributions

According to model predictions, most of the conservation practices proposed for implementation under the AgNPS –SALT grant will reduce sediment, nutrient, and/or chemical yields (Table 6). Erosion control practices had the greatest effect on sediment and nutrient yields of any single practice scenario. This alternative also provided a substantial reduction in atrazine yields; nearly equivalent to the pesticide management practice of reducing atrazine applications by 50% (Alternative 1). Grazing practices (Alternatives 3, 4, and 5) had no effect on atrazine yields because they did not affect corn ground.

The model predicted slightly higher sediment and phosphorus losses under the nutrient and pesticide management practices (Alternative 1) compared to the baseline. Reduced nitrogen applications slowed corn growth in the model, allowing more rainfall to reach the ground and affect erosion rates. Most phosphorus moves with sediment, so it is understandable that phosphorus losses would track sediment losses.

As expected, the synergistic effects of combining all the practices in the Combined BMP scenario (Alternative 6) achieved greater reductions in pollutant yields than any of the practices individually. In this scenario, the combination of buffers and reduced application is expected to reduce atrazine yields by nearly one-third. Combining the grazing and cropland practices indicated reductions in sediment and nutrient yield of 7-13%. Treating all the acres in need of treatment (Alternative 7) would achieve substantially higher yield reductions for all the environmental indicators we investigated.

Table 6. Expected impacts of the AgNPS SALT project at the subbasin level, percentage change in pollutant yields from the baseline.

Alternative Scenarios		**Sediment** (% change)	**Nitrogen** (% change)	**Phosphorus** (% change)	**Atrazine** (% change)
1	**Nutrient & Pesticide Management**	1.0	-0.3	1.6	-14.9
2	**Erosion Control**	-6.0	-6.3	-6.7	-13.5
3	**Planned Grazing**	-4.7	-3.8	-3.0	0.0
4	**Cover Enhancement**	-3.2	-0.3	-0.8	0.0
5	**Woodland Protection**	-0.1	-1.4	-0.6	0.0
6	**Combined BMPs**	-13.3	-7.6	-10.1	-28.8
7	**All Acreage Needing Treatment**	-31.3	-20.8	-25.9	-38.5

Reservoir loads

The reductions in sediment achieved at the subbasin level were not visible at the reservoir because of sediment deposition in the stream. The stream loads are controlled by the stream capacity and a reduction of incoming sediment does not translate in a reduction of stream loads. The combined BMPs scenario resulted in a 2% sediment load reduction for the entire watershed (Table 7). There was little difference in nitrogen, phosphorus, and atrazine load reductions because we left the stream water quality processes inactive. The lack of water quality data in Long Branch Creek and East Fork of the Chariton does 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 7. Expected impacts of the AgNPS SALT project at the reservoir, percentage change in pollutant yields from the baseline.

Alternative Scenarios		**Sediment** (% change)	**Nitrogen** (% change)	**Phosphorus** (% change)	**Atrazine** (% change)
1	**Nutrient & Pesticide Management**	0.5	0.7	1.0	-14.9
2	**Buffers & Erosion Control**	-0.5	-5.4	-4.9	-13.5
3	**Planned Grazing**	-0.1	-2.7	-4.8	0.0
4	**Cover Enhancement**	-1.2	0.6	-1.4	0.0
5	**Woodland Protection**	-0.3	-0.5	-0.5	0.0
6	**Combined BMPs**	-1.9	-7.6	-10.9	-28.8
7	**All Acreage Needing Treatment**	-5.1	-19.3	-25.7	-38.5

Erosion control practices and buffers were the most effective practices to reduce reservoir loadings of nitrogen. Nitrogen management increased reservoir loads slightly due to an increase in the movement of organic nitrogen with sediment. Cover enhancement also caused a slight increase in nitrogen loads due to increased nitrogen movement with water resulting from the additional fertilization. The combined BMPs are predicted to produce an 8% reduction of the nitrogen stream loads (Table 7). If practices were installed on all acreage needing treatment, that reduction would rise to 19%.

The total phosphorus loads to the reservoir could be reduced if erosion control practices, grazing management, or cover enhancement practices are implemented. The combined BMPs scenario represented a decrease of 11% in the reservoir's phosphorus load, while treating all acreage needing treatment showed a substantial decrease of 26% (Table 7).

Conclusions

This analysis estimated the individual and combined impact of practices proposed in the AgNPS-SALT project in the Long Branch Lake watershed using target acreages provided in the grant proposal. The model was calibrated using flow data collected at the USGS near Atlanta. Comparisons of pollutant yields and loads in the watershed with and without the practices installed 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, results indicated reductions in sediment, nutrient, and chemical yields and loads when the conservation practices were implemented.

Implementation of erosion control practices (modeled as filter strips in this analysis) appears to be the most efficient method to reduce the sediment and nutrient yields. These practices should also reduce chemical yields. Grazing managements (planned grazing and cover enhancement) also showed good reductions in sediment yields due to increased grass cover on pastures. Nutrient management (i.e., reduced nitrogen application) actually increased sediment and phosphorus yields slightly due to slower crop growth. However, the increases were small (<2%) and would not likely be observed.

The most effective method for reducing pesticide losses from cropland was reducing application by 50% (pesticide management). The filter strips modeled in the erosion control practice scenario were a close second. The model assumed fixed dates for atrazine applications and did not adjust these dates in the event of precipitation. Producers likely shift application dates to avoid rainfall events and keep more of this water soluble pesticide on the field. Currently, this management practice cannot be simulated with SWAT. Another practice that would help reduce atrazine losses is incorporation, but this practice would likely increase sediment yields.

The benefits of conservation practices at the field scale may not transfer to the watershed scale. Reductions in reservoir loadings due to implementation of individual conservation practices in the AgNPS-SALT grant tended to be less than the reductions in stream loadings (i.e., yields). This was especially true of sediment loadings because a large amount of the sediment was deposited in streambeds. Reservoir nitrogen loadings increased slightly over stream loadings under the nitrogen management and cover enhancement practices due to an increase in leaching. However, it is important to note that the change in loadings from the baseline condition was very small (<1%). Reductions in reservoir pesticide loadings were identical to stream load reductions because stream processes were turned off in the model. This assumption is not unrealistic in relatively small watersheds with short travel times such as the Long Branch Lake watershed.

The AgNPS-SALT project seeks to implement a variety of conservation practices simultaneously, which may yield synergistic effects and increase the benefits of the project. When all of the conservation practices were implemented simultaneously on the target acres under the Combined BMPs Scenario, the sediment, nutrient and pesticide reductions in the stream were significant. Nutrient and pesticide reductions in the reservoir also were significant. In most cases, the reductions in stream or reservoir loads under the Combined BMPs Scenario were greater than the sum of the individual reductions.

The AgNPS-SALT project identified more acres needing treatment than it proposed to treat with conservation practices. Limitations on funding, personnel, and producer interest likely impede our ability to fully implement conservation practices. However, we can use models to show how close to ideal current efforts might achieve. The All Acres Needing Treatment Scenario was designed to show what the pollutant loads might be if we could treat all degraded acres. Model results indicated that reductions in stream and reservoir loadings of sediment and nutrients could be more than doubled. However, reductions in atrazine loadings would only be increased by about one-third if all acreage in need were treated with pesticide management and buffers. Thus, it appears that full implementation of conservation practices on targeted acreage under the AgNPS-SALT project will achieve near maximal reductions in pesticide loading but leave lots of work to be done on sediment and nutrients. This scenario also shows that pollutant loads could be minimized but not eliminated. Models such as SWAT can evaluate the relative potential of various conservation practices to reduce pollutant loads, and reveal the balance points between the efficacies of conservation plans and their costs.

Appendix A: Model Calibration

Flow, sediment, and water quality parameters are estimated with the SWAT model. When data are available, it is always best to compare the simulated values obtained during a given numbers of years to measured data during that time and adjust the model parameters so that they match. The process is called calibration. Simulated values and measured data are then compared for a different period of time not used for the model calibration; this is called model validation. Ideally, one would have flow, sediment, and water quality data over several years to calibrate and validate the model. In reality, the data are rarely available and the model is calibrated, validated, or simply verified with what is available.

Flow data were available for the Long Branch Lake watershed from July 7, 1995 to September 30, 2005. Thus, we had enough years for calibration and validation. We used 4 years for calibration (1996 – 1999), and 4 years for validation (2000 – 2003). The calibration period captured a larger range of precipitation values than the validation period. The flow gauge is at the outlet of subbasin 4 on Long Branch Creek near Atlanta; the weather station where daily precipitation and temperature were measured is near Kirksville. Although subbasin 4 stretches towards Kirksville from the gauge, the distance between the gauge and the station was great enough to create error in the calibration process. We chose to retain the Kirksville station instead of using a closer station because of the completeness of its data. No sediment, nutrient, or pesticide data were available for comparison to model outputs.

The base flow separation program described in Arnold et al. (1995) and Arnold and Allen (1999) was run and indicated that the base flow represented between 6 and 22% of the total flow. The alpha factor used by the SWAT model to control return flow was not estimated by the program. Thus, the default value (0.3) was used for the model.

Several calibration indicators were used to quantify how well the model reproduces the measured flows and crop yields. 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%. The model under predicted flow values by greater than 10%, but we accepted these values because the gauge was so far from the weather station. Average corn yields obtained with the model during this period were high but within the range seen in Macon and Adair Counties. Soybean and wheat yields were higher than expected from historical values. The Nash-Sutcliffe coefficient compares the difference between predicted and observed values relative with the difference between observed values and the median of the observed values. Table A1 presents the values of the indicators during calibration of the model based on 4 years of data (1996-1999).

Table A1. Calibration criteria for the Long Branch Lake Watershed.

Criteria	Goals	Value
Surface runoff deviation	[-10%, 10%]	-16%
Base flow deviation	[-10%, 10%]	-11%
Total flow deviation	[-10%, 10%]	-15%
Base flow proportion	[6%, 22%]	14%
Nash-Sutcliffe (monthly)	[> 0.20]	0.36
Corn yield (bu/ac)	[68-121]	118
Spring soybeans yield (bu/ac)	[25-35]	56
Winter wheat (bu/ac)	[33-52]	68

The same indicators were examined to quantify how well the model performed during the validation period. The surface runoff, base flow, and total flow deviations were greater than 10% and the model appeared to do a much poorer job of matching measured flows in the validation period, over predicting surface flows, base flows, and total flows. However, measured flows in the validation period were approximately half the levels they were in the calibration period. Percentage differences between small values can be large even if the differences are small. The other criteria that are not so dependent on the magnitude of the flow, i.e.: comparison graphs, Nash-Sutcliffe coefficients, and base flow proportion all showed the model was performing at least as well as in the calibration period. Further, yields for all crops in the validation period were within the ranges of those reported for Macon and Adair Counties. Table A2 presents the values of the indicators after calibration of the model based on 4 years of data (2000-2003).

Table A2. Validation criteria for the Long Branch Lake Watershed.

Criteria	Goals	Value
Surface runoff deviation	[-10%, 10%]	56%
Base flow deviation	[-10%, 10%]	89%
Total flow deviation	[-10%, 10%]	59%
Base flow proportion	[6%, 22%]	12%
Nash-Sutcliffe (median)	[>0.20]	0.38
Corn yield (bu/ac)	[102-152]	104
Spring soybeans yield (bu/ac)	[29-42]	42
Winter wheat (bu/ac)	[51-65]	63

Appendix B: BMP Simulation

Nutrient & Pesticide 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, and can include a split application of nutrients. Although nutrient management may be needed on cropland and grassland in the Long Branch Lake Watershed, the AgNPS-SALT project focused nutrient management on crop ground. The primary practice promoted was to reduce applications of anhydrous ammonia a month prior to planting from 150 lbs/ac to 120 lbs/ac. Thus, this was the only nutrient management difference between this scenario and the baseline scenario.

Pesticide management in the Long Branch Lake Watershed focused on atrazine, the herbicide used on corn and sorghum that replaced cyanazine when it was discontinued. The project promotes reduction of atrazine application rates by 50%. Project managers expected that most of the pesticide management practices would be applied on the same fields receiving the nutrient management practice. Thus, each field that received reduced nitrogen applications also had both atrazine applications (pre-plant and post-plant) reduced by 50%. Pest damage is not simulated with SWAT and we cannot estimate potential crop yield reductions due to pests.

Erosion Control Practices

The AgNPS-SALT project proposed a number of erosion control practices for cropland (See Table 2). Because many of these practices converted small amounts of cropland and have similar environmental effects, we lumped them together in a single scenario. We selected grass filter strips as the practice to represent this suite of practices. Filter strips were implemented on a subset of ground under each rotation by changing 2 parameters in the management file. Filter width was set to 35 m (the maximum width allowed under CRP) and the curve number (CN2) was reduced from 83 (corn-soybean and soybean-wheat) or 86 (continuous soybeans) to 79.

Planned Grazing

Planned grazing, also called rotational grazing, seeks to improve the ground cover, the quantity and quality of forage for cattle. 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.

While grazing systems are designed for the peculiarities of individual operations, a typical scenario had to be designed for the purpose of model simulation. Planned grazing was simulated by switching to more intensive grazing management - the number of pastures used was increased, the duration of grazing was reduced from 1 month to only 7 days, the minimum amount of grass left after grazing (BIOMIN) was raised from 400 to 1,180 kg/ha, 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 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. This was simulated by assuming the pasture condition improved under a prescribed grazing system, which was implemented in the model by reducing the curve number (CN2) from 81 to 76. To simulate the rotation of cattle between pastures, cattle were moved between adjacent subbasins.

Cover Enhancement

Cover enhancement seeks to improve pasture condition and thereby reduce erosion. This was implemented in the model by shifting the appropriate acreage in each subbasin from un-fertilized pasture to fertilized pasture and reducing its curve number (CN2) from 88 to 80.

Woodland Protection

The goal of Woodland Protection and Use exclusion practices is to reduce erosion rates and promote regrowth of vegetation in grazed forests. Project managers and the panel of producers we consulted indicated that many producers allow their cattle free access to forests, especially wooded draws. These 2 practices were assumed to have equivalent environmental effects and their target acreage was lumped together in the model. The practices were implemented in the model by removing forests from the regular rotation of grazing and reducing the curve number (CN2) on those acres from 79 to 72 (equivalent to other forest ground in the model).

Appendix C: Baseline management scenarios

Corn – soybeans rotation

		Rates	
Date	Operation	Metric (kg/ha)	English (lbs/ac)
March 25	N fertilizer	168	150
April 1	Atrazine	1.26	1.125
April 2	N fertilizer		
April 2	P fertilizer		
April 25		**Corn planting**	
May 8	Atrazine	1.26	1.125
October 1		**Corn harvest**	
May 10	N fertilizer	22	20
May 10	P fertilizer	20	18
May 10	Round-up	1.12	1.0
May 12		**Soybeans planting**	
June 12	Round-up	1.12	1.0
October 1		**Soybeans harvest**	
October 10	Fall tillage	Generic Conservation Tillage	

Continuous soybeans

		Rates	
Date	Operation	Metric (kg/ha)	English (lbs/ac)
May 10	N fertilizer	22	20
May 10	P fertilizer	20	18
May 10	Round-up	1.12	1.0
May 12		**Soybeans planting**	
June 12	Round-up	1.12	1.0
October 1		**Soybeans harvest**	
October 10	Fall tillage	Generic Conservation Tillage	

Soybeans - wheat rotation

		Rates	
Date	Operation	Metric (kg/ha)	English (lbs/ac)
May 10	N fertilizer	22	20
May 10	P fertilizer	20	18
May 10	Round-up	1.12	1.0
May 12		**Soybeans planting**	
June 12	Round-up	1.12	1.0
October 1		**Soybeans harvest**	
October 2	Fall tillage	Generic Conservation Tillage	
October 5	N fertilizer	45	40
October 5	P fertilizer	30	27
October 5		**Wheat planting**	
March 15	N fertilizer	67	60
June 25		**Wheat harvest**	