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Assessment of Best Management Practices for Water Quality Improvement for the Deep Hollow Watershed in Mississippi Delta MSEA Project Using AGNPS

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Abstract

Sediment and its associated pollutants entering a water body can be very destructive to the ecological health of that system. Best Management Practices (BMPs) can be used to reduce these pollutants, but understanding the most effective practices is very difficult. Watershed models are the most cost effective tool to aid in the decision making process of selecting the BMP that is most effective in reducing the pollutant loadings. The Annualized Agricultural Non-Point Source Pollutant Loading model (AnnAGNPS) is one such tool. Objectives of this study were to assemble all necessary data from the Mississippi Delta Management System Evaluation Area (MDMSEA) Deep Hollow watershed to validate AnnAGNPS and to use the validated AnnAGNPS to evaluate the effectiveness of BMPs for water quality improvement.

In this study, AnnAGNPS predictions were compared with three years of field observations from the MDMSEA Deep Hollow watershed. Using no calibrated parameters, AnnAGNPS underestimated observed runoff for extreme events, but the relationship between simulated and observed runoff on an event basis was significant (R^2=0.9). In contrast, the lower R-square of 0.5 for event comparison of predicted and observed sediment yields demonstrated that the model was not best suited for short-term individual event sediment prediction. This may be due to the use of Revised Universal Soil Loss Equation (RUSLE) within AnnAGNPS and parameters associated with determining soil loss were derived from long term average annual soil loss estimates. The agreement between monthly average predicted sediment yield and monthly average observed sediment yield had a R-square of 0.7. The monthly predicted nitrogen loading is

not significantly different from observed nitrogen loading at the 95% level of confidence. Three-year predicted total runoff was 89% of observed total runoff and three-year predicted total sediment yield was 104% of observed total sediment yield. Three-year predicted total nitrogen loading was 127% of the observed total nitrogen loading. Alternative scenario simulations showed that: for the Mississippi Delta, no-till, slotted inlet pipes, and impoundments appear to be promising technologies. Information on cost of adopting the BMPs and the impact of BMPs on water quality should both be considered in choosing combination of BMPs.

Introduction

Soil erosion has long been recognized as a threat to the productivity of U. S. farms and the quality of surface waters. Excessive amounts of sediment cause taste and odor problems for drinking water, block water supply intakes, foul treatment systems, and fill reservoirs. A high level of sediment adversely impacts aquatic life, reduces water clarity, and affects recreation. Even in relatively flat areas, such as the Mississippi Delta, considerable soil erosion can occur. Murphree and Mutchler (1981) reported a 5-year average sediment yield as high as 17.7t/ha.y from a flat watershed in the Mississippi Delta. Cooper and Knight (1990) found that suspended sediment loads generally exceeded 80 to 100 parts per million (maximum for optimal fish growth) during and immediately following storm events in two upland streams in Mississippi. Ritchie et al. (1979) found that one to three inches of fine sediments accumulated per year in natural lakes along Bear Creek, a drainage system in the Mississippi Delta where 75 percent of the land is in cultivation.

Accumulated sediment has covered the bottom of many lakes and stream sections with fine silt (Ritchie et al., 1986).

To increase crop production, fertilizers are extensively used in the United States. The wide spread use of fertilizer continues to be a major public concern because of possible human health risks and the eutrophication of surface water (Novotny and Olem, 1994). Nitrate concentration is a parameter of particular concern because it has been linked with "blue baby" syndrome and formation of carcinogenic compounds (NCSU, 2000).

The improvement of water resources in the United States has been an issue of significant societal and environmental concern for many years. Off-site transport of sediment and its transported pollutants from agricultural cropland has been classified as one of the major sources of water quality impairment and water quality would directly benefit if the amount of soil loss was reduced (NRCS, 1997). The impairment to surface water quality due to sediment and nutrient transport from agricultural cropland has been estimated to be about $9 billion per year (Ribaudo, 1992). Although more than $500 billion has been spent on water pollution control since the implementation of the Clean Water Act in 1972, the quality of the nation's water still remains largely unknown (Akobunbo and Riggs, 2000).

In reducing soil erosion and solving nonpoint source water quality problems, regulatory agencies promote BMP adoption on areas most susceptible to NPS pollution to reduce sediment and pollutant losses from agricultural land areas. Under the Environment Quality Incentive Program (EQIP), cost sharing is available from government agencies to agricultural producers who voluntarily implement BMPs (NRCS, 2001). Depending on local priorities and fund availability, the cost-sharing rate is up to 50 percent and may be more. Therefore, a significant amount of research has been conducted to identify management options for minimizing sediment yield and nonpoint source pollution from agricultural land areas. Examples of such management options include conservational tillage (Loehr et al., 1979; Mueller et al., 1984), grass filter strips (Dillaha et al., 1989; Line, 1991; Cooper and Lipe, 1992; Robinson et al., 1996), and impoundments that retard flow and allow suspended sediment transported in runoff sufficient time to drop out of suspension (Laflen et al., 1978). However, the impact of a particular BMP on water quality is still a challenge to estimate before any actual implementation (Parker et al., 1994; Walker, 1994) at a particular location since data from one location may not be applicable to other locations. It is even more difficult to predict the integrated effects of implementation of several BMPs. Data on how BMP implementation improves quality of water would help decision makers determine a cost/benefit ratio of BMP implementation. Such data also would allow them to choose which BMP combination would produce the maximum benefit.

The complexity and expensive nature of laboratory and field observations necessitate the development and use of water quality models such as AnnAGNPS (Annualized Agricultural Non-Point Source Pollutant Loading model) (Cronshey and Theurer, 1998) and SWAT (Soil and Water Assessment Tool) (Arnold et al., 1993). Such models have been developed for evaluating the hydrologic and water quality responses of a watershed to alternative management practices. An effective simulation tool can increase awareness and understanding of BMPs by producers and watershed planners and promote adoption of alternative management practices. Ultimately, this will reduce adverse agricultural effects on water resources and ecological processes.

Physically based models have the potential to simulate the erosion processes or behavior of sediment movement accurately, with little or no calibration of the parameters used. Using such models is significantly less expensive than large-scale monitoring of these processes in the field. Annualized Agricultural Pollutant Simulation Model (AnnAGNPS) is one of such models developed for use with little local calibration on ungauged watersheds. For in-field erosion estimation, AnnAGNPS includes the advanced soil erosion prediction technology contained with the Revised Universal Soil Loss Equation (RUSLE) (Renard et al, 1997).

AGNPS 2001 is a suite of computer models for nonpoint source pollution control. It includes AnnAGNPS, Channel evolution simulation model (CONCEPT), Stream temperature simulation (SNTEMP) and lake modes. It also includes TOPAGNPS, AGFLOW for input topographic data process, Input Editor (a graphical user interface for data preparation), Output processor for output reformatting and analysis. Detailed information about each component of AGNPS 2001 can be obtained through website at http://www.sedlab.olemiss.edu/AGNPS.html.

AnnAGNPS, a continuous simulation model, was developed as a direct replacement for the single event model, AGNPS 5.0. AnnAGNPS includes significantly more advanced features than AGNPS 5.0, but retains many of the important features of AGNPS 5.0 (Cronshey and Theurer, 1998). Many studies conducted using AGNPS indicated that the simulated results for runoff and sediment yield from AGNPS compare favorably with observed data (Young et al., 1989a; Bingner et al., 1989; Mitchell, et al., 1993). Young et al (1989b) also tested the chemical component of the model using three-year monitored data from seven different watersheds in Minnesota. They found that the simulated nitrogen and phosphorus concentrations agreed reasonably well with measured concentrations. Mostaghimi et al. (1997) used AGNPS 5.0 to assess the impact of management practices on the water quality and quantity for Owl Run Watersheds in Virginia and concluded that the model is applicable for nonpoint source impact assessment. However, there is a need to validate the continuous version, AnnAGNPS, before it is used for watershed analysis.

The Mississippi Delta Management Systems Evaluation Area project (MDMSEA) within the state of Mississippi has been developed as part of the national program "Agricultural Systems for Environmental Quality (ASEQ)" to reduce adverse agricultural impacts on water resources and ecology through developing alternative farming systems. Comprehensive data collection efforts have been ongoing for five years to monitor runoff, sediment and pollutant loadings into lakes from various farming practices (USDA-ARS-NSL, 2000).

The objectives of the MDMSEA project include evaluating the effect BMPs have on lake water quality. In order to accomplish this, application of AGNPS 2001 was performed to simulate the processes within the MDMSEA watersheds which include validating simulation results and use of the simulation model to assess and evaluate the effects of additional innovative BMP combinations used for improved water quality and ecology in the Mississippi Delta.

The features and capabilities of AGNPS 2001 are well suited to meet the modeling objectives of MDMSEA project. The main objectives of this study included: 1) assemble all necessary data from the Mississippi Delta Management System Evaluation Area (MDMSEA) Deep Hollow watershed; 2) validate and evaluate the capability of AnnAGNPS to predict runoff and sediment yield on Deep Hollow watershed using three years of field observed data; 3) assess effects of several BMPs on sediment yield from a cropped watershed after AnnAGNPS is validated; (4) combine predicted benefits with BMP cost estimates to identify the most cost effective BMP combinations for Mississippi Delta farmland.

Methods and Procedures

AnnAGNPS Model Description

AnnAGNPS is an advanced technological watershed evaluation tool, which has been developed through a partnering project between the United States Department of Agriculture – Agriculture Research Service (USDA-ARS) and Natural Resources Conservation Service (NRCS). It is designed to aid in the evaluation of watershed response to agricultural management practices (Cronshey and Theurer, 1998).

AnnAGNPS is a continuous simulation, daily time step, pollutant loading model. Daily climate information is needed to account for the temporal variation in the weather. The spatial variability of soils, landuse, and topography within a watershed, is accounted for by dividing the watershed into many homogeneous drainage areas. These simulated drainage areas are then integrated together by simulated rivers and streams, which route the runoff and pollutants from each individual homogeneous area downstream. From individual fields, runoff can be produced from precipitation events that include rainfall, snowmelt and irrigation. A daily soil water balance is maintained, so runoff can be determined when a precipitation event occurs. Soil erosion from each field is predicted based on the RUSLE (Renard et al, 1997). The sediment yield leaving each field is based upon the Hydro-geomorphic Universal Soil Loss Equation (HUSLE) (Theurer and Clarke, 1991). The model can be used to study the effects of alternative cropping and tillage systems including the effects of fertilizer, pesticide, irrigation application rate as well as point source yields and feedlot management (Bosch et al., 1998).

Required input parameters for application of the model include climate data, watershed physical information, and management. Physical information includes watershed delineation, cell (Subwatershed) boundaries, land slope, slope direction and reach information which can be generated by the AGNPS 2001 data preparation tools TOPAGNPS (Garbrecht and Martz, 1995) and AGFLOW (Bingner et al, 1997 and http://www.sedlab.olemiss.edu/AGNPS.html). Management information can be developed using the AGNPS 2001 Input Editor, a graphical user interface developed to aid users in the selection of appropriate input parameters. Additional input information includes land characteristics, crop characteristics, field operation data, chemical operation data, feedlots, and soil information. Much of this information can be obtained from databases imported from RUSLE or from NRCS sources. Climate data not available from measured data sources can be generated using the climate data generator (GEM) program (Johnson et al, 2000) based on climate stations located in the region surrounding the watershed.

Output files can include runoff, sediment, nutrient and pesticide yields on a daily, monthly or yearly basis according to user's specification. Output parameters can be specified for any desired watershed source location such as specific cells, reaches, feedlots, point sources, or gullies. More information can be found in Cronshey and Theurer (1998), Geter and Theurer (1998), and Theurer and Cronshey (1998).

Watershed Description

The Deep Hollow Lake watershed (-90.22 W, 33.41 N) is located in Leflore County, Mississippi (Figure 1). Deep Hollow is one of three watersheds studied in the MDMSEA, which seeks to develop and assess alternative innovative farming systems for improved water quality and ecology in the Mississippi Delta. The main crops grown in the Deep Hollow watershed are cotton (*Gossypium hirsutum* L.) and soybean [*Glycine max* (L.) Merr.]. Part of the watershed at the back of lake is forest (Figure 1).

The entire Deep Hollow watershed is about 113 ha with very flat slopes and drains into Deep Hollow Lake. About 30% of the entire area is forest. The Deep Hollow Lake is an oxbow lake (Figure 1) cutoff from the Yazoo River. There are many inlets from the Deep Hollow watershed contributing to the Deep Hollow Lake. In 1995-1996, the US Geological Survey (USGS) installed two gauging stations to monitor runoff, sediment yield, and nutrient and pesticides loadings at two of the inlets to the Deep Hollow (UL1 and UL2, see Figure 2). Data collected at the outlet of the southeast site UL2 (Figure 2) were used for model validation. The drainage area for the monitored site was 11 ha. Runoff was monitored using a critical flow flume. Both discrete and composite samples were taken during rainfall events for sediment and nutrient analyses. Rainfall was monitored at the flume using a tipping bucket raingauge.

In October of 1998, a detailed watershed topographic survey was performed. Figure 3 shows the topographic survey points. The elevations within the watershed range from 35 to 39 m. The maximum elevation difference is 4 meters, making the delineation of the watershed boundaries difficult. Deep Hollow Lake is adjacent to the Yazoo River. When the Yazoo River floods during heavy rainfalls, the water level in the Deep Hollow Lake can rise high enough to pond water on the field, which causes difficulty in measuring runoff during such periods.

Information describing the soils of Deep Hollow watershed was obtained from the USDA-NRCS area office in Greenwood, Mississippi. The watershed contains 15 soil series varying in texture from loamy sand to silty clay, but only three series cover 80% of the total area (Figure 4). Detailed records of agricultural operations including tillage, planting, harvesting, fertilization, cover crop planting, and pesticide usage have been maintained since 1996 (Appendix A).

BMPs implemented in the watershed were based on Mississippi USDA-NRCS practice standards (http://www.ms.nrcs.usda.gov/fotg.htm) and included: reduced-tillage (NRCS Code 329B) cotton, no-tillage (NRCS Code 329A) soybean (Figure 5), winter wheat (*Triticum aestivum* L.) cover crops (NRCS Code 340) for both cotton and soybean (Figure 6), grass filter strip (Figure 7) and impoundment (Figure 8). Impoundment can be classified as a detention pool or sediment basin which is designed to pond water in critical flow areas so as to allow sediment transported in runoff sufficient time to drop out of suspension before reaching the lake. The sediment basin also facilitates pesticide biodegradation. These practices are widely used today in the Mississippi Delta, but their relative contributions to water quality improvement are uncertain.

Input file preparation

AnnAGNPS cell generation

The topographic survey (Figure 3) is an incomplete survey because: 1) natural drainage pattern was destroyed by building a levee along the edge of field; 2) only part of watershed was measured (forest areas at the back of Deep Hollow Lake were not measured); 3) since the watershed is very flat, field plowing and farming practices from each year affect the drainage pattern of the watershed. Therefore, it was very difficult to generate an accurate Digital Elevation Model (DEM) for the entire watershed. Choosing the right grid size is very important and this process is a trial and error process.

Based on the topographic survey, two Digital Elevation Models (DEMs) were generated using ArcView (Figure 9) because of the discrete topographic measurement (Figure 3). The grid size used for DEM generation was 3m*3m. Stream network was generated for Deep Hollow Watershed using TOPAGNPS (automated digital landscape analysis tool for Topographic Evaluation, Drainage Identification, Watershed Segmentation and Subcatchment Parameterization) and AGFLOW (a fortran program written for generating DEM related input parameters) based on those two DEMs (Figure 10). In April of 2000, National Sedimentation Laboratory measured location of main channels for the two monitoring sites using GPS units (Figure 11). TOPAGNPS and AGFLOW generated channels matched the measured channels well (Figure 11).

Based on the stream network (Figure 10) and DEM files (Figure 9), watershed and subwatershed boundaries were delineated for each inlet to the Deep Hollow Lake using TOPAGNPS and AGFLOW. Since TOAGNPS and AGFLOW can only generate drainage area for one outlet at one time. Therefore, it was very time-consuming to complete subwatershed delineation based on the multiple inlets to the Deep Hollow Lake (Figure 10).

Figure 12 shows TOPAGNPS and AGFLOW generated watersheds and their subwatersheds for all the inlets of the small area of DEM. Figure 12 shows four watersheds drain to the Deep Hollow Lake, two of them drain to the woods area behind the lake then drain to the Lake, while other two drain to the lake directly. Two watersheds drain away from the lake.

Figure 13 shows some of the TOPAGNPS and AGFLOW generated watersheds and their subwatersheds for inlets of the large area of DEM to the Deep Hollow Lake. As it was done for the small area, each watershed was analyzed to identify if it drains to the Deep Hollow Lake or away from the lake.

Figure 14 shows the drainage area for the south flume monitoring station and its subwatersheds, which are called cells by AnnAGNPS. For each cell, physical information such as cell area, length and slopes were calculated by AGFLOW. Soil and land use maps were overlaid on the subwatershed map, the predominant soil and land use for each cell were determined through ArcView analysis (Figure 15 and 16). Listed tables below Figure 15 and 16 showed the soil type and landuse used by AnnAGNPS for each subwatershed. This process was repeated for each drainage area of Deep Hollow Lake until land use and soil information were determined for each AnnAGNPS cell.

Figure 17 shows the TOPAZ and AGFLOW generated watersheds and their subwatersheds for all the inlets of the large area of DEM. Additional field investigation found that a levee was built on the upper north area (Blue line) so that the upper north area that was not included in the drainage area of Deep Hollow Lake from the TOPAZ and AGFLOW generation, now drains to the lake. Figure 17 showed the levee survey performed by the USDA-ARS-NSL in May of 2000. Another area should be pointed out is the lower south area of Deep Hollow Watershed which was cut out by building a levee along the field edge (yellow line) (Figure 17).

From Figure 17, even after intensive delineation of Deep Hollow Watershed, there are still some areas which TOPAZ and AGFLOW can not catch. It is assumed that those areas contribute flow to the Deep Hollow Lake. They are treated as a single cell with outlet to the Deep Hollow Lake and their physical information was assumed the same as a nearby cell. The landuse and soil information was determined the same way as other AnnAGNPS cells.

AnnAGNPS parameter selection

a). Soil parameters

The required soil parameters for AnnAGNPS were generated using Map Unit Use File (MUUF) SSURGO search. MUUF is a software specifically used for soil parameters generation for water quality models. MUUF software and documentation on how to use it can be downloaded free of charge from website at ftp://ftp.wcc.nrcs.usda.gov/water_mgt/muuf/.

b). Curve number selection

The SCS curve number (CN) is a key factor in obtaining accurate prediction of runoff and sediment yields. Curve numbers were selected based on the *National Engineering Handbook*, Section 4 (Soil Conservation Service (SCS), 1985). CN's used in the model simulation are listed in Table 1. The CN for row-crop was used for cotton and soybeans when the crops were growing; the CN for fallow with residue was used when the crop was harvested but winter wheat had not yet been planted; and the CN for small grain was used during the winter wheat growth period. Curve numbers was adjusted based on daily soil moisture condition varying between CN_1 corresponding to the wilting point (the minimum value of soil moisture storage) and CN_3 corresponding to field capacity. CN is taken to correspond to a soil moisture halfway between wilting point and field capacity (SCS, 1985). Additional curve numbers were selected for forest, pasture and fallow for the purpose of alternative scenarios simulation.

c). Operation and operation reference

Crop management operation information is important to determine sediment yield accurately because this reflects the impact human activities will have on the watershed. Therefore, the operation management information was developed with as much detail as possible based on the crop management record (Appendix A); especially concerning operations that caused soil disturbance or land cover changes. Operation information for the watershed was set up for each field based on RUSLE guidelines and databases.

d). Nutrient information

The fertilizer's properties, soil initial nitrogen level and plant nitrogen uptake are most important parameters in accurately simulate nitrogen losses. Fertilizer's properties and soil initial nitrogen level were selected from the AnnAGNPS reference database. Soil initial organic nitrogen ratio was set as 500 PPM for the top layer and 50 PPM for the subsequent layers. Soil initial inorganic nitrogen ratio was set as 5 PPM for the top layer and 0.5 PPM for the subsequent layers. Soil initial organic phosphate ratio was set as 500 PPM for the top layer and 250 PPM for the subsequent layers. Soil initial inorganic phosphate ratio was set as 250 PPM for the top layer and 250 PPM for the subsequent layers.

Additional literature investigation found that total nitrogen content in the natural soil top one foot ranges from 0.03 to 0.4% (Tisdale et al., 1985). Most soil nitrogen is in organic matter which is derived from biological materials such as roots, microflora, fauna, leaf litter and humification processes (Stevenson, 1982). Organic nitrogen are mostly sorbed by clays. In such forms, it can be considered immobile and slowly available to plants. But those immobile forms can be transformed into nitrate, which is highly mobile. Only mobile nitrogen can be used by plants and transported by water.

Plant uptake is another important parameter in simulating nitrogen loss. Through literature investigation, cotton nitrogen uptake was set at 0.017 (weight of Nitrogen / weight of harvest unit); cotton phosphate uptake was set at 0.0023 (weight of phosphate / weight of harvest unit) (Mullins and Burmester, 1990; Breitenbeck and Boquct, 1993). Soybean nitrogen uptake was set at 0.092 (weight of Nitrogen / weight of harvest unit); soybean phosphate uptake was set at 0.0095 (weight of phosphate / weight of harvest unit) (Flannery 1986). Winter wheat nitrogen uptake was set at 0.022 (weight of Nitrogen / weight of harvest unit); winter wheat phosphate uptake was set at 0.0025 (weight of phosphate / weight of harvest unit) (Baethgen and Alley, 1986).

e). Climate information

The Greenwood climate station is about 15 kilometers away from the Deep Hollow watershed and is the nearest climate station to the Deep Hollow watershed. Using climate information from Greenwood climate station and relative location of Deep Hollow watershed to Greenwood climate station, GEM generated AnnAGNPS required climate information: daily precipitation, maximum and minimum temperature, dew point temperature, sky cover and wind speed. For model validation purpose, precipitation measured at the monitoring site was used as input to AnnAGNPS during runoff and sediment monitoring periods in order to compare predicted with observed runoff and sediment yield. For BMPs simulation, 50-year historical climate records for Greenwood, MS, were used in order to see the long-term effects of BMPs simulation.

Model simulation for runoff, sediment yield and nitrogen loading Validation

AnnAGNPS was used to predict the runoff, sediment yield and nitrogen loadings to the monitoring flume. In this study, dissolved nitrate and ammonia, is referred to as the nitrogen loadings. Predicted runoff, sediment yield and nitrogen loading were compared with observed runoff, sediment yield and nitrogen loading. Predicted and observed monthly runoff, sediment yield and nitrogen loading listed in table 2 and 3 do not include all runoff, sediment yield and nitrogen loading that occurred in the watershed. Although an attempt was made to collect samples for every storm event, some storm events were not sampled due to unforeseen circumstances such as equipment malfunctions. Therefore, comparisons between model predictions and observations were made only when monitoring data were available. Predicted and observed runoff by events and monthly average were plotted in figures 18 and 19; predicted and observed sediment by events and monthly average were plotted in figures 20 and 21; and predicted and observed monthly average nitrogen loading was plotted in figure 22. Total monthly rainfall and rainfall associated with monitored data are reported in table 2.

Input parameters for the simulation were not calibrated after initial estimation. This analysis reflects the capability of AnnAGNPS to estimate runoff and sediment loads that would be typical for ungauged watersheds. AnnAGNPS has been developed to include processes that utilize input parameters from databases developed by NRCS for any location in the U.S such as climate, soil information and crop management operations. This reduces the effort users would need to acquire the needed information to apply AnnAGNPS for ungauged watersheds and the need for calibration.

Ratios are computed from the simulation period data for the sediment source accounting component (cell). This function of the model gives user the intuitive view of critical areas which caused the most serious pollution so that the user can easily identify the watershed problems.

BMPs Simulations for sediment reduction

Input management files for AnnAGNPS validation were modified to simulate conventional tillage (CT) for both cotton and soybean with no winter weed growth and no pipe grade controls. This was called the “base case” to which we compared simulation results reflecting individual and combined impacts of BMPs (Table 4): reduced-tillage (RT), no-tillage (NT), volunteer winter weeds (W), a planted winter wheat cover crop (C), grass filter strips (F), and grade stabilization pipes (see below). Additional simulations included the effect of changing land use from cropland to pasture or forest.

Conventional Tillage consisted of stalk shredding and deep tillage (subsoiling) in the fall, disking in February and March, row building (hipping) in April, followed by harrowing, hipping again, and harrowing again before planting. In Conventional Tillage only, weeds were controlled with post-emergence cultivation. No-tillage received no soil or residue disturbance except that associated with the planter. Reduced tillage involved subsoiling and rebuilding rows in the fall each year followed by no-till planting in the spring. In season weed control in no-tillage and reduced tillage systems was done with a hooded sprayer. Wheat cover crops were aerially seeded in October or later after harvesting cotton and soybeans and were chemically killed the following spring in all tillage systems, adding 4.5 Mg/ha of surface residue. When simulated, weeds were assumed to begin growth immediately after harvest and to produce 0.78 Mg/ha of residue when killed in the spring. Filter strips were simulated in AnnAGNPS as strip crops with a large roughness factor (cover code 3). To account for sediment settling in backwaters, the filter strip length was simulated as 12% of slope length.

Three kinds of pipe inlets were simulated. The simplest, called a “slotted-inlet” pipe (SIP) had a weir welded across the bottom half of the pipe end and had the top half of the upstream 0.5 m of the pipe removed to improve resistance to clogging with debris. A more elaborate inlet, termed a “slotted-board riser” (SBR), was a box inlet into which boards could be stacked in the winter to impound water on the field. Leaving the boards in for the entire year, a 1.2 m deep impoundment (IMP), with a grade of 0.008 upslope of the pipe location, holding water on 0.35 ha of land was simulated. “Slotted-board riser” performance was estimated by combining the December through February sediment yields of impoundment with those from “slotted-inlet” pipe for the rest of the year.

BMP Cost Estimation

Unless otherwise indicated, cost estimates were based on Mississippi average prices reported in the cost estimator spreadsheet available from http://www.ms.nrcs.usda.gov/ecolog.htm. Land rent costs were generously estimated to be $480/ha ($200/ac.). The term “distributed cost” refers to the total cost of a practice divided by the subwatershed area (12 ha). Costs were divided into one-time initial (establishment or construction) costs and ongoing or annual costs.

Initial cost of a “slotted-inlet” pipe (SIP) grade stabilization pipe (Code 410) was estimated at $1300 including the costs of pipe, earthwork for construction of an embankment to store 0.15m of runoff, and labor. An extra charge of $200 was added for the box inlet of the “Slotted-board riser” (SBR) and impoundment (IMP practices. Spreading these initial costs over a 12 ha watershed resulted in a distributed initial cost of $108 to $125/ha. A distributed annual cost of $14/ha was assigned to the impoundment for removing 0.35 ha from production.

NRCS estimates annual cover crop costs (Code 340) at $34/ha for cereals and $96/ha for legumes. In this study the $34/ha figure was utilized. NRCS estimates filter strip establishment costs (Code 393) at $380/ha (filter strip area). Assuming that a 10 m filter strip is established along 400 m of downslope field edge, the distributed establishment cost would be $12/ha. An additional recurring land rent cost, at a rental rate of $480/ha, is estimated to be $16/ha. For sediment control, grass strip recurring costs can be reduced by up to a factor of 10 by employing a 1-m wide Vegetative Barriers (Code 734) in place of a filter strips.

Reduced tillage and no-tillage costs are difficult to estimate. Parvin and Cook (2000) compared cotton budgets from commercial Mississippi no-till cotton fields with standard budgets and concluded that costs were lower and profits, at current prices, were higher with no-till than with conventional management. The Mississippi 2001 cotton budgets for 8-row equipment on sandy soil (http://www.agecon.msstate.edu/researchandinformation/budgets/default.asp?year=2001) indicate no-till has $120/ha lower production costs than "usual practices." Profits, however, depend greatly on crop yield and some producers have had difficulty being successful with no-till. NRCS offers a one-time incentive payment of up to $72/ha to assist producers in adopting no-till management. For comparison with other practices, in this study, reduced tillage and no-tillage costs were each estimated at ±$75/ha.

Simulation of runoff and sediment yield from the entire Deep Hollow Watershed on current watershed situation.

AnnAGNPS can simulate runoff, sediment and pollutant loadings for a single outlet at one time. Thus, it takes significant effort to get all the loadings to the Deep Hollow Lake since there are multiple inlets to the Deep Hollow Lake from the Deep Hollow watershed.

There are two ways in getting total loadings for a watershed with multiple inlets. The first is simulating loadings from each inlet individually, then adding all the loadings from each inlet together and get the total loading for the entire watershed. The second method is: assuming loadings from different outlets have a single same outlet which is the lake or water storage, this is a reasonable assumption because loadings through different outlets will drain to lake eventually. This method requires putting drainage areas from different outlets together by assuming that they have the same outlet. In doing this, a user should rename the channels and AnnAGNPS cells to make sure no channels and cells have the same name. The second method takes effort in putting all the drainage areas together, but it saves effort in putting all the simulation results together. For this watershed, the second method was used in getting total runoff and sediment loadings for the entire watershed.

Runoff and sediment yield to the Deep Hollow Lake from the entire watershed was simulated using AnnAGNPS for year 1996 to year 1999 because the complete operation records were available during that period. Rainfall measured at the south flume was used for the entire watershed simulation. This simulation was done based on the recorded cropping and operation information from Mr. Frank Gwin. Results were listed in table 5.

Results and Discussion

Model Validation on runoff, sediment yield and nitrogen loading

Predicted versus observed runoff

A comparison between the predicted and observed runoff from individual events produced results that were reasonably close with a slope of 0.8 and an R-square of 0.9 (Figure 18). Statistical tests showed that the predicted storm event runoff is not significantly different from observed storm event runoff at the 95% level of confidence. Generally, the runoff events were slightly underpredicted by AnnAGNPS although a few rainfall events were overpredicted. Several investigators (Smith, 1978; Hawkins, 1978 and 1979; Hjelmfelt et al., 1981) have expressed concern that the SCS-CN procedure may not reproduce measured flow from individual storm rainfall because of unique storm characteristics, tillage, and plant growth interact with previous moisture. AnnGNPS tended to underpredict runoff for larger rainfall events (over 80-mm). The observed runoff for each of the four largest rainfall events (Figure 18) was greater than the predicted runoff in this study. In a study conducted by Rosenthal et al (1995), observed stream flow was also underestimated for extreme events using the Soil and Water Assessment Tool (SWAT) without calibration. Both SWAT and AnnAGNPS used the modified SCS-CN procedure to predict runoff volume. For this study, the underprediction of runoff for large rainfall events may be attributed to the fact that the water was impounded at the watershed outlet for large rainfall events due to the small culvert opening at the monitoring station. Theoretically the impoundment behind a culvert would change the shape of hydrograph for rainfall events but not the volume of total discharge. However, the impoundment of water at the monitoring flume could have increased the apparent depth of flow, which affects the stage-discharge relationship. This could produce an overestimate of the observed runoff for large runoff events.

Over a three-year period (1997-1999), AnnAGNPS predicted runoff was 89% of the observed total runoff (table 2). Figure 19 shows, the AnnAGNPS underpredicted runoff every month but May, August, September, October and November. Except for April, May, October and November, fields were covered either by cotton (soybeans) or winter wheat, which reduced runoff. This showed the model is sensitive to the cover crop conditions. No runoff was observed in August and September because of low rainfall and high evapotranspiration.

Predicted versus observed sediment yield

The predicted and observed sediment yield results by event are shown in Figure 20. Regression slope is close to 1 but outliers result in an R-Square of only 0.5. However, the predicted sediment yield is not significantly different from observed sediment yield at the 95% level of confidence. The AnnAGNPS predicted sediment yield over a three-year period (1997-1999) was 104% of the observed total sediment yield (table 2). The agreement between monthly predicted sediment yield and monthly observed sediment yield has a R-square of 0.7 (table 2). The use of RUSLE is intended to determine long term annual average soil erosion. For this reason, comparison of individual events may not agree as well as long-term average monthly and annual values.

The predicted and observed monthly average sediment yields plotted in Figure 21 shows the variation of sediment loss throughout the years of study. Sediment yield is greater in December and January because of more rainfall in the winter months. In addition, some disturbance of soil by subsoiling occurs in the fall after cotton harvest prior to the December through January rainfall events. High sediment yield was both predicted and observed in May even though there was not as much runoff as during December and January (Figure 21). During May, there was some minimal disturbance of soil during planting of the cotton fields, thus causing higher sediment yield. Also, before cotton or soybeans are planted in May, the soil is fallow, which can cause higher sediment yield.

Although the model tended to under predict runoff, the model slightly over predicted sediment yield. Water impounded upslope of the gauge flume during large rainfall events may have allowed sediment to deposit in front of the flume, and thus, not included in the measured sediment yield results.

In AnnAGNPS, erosion only occurs when runoff occurs, but the runoff amounts do not directly influence the level of erosion in the field, rainfall is used by AnnAGNPS to determine an erosion index value for each storm for use with RUSLE. RUSLE estimates gross total sheet and rill erosion within a field. AnnAGNPS contains processes to determine the amount of sediment deposition that occurs in the field before entering a stream system, thus providing the sediment yield leaving a field.

Predicted versus observed nitrogen loading

The predicted and observed nitrogen loadings by month listed in table 3 show that the monthly predicted nitrogen loading is not significantly different from observed nitrogen loading at the 95% level of confidence. The AnnAGNPS predicted nitrogen load over three-year period (1997-1999) was 127% of the observed total nitrogen loading. The model over predicted the nitrogen loading by 27%. Three-year monthly averaged predicted and observed nitrogen loading plotted in figure 22 shows that AnnAGNPS over predicted nitrogen loading during dormant season and under predicted nitrogen loading during cropping season. One possible reason for winter (especially during January and December) over prediction is denitrification. AnnAGNPS was originally developed for upland row crops in cold areas where denitrification rarely occurs although in tile drained systems it may occur, but in Deep Hollow Watershed of Mississippi, the average high temperature is 15 degree Celsius and low temperature is 3 degree Celsius for January and December, denitrification in the winter may reduce amount of nitrate-nitrogen for loss. Morever, ponding water in the field during high rainfall period which often happen in the winter increases the denitrification processes. AnnAGNPS under predicted the nitrogen loading during plant season. A possible reason for the model under prediction is the plant uptake parameters. As discovered in the model sensitivity analysis, AnnAGNPS is very sensitivity to plant uptake (Yuan et al, 2001), but those parameters are very difficult to determine. Also, fertilizer was usually applied during the later part of April, which can be a wet period in Mississippi. During this wet period, fertilizer could be dissolved in the runoff and leached away from field.

Evaluation of BMPs on sediment reduction

Fifty year annual average sediment yield simulated for the alternative scenarios are listed in Table 4. The percentage of sediment reduction relative to the conventional baseline was calculated to clarify what combinations of BMPs could achieve a desired degree of reduction in sediment yield.

The practice that had the most dramatic impact on sediment reduction was with no-tillage. By itself, no-tilage reduced sediment yield by 64%. Combined with a "slotted-inlet" pipe, reductions achieved 85%. Because little sediment was generated in the fields, the edge-of-field sediment trapping practices such as filter strip "Slotted-board riser", and impoundment produced only small additional benefits when combined with no-tillage. The large uncertainty of the cost of no-tillage systems makes conclusions about the cost effectiveness of this practice for a particular farmer difficult. However, for farmers who find no-till management more profitable that conventional tillage, soil conservation benefits make no-tillage a dramatic win-win situation.

In the validation case, "slotted-inlet" pipe, reduced tillage cotton, no-tillage soybean, and a wheat cover crop resulted in a 60% reduction in sediment yield compared to no BMPs. Gully erosion control by the pipe accounted for nearly half of this (Table 4). The impact of the "slotted-inlet" pipe was between 21 and 28% of control similar for all tillage systems. Only with pasture and forest land uses was runoff reduced to the point that appreciable gully erosion did not take place if a pipe grade control was not installed.

The impact of a cover crop on simulated sediment yield differed greatly between tillage systems. In conventional tillage, the cover crop reduced sediment yield by 22%, compared to 39% for reduced tillage and only 3% for no-tillage. However, if no winter cover crop is planted, voluntary winter weed might grow that might function as a winter cover crop; but the function of voluntary winter weed was not simulated in this study. In Mississippi winter weeds frequently acts as a winter cover crop for reducing soil erosion.

Without a cover crop, there is little difference between reduced tillage and conventional tillage because fall tillage buried fragile crop residue in both systems. Without cover crop or winter weed growth, the additional spring and summer tillage with conventional tillage has relatively little effect on residue cover. In contrast, in no-tillage, cover crop growth had less effect because residue cover was already good. The relatively large annual cost of cover crops is noted. Reseeding legume cover crops (Dabney et al., 2001) may substantially reduce this cost, as well as saving on fertilizer nitrogen costs.

For conventional tillage farmers, the impoundment appears to be most cost effective way to achieve at least a 50% reduction in sediment yield. Sediment trapped in the impoundment would need to be removed periodically to maintain the functionality of this practice and the cost of this maintenance has not been estimated.

Total runoff and sediment yield for entire watershed

Total monthly runoff and sediment yield entering Deep Hollow Lake listed in table 5 showed the time variation of rainfall, runoff and sediment. Listed rainfall, runoff and sediment yield are the amount of total happened during that period in the watershed.

Conclusion

The study demonstrates that AnnAGNPS adequately predicts long-term monthly and annual runoff and sediment yield. The comparison of sediment yield for individual events was not as good as long-term average annual values because the use of RUSLE and the parameters associated with determining soil loss are meant to be used as long-term estimates. In evaluating the effects of BMP's within a watershed, long-term results are needed to determine the influence of local climatic variation. Study results also show that AnnAGNPS is capable of estimating nitrogen loading (127%) although the model over-predicted the nitrogen loss during winter because of denitrification and under predicted nitrogen loadings during crop season due to the selection of plant uptake parameters. Denitrification process should be added for nitrogen cycle simulation and parameters such as soil initial nitrogen concentration and crop nitrogen uptake should be selected carefully.

The accuracy of model predictions depends on how well a user can describe the watershed characteristics. Runoff prediction is very sensitive to curve number selection; sediment prediction is sensitive to crop cover and soil disturbance. Therefore, accurate decomposition of operation information such as tillage that affect residue and crop cover is very important for realistic sediment simulation.

For this study, all inputs into the model were developed using the available database information with no modification. Without calibration, model results were reasonable for evaluation of long-term monthly and annual runoff and sediment yield. Therefore, AnnAGNPS can be recommended for ungauged watershed simulation of runoff and sediment yield.

BMPs simulation results showed that AnnAGNPS is capable of simulating the effects of a variety of BMPs and BMP combinations on sediment reduction.

All BMPs studied reduced sediment yield. The practice that produced the most dramatic reductions was with no-tillage. The effectiveness of a winter cover crop varied with tillage system. Benefits were most pronounced when cover crop was combined with reduced tillage. However, the annual cost of growing cover crops must be reduced to increase the attractiveness of this BMP.

Where no-tillage is not a viable alternative, an impoundment or constructed wetland was predicted to be the most cost effective way of reducing sediment by at least 50%. Filter strips could be installed at lower initial cost than pipes, but were less effective in reducing sediment yield as an impoundment had similar ongoing annual land rent costs. With appropriate vegetation and management, narrower vegetative barriers may reduce annual costs of grass strips.

More research is needed to fully evaluate the cost effectiveness of BMP combinations. The costs and benefits may vary in other regions. For the Mississippi Delta, no-till, slotted inlet pipes, and impoundments appear to be promising technologies. Final decisions on adoption of a BMP or combination of BMPs should be made after consideration of both costs and improvements in water quality.

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Table 1. Selected SCS curve numbers for Deep Hollow Watershed and model simulation.

Land Cover Class	Curve Number			
	Hydrologic soil group			
	A	B	C	D
Cotton_Straight_Row_Poor	72	81	88	91
Soybean_Straight_Row_Poor	72	81	88	91
Small_Grain_Straight_Row+Crop_Res._Poor	64	75	83	86
Fallow_+_Crop_Residue_Poor	76	85	90	93
Fallow	79	89	95	96
Pasture	68	79	86	89
Forest	45	66	77	83

Table 2. Monthly observed rainfall and predicted and observed runoff and sediment yield.

Year	Month	Rainfall (mm)	Runoff (mm)		Sediment Yield (Tons/ha)	
			Observed	Predicted	Observed	Predicted
1996	October	63.8	4.8	25.6	0.02	0.15
	November	122.4	27.4	49.5	0.07	0.09
	December	127.5	70.6	71.2	0.13	0.18
1997	January	182.1	129.5	101.4	0.70	0.23
	February*[110]	81.8	70.4	45.8	0.23	0.07
	March*[170.7]	0.0	0.0	0.0	0.0	0.0
	April	86.5	30.9	26.3	0.15	0.04
	May	152.4	82.7	70.8	1.10	0.57
	June	130.3	37.6	31.4	1.24	0.33
	July	41.1	4.1	3.1	0.12	0.02
	August*[58]	49.1	0.0	5.7	0.00	0.00
	September*[76]	0.0	0.0	0.0	0.00	0.00
	October	85.6	5.5	21.2	0.05	0.19
	November	56.4	13.1	16.6	0.06	0.29
	December	133.3	56.8	73.9	0.72	0.37
1998	January*[142]	106.6	59.3	69.6	0.58	0.51
	February*[98]	90.0	36.5	35.3	0.47	0.22
	March*[95]	88.7	37.7	18.9	0.18	0.08
	April	130.8	72.6	48.9	0.46	0.43
	May	111.5	84.6	64.3	0.81	2.08
	June	31.0	12.3	7.8	0.29	0.09
	July	166.1	53.6	48.8	0.23	0.42
	August*[29]	0.0	0.0	0.0	0.00	0.00
	September*[74]	0.0	0.0	0.0	0.00	0.00
	October	27.2	0.0	0.0	0.00	0.00
	November	141.2	39.9	50.8	0.11	0.70
	December	205.2	155.0	134.4	0.51	1.51
1999	January	224.3	214.8	147.3	1.68	1.89
	February	50.0	7.2	8.1	0.04	0.04
	March	120.4	58.1	45.9	0.24	0.22
	April	110.0	65.4	47.5	0.19	0.30
	May	73.7	6.5	7.0	0.10	0.12
	June	29.8	0.0	2.2	0.00	0.00
	July	7.1	0.0	0.1	0.05	0.01
	August	0	0.0	0	0.0	0.0
	September	40.5	0.0	3.6	0.0	0.0
Three Year Total		3227.5	1437	1283	10.9	11.3
Regression			Y=0.8X	R^2=0.9	Y=0.9X	R^2=0.5

* Indicates months when less than all storms were successfully monitored for runoff and sediment. The number besides * showed total rainfall during that month. Rainfall reported under rainfall column reflects only the amount of rainfall associated with monitored data.

Table 3. Monthly observed rainfall and predicted and observed runoff and nitrogen loadings

Year	Month	Rainfall (mm)	Runoff (mm)		Nitrogen Loading (g/ha)	
			Observed	Predicted	Observed	Predicted
1996	October	63.8	4.8	25.6	73.5	64.6
	November	122.4	27.4	49.5	45.5	251.3
	December	127.5	70.6	71.2	38.4	179.5
1997	January	182.1	129.5	101.4	23.9	398.3
	February*[110]	81.8	70.4	45.8	4.9	212.4
	March*[170.7]	0.0	0.0	0.0	7.0	101.8
	April	86.5	30.9	26.3	393.8	108.1
	May	152.4	82.7	70.8	214.5	138.9
	June	130.3	37.6	31.4	210.0	238.9
	July	41.1	4.1	3.1	13.5	96.5
	August*[58]	49.1	0.0	5.7	0.0	0.0
	September*[76]	0.0	0.0	0.0	0.0	0.0
	October	85.6	5.5	21.2	7.3	160.4
	November	56.4	13.1	16.6	11.7	51.8
	December	133.3	56.8	73.9	16.1	150.2
1998	January*[142]	106.6	59.3	69.6	18.2	373.7
	February*[98]	90.0	36.5	35.3	4.7	130.7
	March*[95]	88.7	37.7	18.9	3.7	41.0
	April	130.8	72.6	48.9	299.6	215.8
	May	111.5	84.6	64.3	398.4	38.4
	June	31.0	12.3	7.8	66.4	39.0
	July	166.1	53.6	48.8	181.8	188.5
	August*[29]	0.0	0.0	0.0	25.4	43.0
	September*[74]	0.0	0.0	0.0	0.0	0.0
	October	27.2	0.0	0.0	0.0	0.0
	November	141.2	39.9	50.8	220.9	243.0
	December	205.2	155.0	134.4	67.7	242.3
1999	January	224.3	214.8	147.3	81.5	178.5
	February	50.0	7.2	8.1	8.8	34.6
	March	120.4	58.1	45.9	66.4	100.7
	April	110.0	65.4	47.5	19.1	94.0
	May	73.7	6.5	7.0	335.5	128.0
	June	29.8	0.0	2.2	0.0	0.0
	July	7.1	0.0	0.1	273.8	113.4
	August	0	0.0	0	767.8	584.7
	September	40.5	0.0	3.6	0.0	0.0
Three Year Total		3227.5	1437	1283	3900.0	4942.1

* Indicates months when less than all storms were successfully monitored for runoff and sediment. The number besides * showed total rainfall during that month. Rainfall reported under rainfall column reflects only the amount of rainfall associated with monitored data.

Table 4. Simulation results and percentage of reduction comparing with no BMP implementation.

Tillage			CC	FS	SIP	SBR	IMP	Sediment (Tons/ha)	Percent reduction	Initial Cost ($/ha)	Annual Cost ($/(ha-y))
CT	RT	NT									
X								10.1	0		
X			X					7.9	22		40
X				X				8.3	18	12	16
X					X			7.3	28	108	
X						X		6.6	35	125	
X							X	4.3	57	125	14
X			X		X			5.8	43	108	40
X			X				X	5.3	67	125	54
	X							9.5	6		±75
	X		X					5.6	45		115 to -35
	X			X				7.8	23	12	91 to -59
	X				X			6.7	34	108	±75
	X					X		6.0	41	125	±75
	X						X	3.9	61	125	89 to -61
	X		X		X			4.0*	60	108	115 to -35
	X		X				X	2.3	77	125	129 to –21
		X						3.6	64		±75
		X	X					3.3	67		115 to -35
		X		X				2.5	75	12	91 to -59
		X			X			1.5	85	108	±75
		X				X		1.4	86	125	±75
		X					X	1.2	88	125	89 to -61
		X	X		X			1.2	88	108	115 to -35
		X					X	0.8	92	125	129 to –21
All pasture								0.14	99		
All Forest								0.02	100		

*Validation case

Table 5. Total monthly runoff and sediment yield for Deep Hollow lake from entire watershed.

Year	Month	Rainfall (mm)	Runoff m^3	Sediment Yield (tons)
			Predicted	Predicted
1996	January	232.5	85391.6	75.9
	February	81	24658.1	11.9
	March	102.5	17030.4	12.7
	April	136.4	42698.9	23.1
	May	80.3	16123.7	23.1
	June	127.9	24544.4	20.9
	July	88.9	18444.8	19.1
	August	46.6	7898.2	1.6
	September	65.3	11219.8	3.7
	October	63.8	18431.2	14.8
	November	122.4	41556.3	9.8
	December	127.5	56191.5	18.6
1997	January	182.1	86991.2	22.2
	February	110.4	36441.1	7.1
	March	170.7	90798.3	25.4
	April	86.5	18791.9	3.8
	May	152.4	51637.2	54.5
	June	130.3	32844.1	29.3
	July	41.1	2160.5	1.0
	August	49.1	3813.2	0.7
	September	65.4	8438.0	6.0
	October	85.6	15172.6	19.2
	November	56.4	12101.7	31.2
	December	133.3	55677.7	62.4
1998	January	142	51501.3	34.5
	February	98	26356.5	16.3
	March	88.7	38715.2	28.2
	April	130.8	41007.8	51.6
	May	111.5	46630.7	205.6
	June	31.0	5756.3	10.0
	July	166.1	45129.9	53.5
	August	29.6	1796.1	1.7
	September	74	28591.1	19.7
	October	27.2	0.0	0
	November	141.2	52932.9	79.8
	December	205.2	104239.0	157.2

Table 5 (continued). Total monthly runoff and sediment yield for Deep Hollow lake from entire watershed.

Year	Month	Rainfall (mm)	Runoff m^3	Sediment Yield (tons)
			Predicted	Predicted
1999	January	224.3	111355.3	194.3
	February	50.0	9789.4	5.5
	March	120.4	38870.8	30.5
	April	110.0	36215.1	33.1
	May	73.7	6970.5	9.7
	June	29.8	1304.4	1.6
	July	7.1	0.0	0
	August	0	0.0	0
	September	40.5	2207.4	2.1
	October	278.3	142205.7	207.5
	November	63.8	21815.8	9.7
	December	42.1	6287.4	2.0

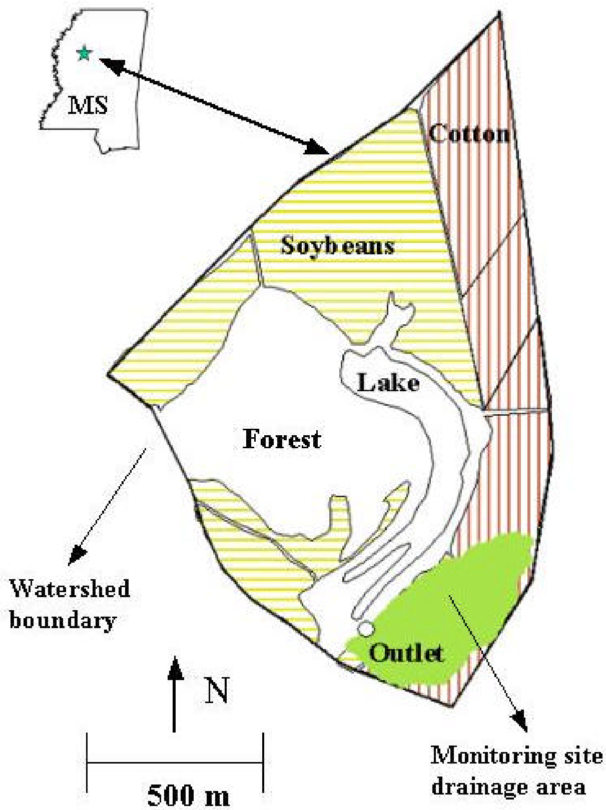

Figure 1. Deep Hollow watershed location and land use

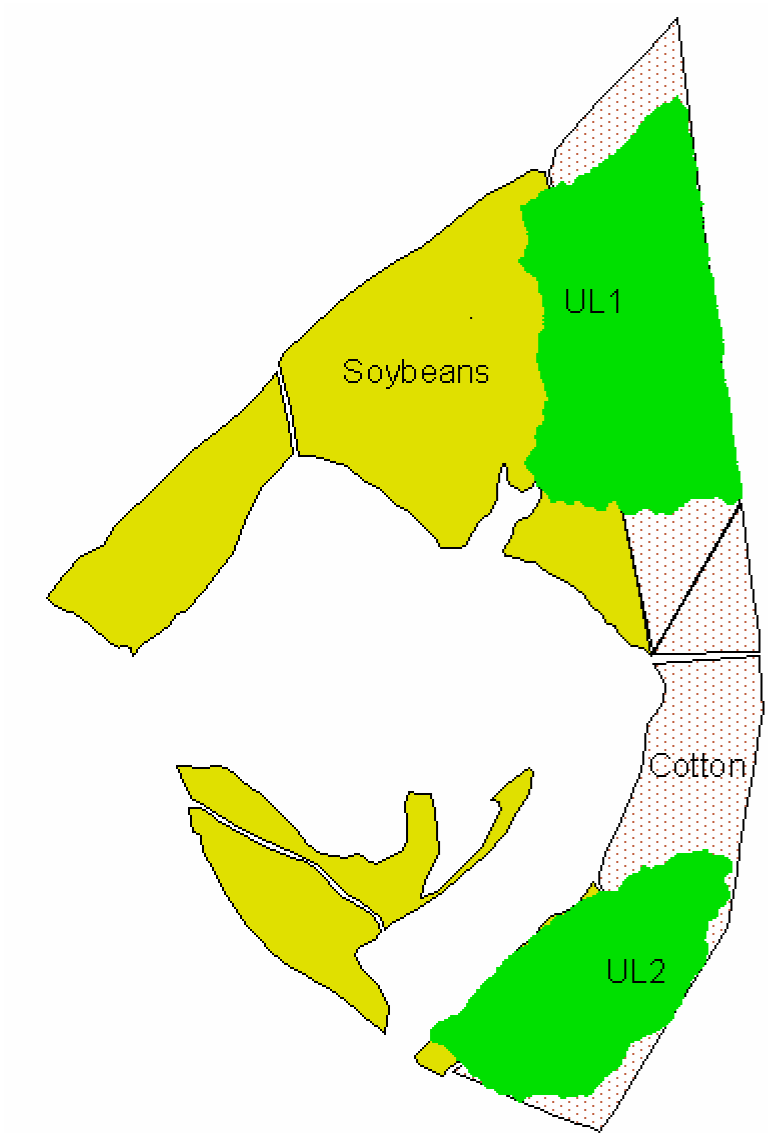

Figure 2. The monitoring flume locations and their drainage areas

Figure 3. Deep Hollow Watershed topographic survey points

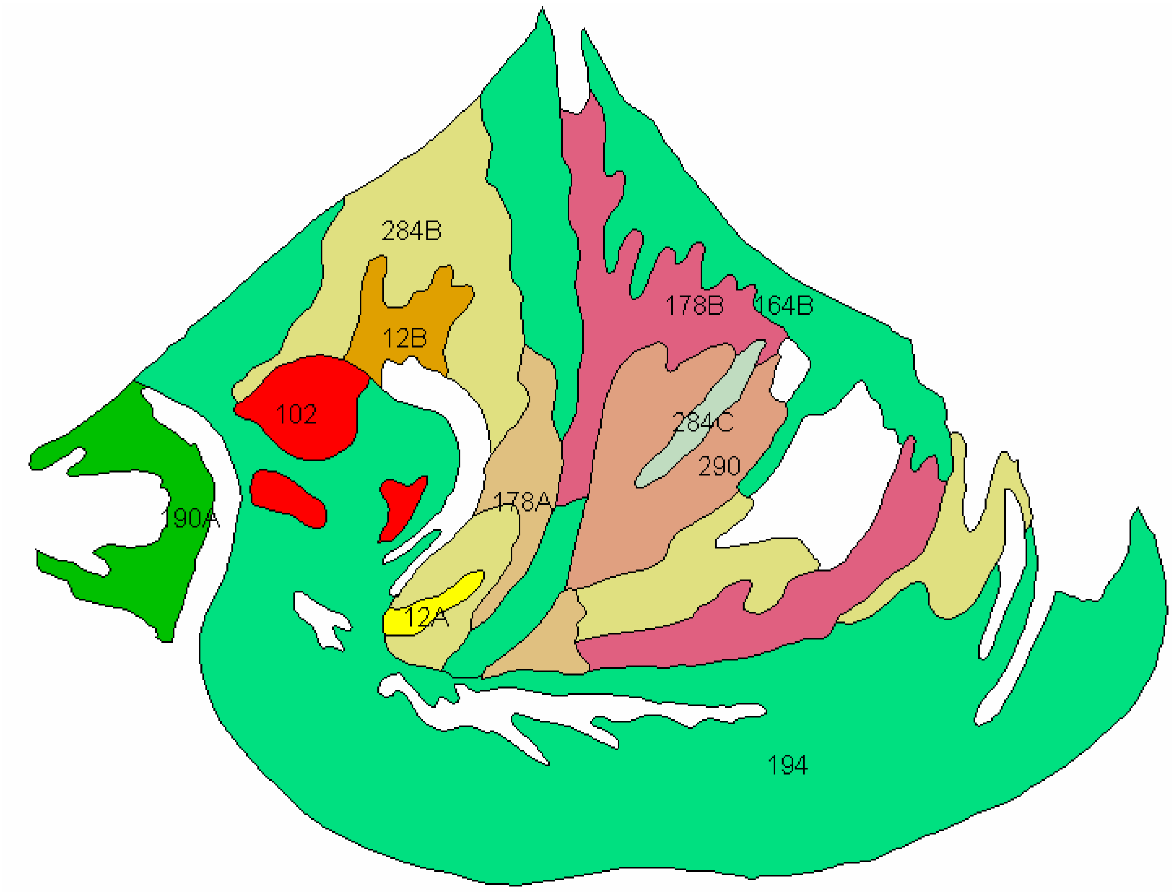

Figure 4. Deep Hollow Watershed soil information

Field Symbol	Alpha Symbol	Map Unit
12A	AgA	Alligator clay, 0-1 percent slopes (rarely flooded)
12B	AgB	Alligator clay, 1-3 percent slopes (rarely flooded
178B	AsB	Askew silt loam, 1-3 percent slopes, (rarely flooded)
102	An	Arents, loamy
164B	DuB	Dubbs very fine sandy loam, 1-3 percent slopes
178A	DnA	Dundee loam, 0-1 percent slopes, rarely flooded
190A	Fao	Falaya silt, 0-2 percent slopes, occasionally flooded
194	AF	Arkabulla and Falaya soils, frequently flooded
284B	TnB	Tensas silty clay loam, 1-3 percent slopes (rarely flooded)
284C	TnC	Tensas silty clay loam, 3-7 percent slopes (rarely flooded)
290	TA	Tensas-Alligator complex, 0-3 percent slopes, occasionally flooded

Figure 5. Conservation tillage

Figure 6. Winter wheat cover crop

Figure 7. Grass filter strip

Figure 8. Impoundment

Figure 9. Generated DEM based on the topographic survey

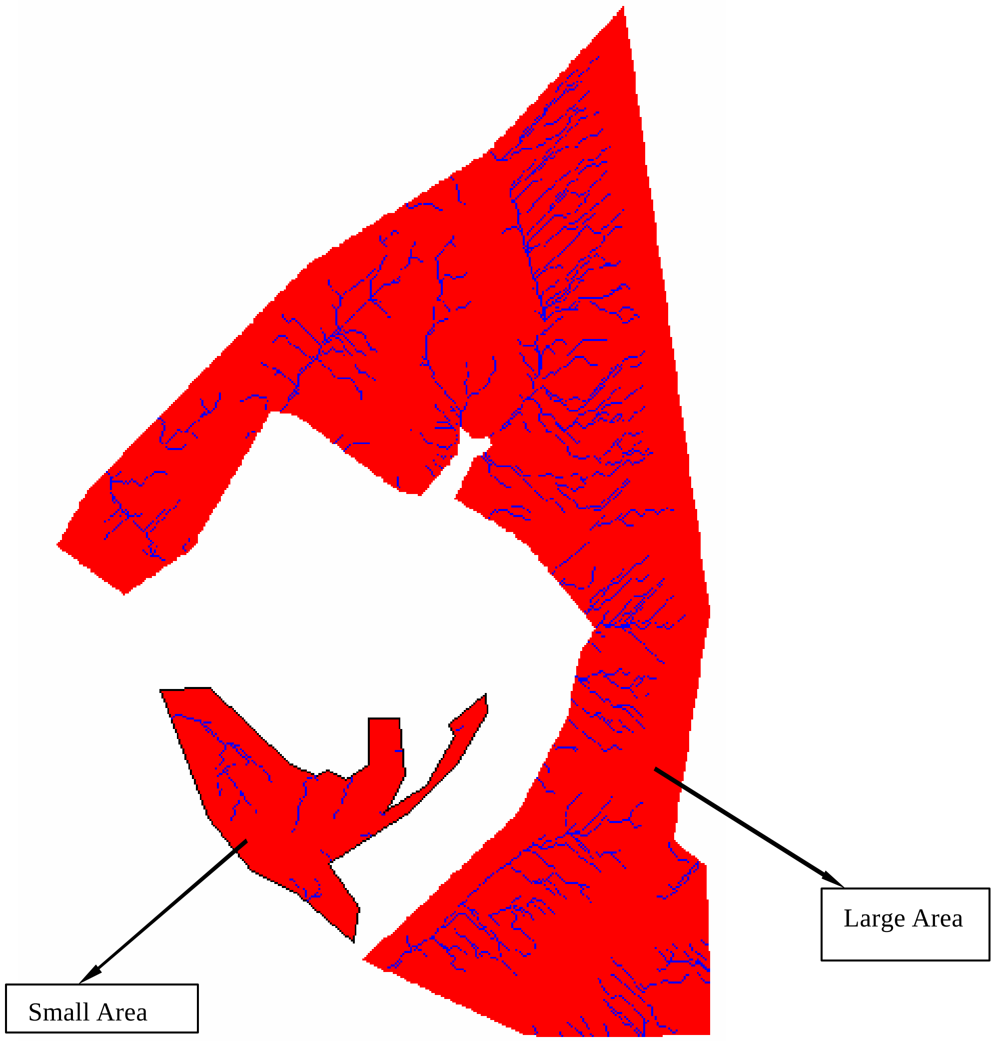

Figure 10. Watershed Stream Network

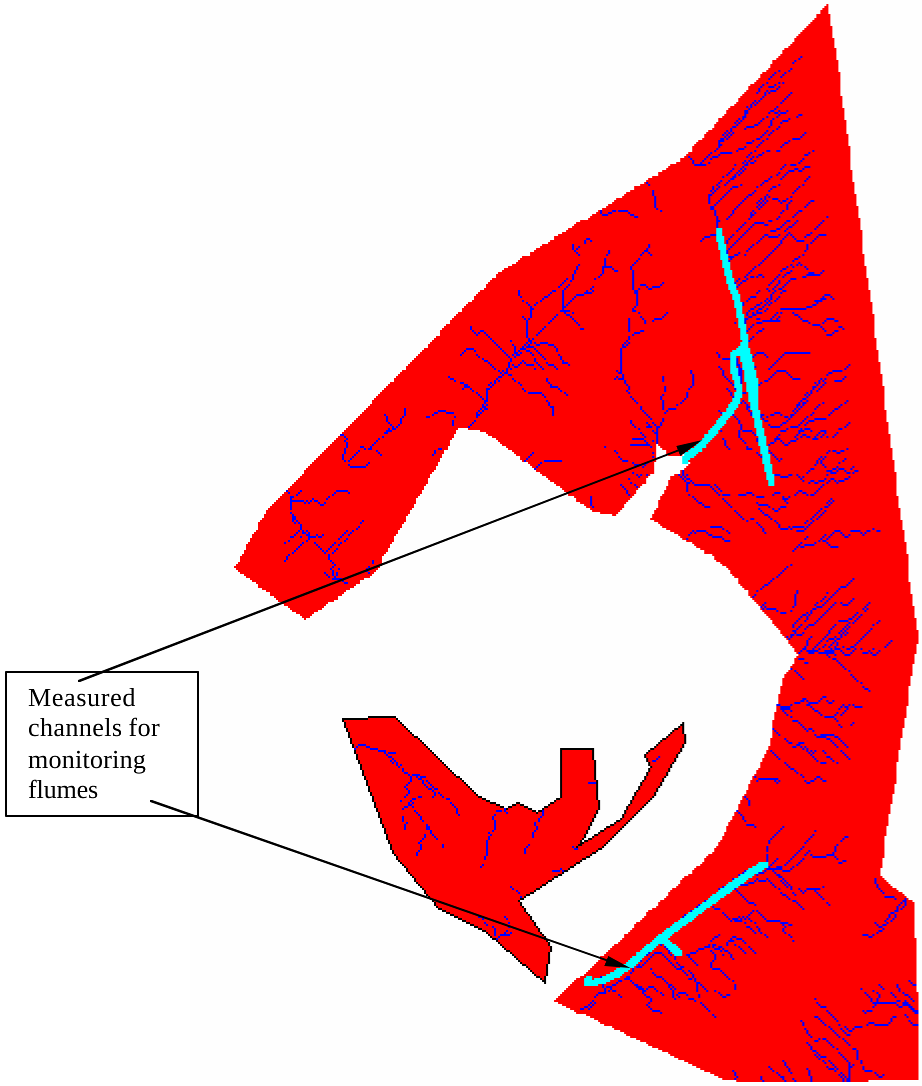

Figure 11. Stream Network and measured main channels for monitoring flumes

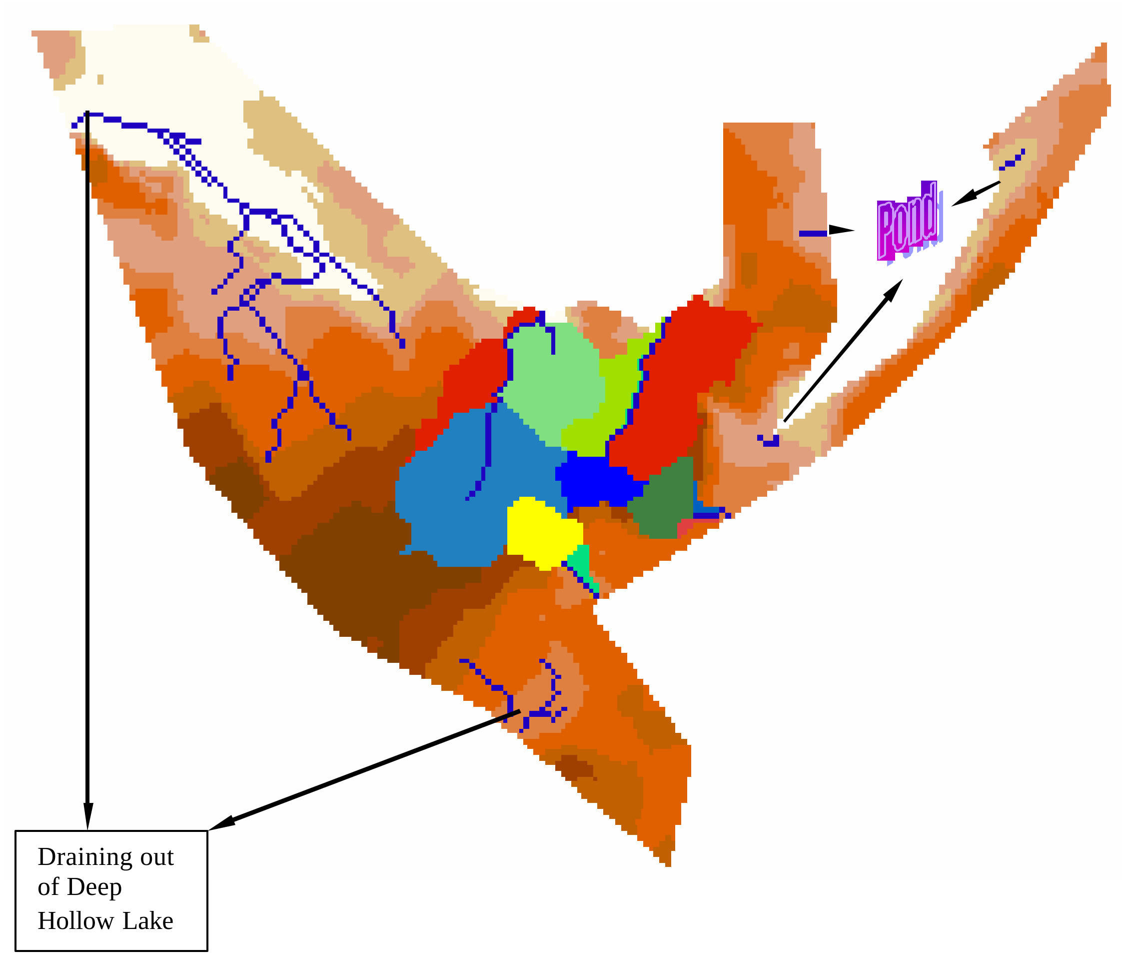

Figure 12. Drainage areas and their boundaries for the small area of Deep Hollow Lake

Figure 13. Some drainage areas and their boundaries for the large area of Deep Hollow Lake

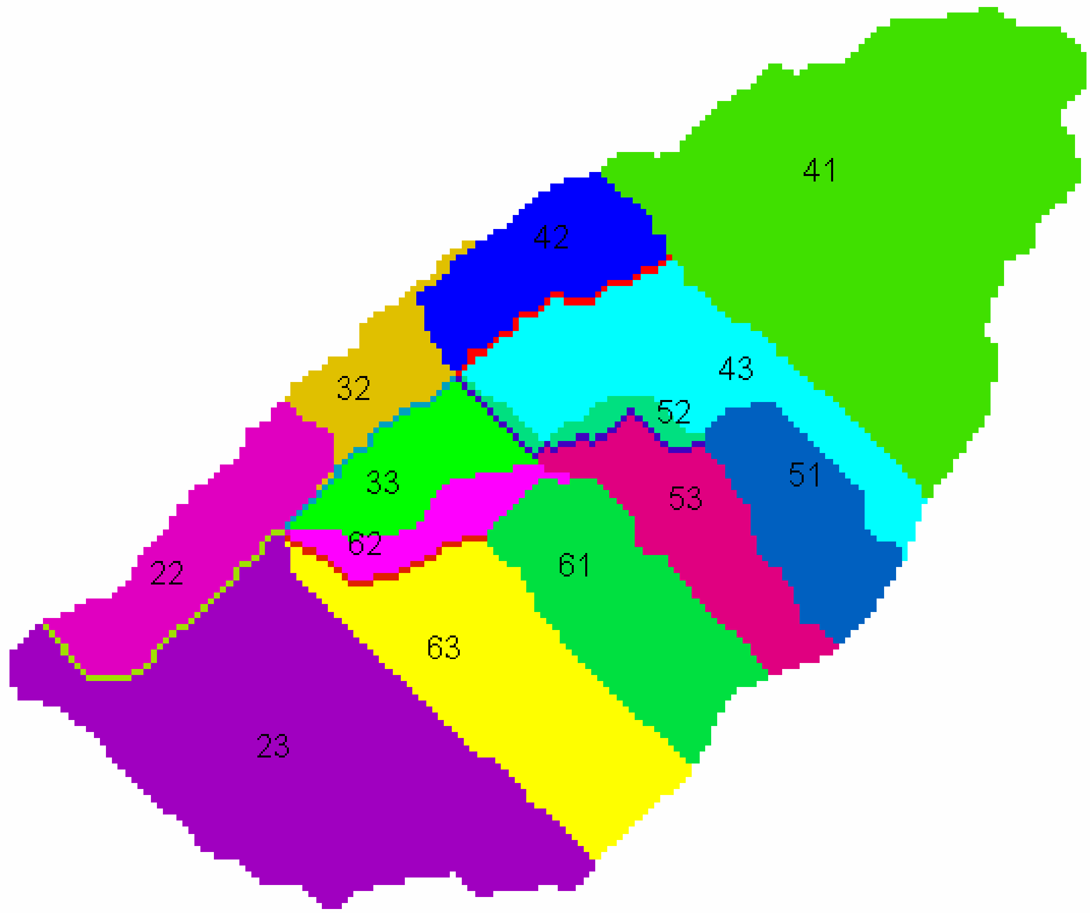

Figure 14. The delineated watershed and subwatersheds for monitoring flume UL2

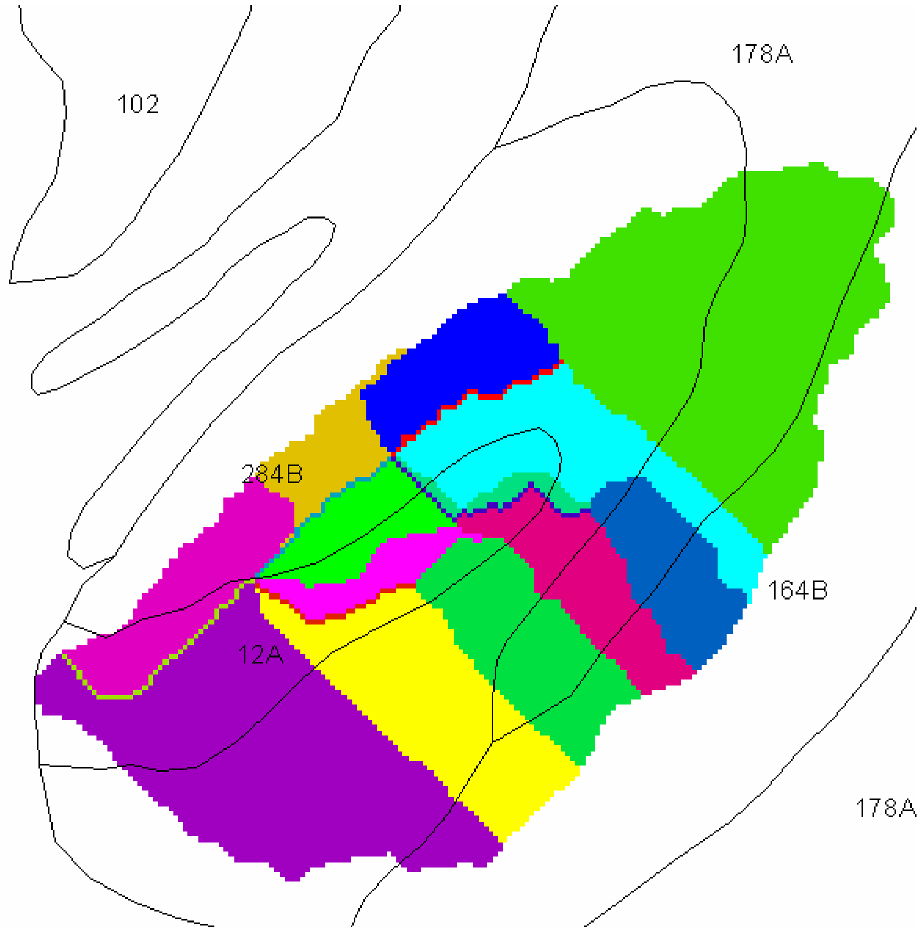

Figure 15. Overlay of soil information on the delineated watershed and subwatersheds for monitoring flume UL2

Cell Number	Soil Type
22	284B
23	284B
32	284B
33	284B
41	178A
42	284B
43	284B
51	164B
52	12A
53	178A
61	178A
62	12A
63	284B

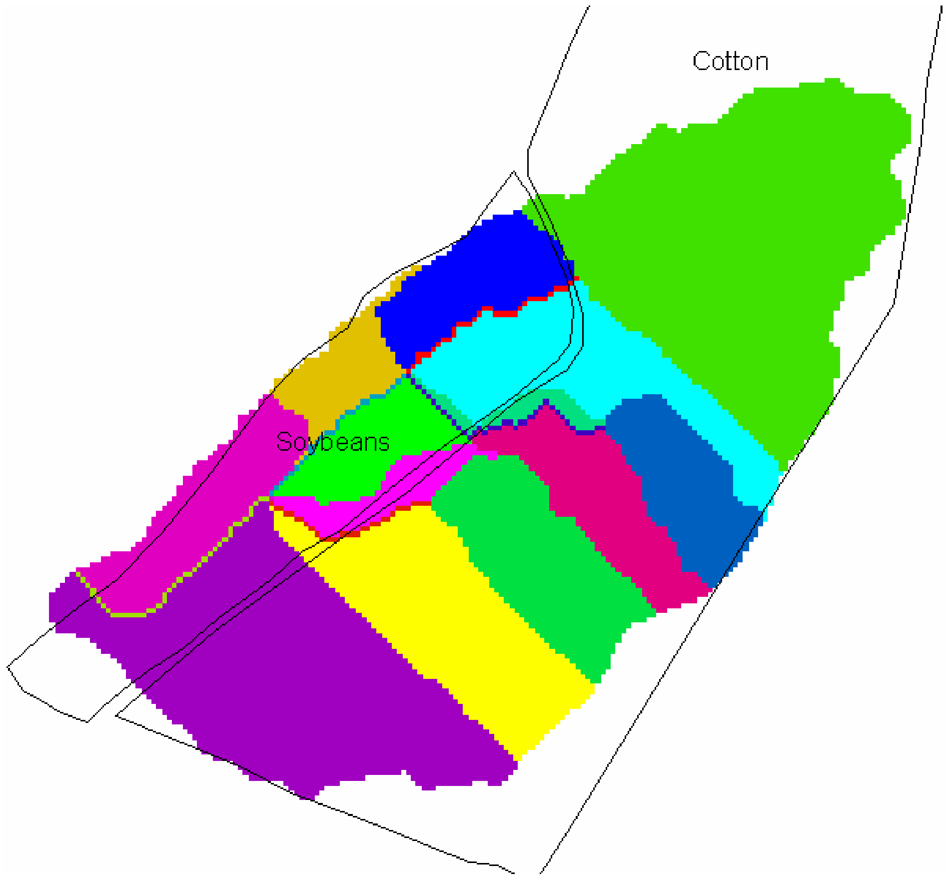

Figure 16. Overlay of land use information on the delineated watershed and subwatersheds for monitoring flume UL2

Cell Number	Land Use
22	Soybeans
23	Cotton
32	Soybeans
33	Soybeans
41	Cotton
42	Soybeans
43	Cotton
51	Cotton
52	Cotton
53	Cotton
61	Cotton
62	Soybeans
63	Cotton

Figure 17. All the drainage areas, levees and cutoff for the big area of Deep Hollow Watershed

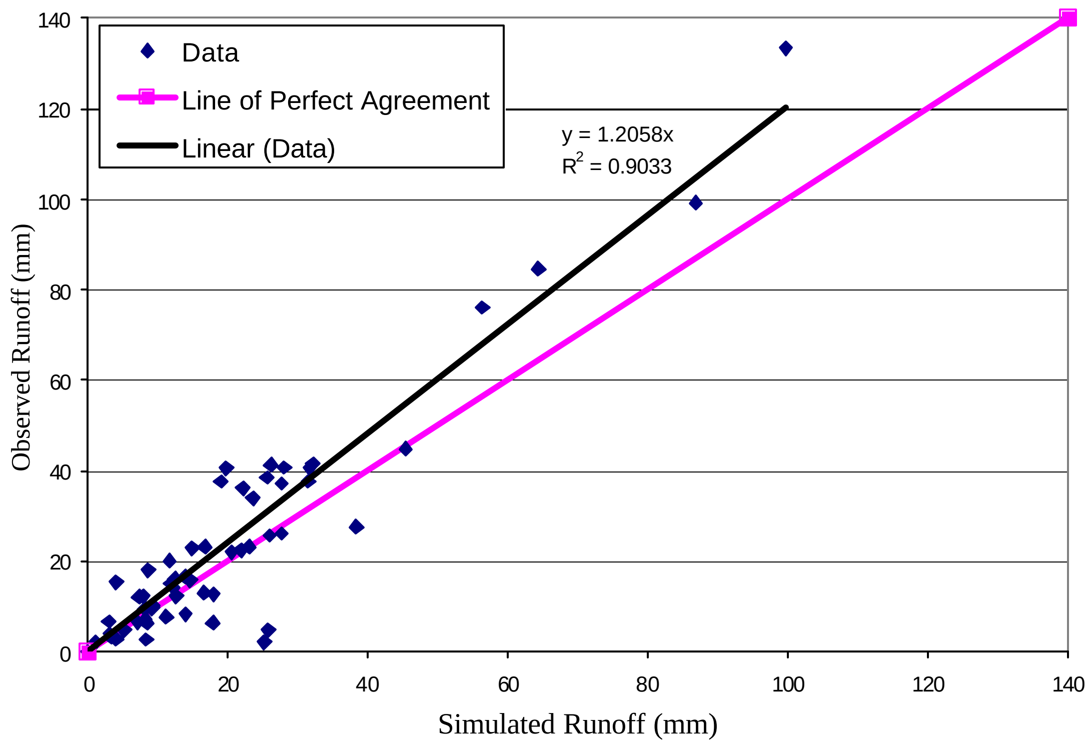

Figure 18. Comparison of observed and simulated runoff by event.

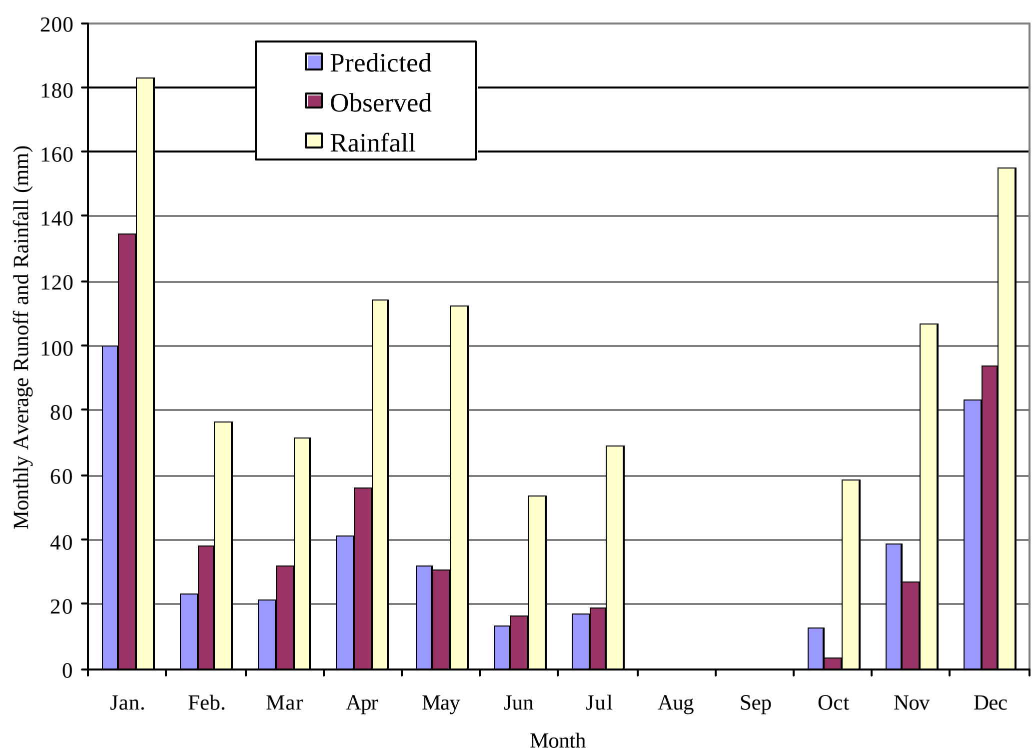

Figure 19. Comparison of monthly average predicted and observed runoff with associated rainfall.

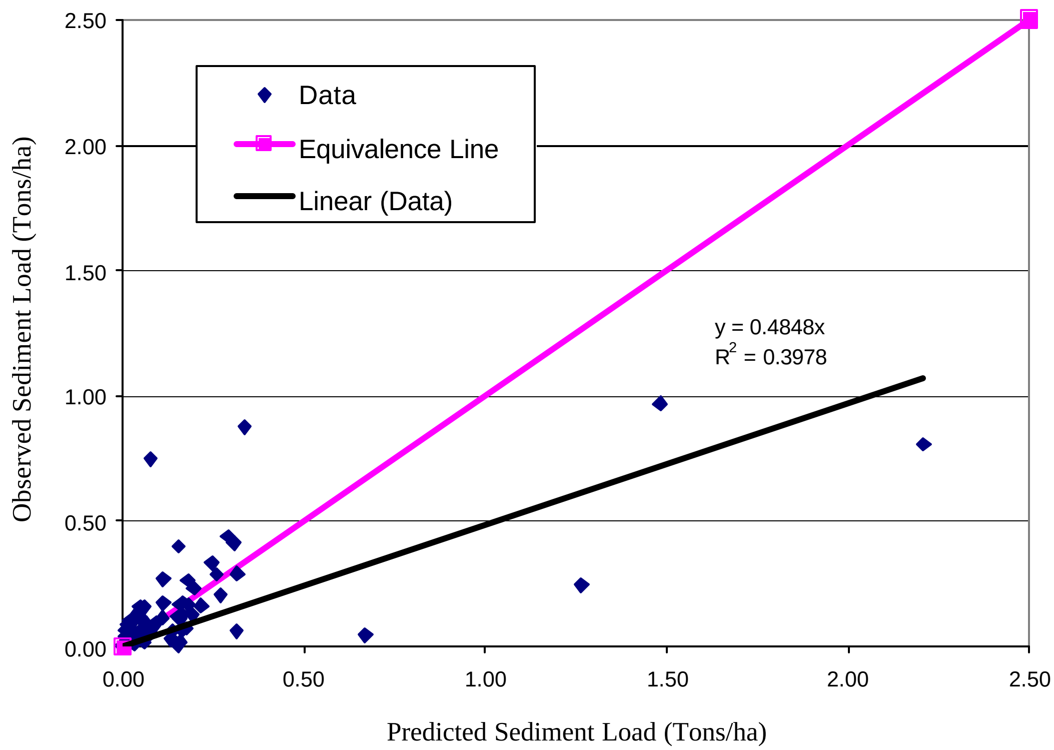

Figure 20. Comparison of observed and predicted sediment yield by event.

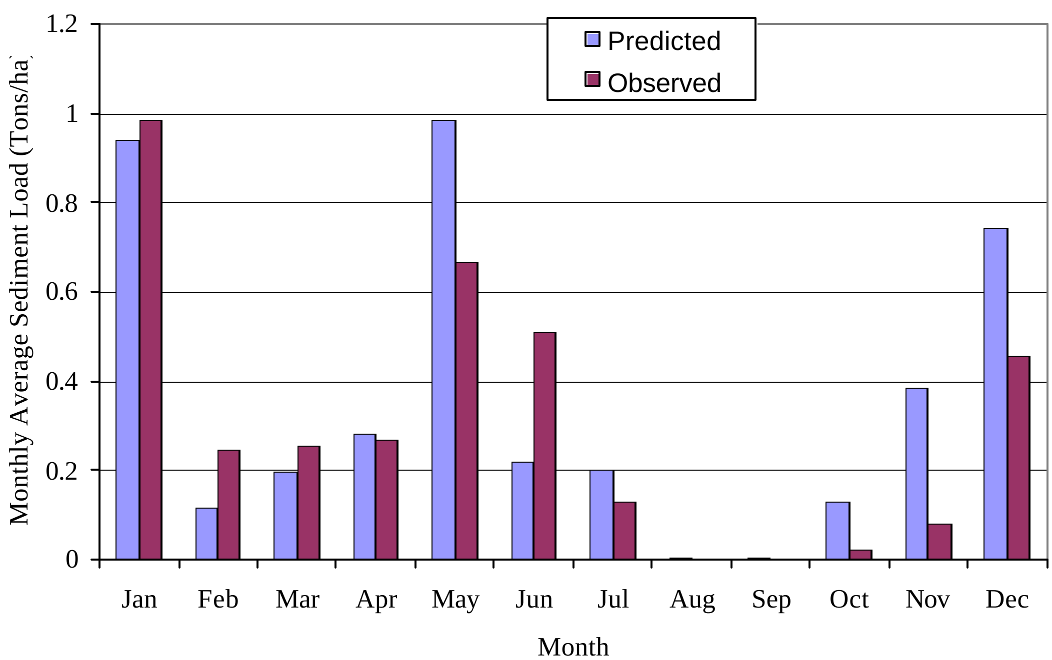

Figure 21. Comparison of predicted and observed monthly average sediment yield.

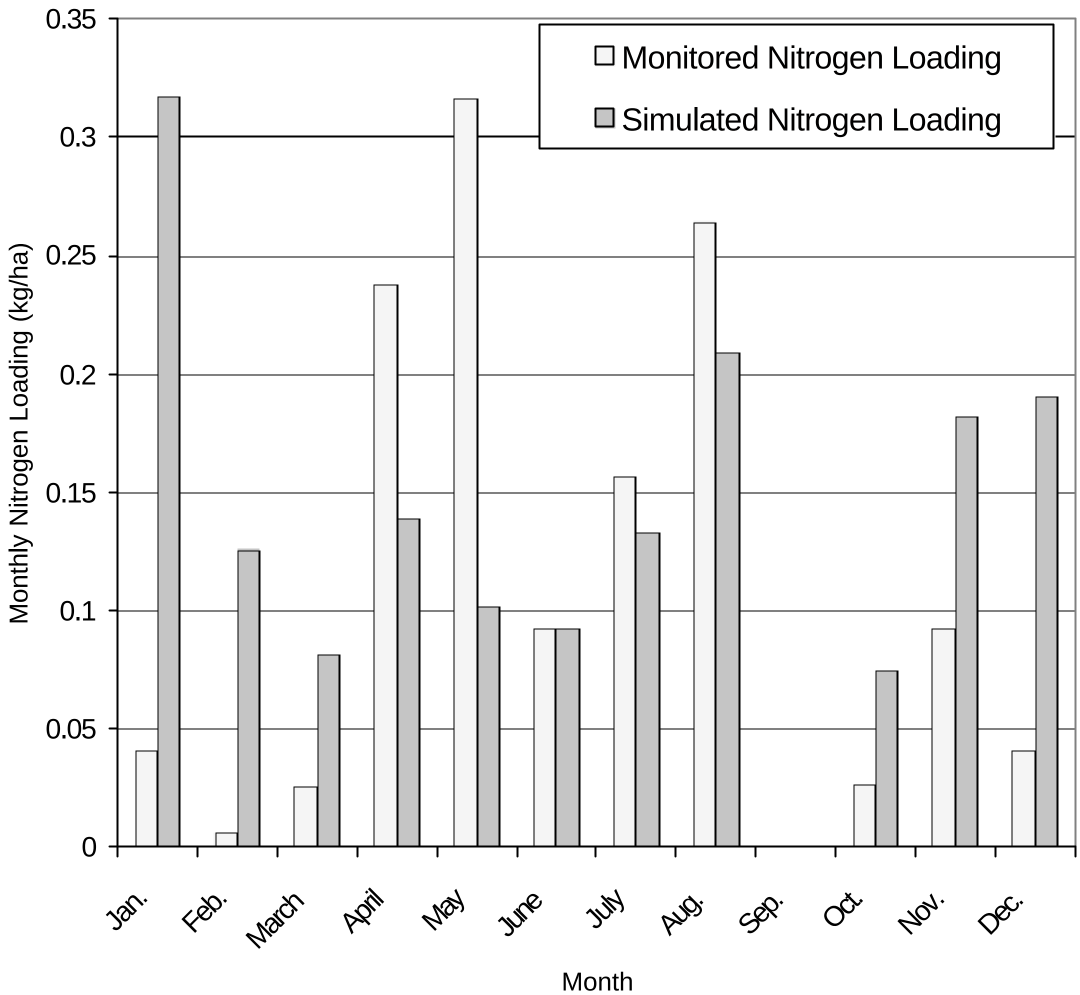

Figure 22. Comparison of monthly average predicted and observed nitrogen loading.

Appendix A: field operation sequence from Frank Gwin's record.

Deep Hollow

RIVERSIDE PLANTATION

Cotton: XP3, XP10, XP24
Soybeans: XP1, XP2, XP8, XP9A, XP9B
Turn row moved in 1995

KEY TO FIELD NUMBERS

NEW NO.	OTHER NO.	NAME	ACREAGE
XP1	DH1	Simon Ward W	17.2 (22 '97) *
XP2	DH2	Simon Ward E	59.1 (65.3 '97) *
XP3	DH3	Big Ridge W	50.2
XP3A	DH3	N End	24.8 acres
XP3B	DH3	Seth Plot (20 8-row plots. 6 each) (8 8-row No Till part) (12 8-row Test plots)	12 acres 4.8 acres 7.2 acres
XP3C	DH3	South End	12.4 acres
XP10	DH10	Moses Turn	48.7 (60.8 '98) •
XP24	DH24	Big Ridge E	60.1 (50.8 '98) •
XP8	DH8	Entrance to Bee Hive	9.0
XP9A	DH9A	Bee Hive Ridge S	12.6
XP9B	DH9B	Bee Hive Ridge N	10.6
XP9C	DH9C	Duck Hole (Wetland)	2.3

1995 HISTORICAL DATA
NO RATES OR DATES OF APPLICATION WERE RECORDED

FSA# 1472

DATE	FIELD	ACTION	MATERIALS	AMOUNT
		COTTON		
1995	XP3 XP10 Land Preparation	Cut stalks,Fall Subsoil (Parabolic) Cut water furrows Disc Spring Field cultivator & Treflan Hip up Apply Fertilizer Rehip Doall and Plant		
	Fertilizer	N-117.7 #/acre 56# preplant 61.7 # sidedress N-Sol (32%) Liquid (injected coulter rig)		
	Varieties	DPL 20 triple treated (Orthene)		
	Herbicides	Preplant Treflan at planting Command + Cotoran 9" band Thimet Postemerge Assure (spot) Hand chop MSMA (spot)		
	Fungicide	Hopper box Deltacote Pix Crop oil		
	Insecticides	MP + Orthene Baythroid Bidrin + MP Fury + Crop Oil Karate	2 times 2 times	
	Defoliant	Drop- Prep Followed by Harvaid, Folex, Roundup		
		SOYBEANS		
1995	XP2,XP8,XP9A VARIETY XP1,XP9B VARIETY	Hornbeck HBK 49 Hutchenson		
	LAND PREPARATION	Row up Burndown (Roundup) Spring Rehip Doall Plant.		
	HERBICIDES	Command + Canopy Premergence Assure (spot)		
Fall	Cut stalks			
		WHEAT		
1995		Wheat Spreader		100 lb/acre

1995 Cotton & Soybean Yields

Field Number	Acreage	Yield	Bu/acre	Lbs/Acre	Price/Unit
COTTON	All Riverside Plantation			899	
SOYBEANS	All Riverside Plantation		30.8		

FALL 1995
XP3 CUT STALKS
DISK TWICE
HIPPED
RIP HIP(SUB SOIL & HIP)
REHIP
ROLLED
PUT IN WATERFURROWS
11/9/95 PLANTED WHEAT (PLANE)
XP10 MOVED TURNROW
CUT STALKS
HIPPED
RIP HIPPED
REHIPPED
ROLLED
PUT IN WATERFURROWS
11/9/95 PLANTED WHEAT (PLANE)
XP1,XP2,XP8,XP9A
DISK ONCE
HIPPED
RIP HIPPED
REHIPPED
ROLLED
PUT IN WATERFURROWS
12/2/95 PLANTED WHEAT(PLANE)
XP9B LEFT SOYBEAN STUBBLE
12/2/95 PLANTED WHEAT(PLANE)

1996 HISTORICAL DATA

DATE	FIELD	ACTION	MATERIALS	AMOUNT
4-1-96 4/15/96	XP3,XP10,XP1 XP2,XP8,XP9A , XP9B XP1,XP2,XP8, XP9A,XP9B	Burndown (plane) Second burndown (plane)	Roundup Roundup	1lb/ai/acre 1lb/ai/acre
		COTTON		
4/29/96	XP3,XP10	Fertilize	NSol (32%)	90lbs/acre
5-3-96	XP3 , XP10	Do-all , plant, & chemical application 19’’ band	Zoral 80DF Cotoran 4L Fury	.75 lbs/acre 0.8lbs/acre 1.2oz/acres
5/14/96	XP3,XP10	Hooded sprayer with sensors	Roundup	1lb/ai/acre
5/17/96	XP3,XP10	Tractor boom	Orthene	.2lbs/ai/acre
5/25/96	XP3,XP10	Hooded sprayer with sensors	Roundup	1lb/ai/acre
6/5/96	XP3, XP10	Hooded sprayer with sensors	Roundup Staple	1lb/ai/acre 1oz/ai/acre
6/20/96	XP3,XP10	Spray over top (plane)	Baythroid	0.05lbai/acre
6/27/96	XP3<XP10	Spray over top(plane)	Bidrin	. 0.05/ai/acre
7/2/96 7/3/96	XP3,XP10 XP3,XP10	Hooded sprayer with sensors Layby	Roundup MSMA 6.6 Bladex	1lb/ai/acre 2lb/ai/acre 1.0lb/ai/acre
7/6/96	XP3,XP10	Spray OT (plane)	Methyl Parathion	1gal/10/acre
7/13/96	XP3,XP10	Spray OT (plane)	Fury (Crop oil)	1gal/50/acres
7/20/96	XP3,XP10	Spray OT (plane)	Karate	1gal/25acres
9/12/96 9/19/96	XP3,XP10 XP3,XP10	Spray OT (defoliate) Spray OT (plane)	Dropp Prep Harvade Folex Crop oil	1lb/8/acres 1.33/pts/acre 0.5pt/acre 2pts/acre
		SOYBEANS		
4/24/96	XP1, XP2,	Do-all plant	Hornbeck 49	50lbs/acre
4/25/96	XP8,XP9A,XP9 B	Do-all, plant,	Hartz 6191	Soybeans 50 lb/acre
5-7/96	XP1,XP2,XP8 XP9A,XP9B	Hooded sprayer with sensors	Roundup	1lb/ai/acre
5/22/96	XP1,XP2,XP8 XP9A,XP9B	Over top 14” band Hooded sprayer with sensors	Reflex & Fusilade Roundup	1.5/acre/mixed 1lb/ai/acre
6-17- 18/96	XP1, XP2, XP8 XP9A,XP9B	Hooded sprayers with sensors	Roundup	1lb/ai/acre/acre
Fall	XP3,XP10	Cut Stalks		
Fall N/A	XP1,XP2,XP3,XP8,XP9A, XP9B,XP10	Spreader behind tractor	WHEAT	100lbs/acre

1996 Cotton & Soybean Yields

Field Number	**Acreage**	**Yield**	**Bu/acre**	**Lbs/Acre**	**Price/Unit**
COTTON					
XP3	45.1			417	$0.7321
XP10	48.3			489.3	$0.7321
TOTAL	103.4			454.3	
XP24	41.0			702.8	$0.7321
DIFFERENCE				248.5	
	248.5x103.4=23210	23210x.732=$16992.04	Rebate $2380.80	Total $19372.84	
SOYBEANS					
XP1	17.6	161	8.54		
XP2	59.1	737	11.35		
XP8	7.9	191	22.73		
XP9	23.2	503	19.42		
TOTALS	107.8	1592.0	14.76		
NON MSEA BEANS	358.9	5285.35	14.73		
DIFFERENCE			.03 BU/ACRE		

Fall 1996: XP3, XP10 subsoil with rows
Fall 1996 XP2(W side) XP3, XP10 hip up rows
Fall 1996: Plant wheat 100 lbs/acre (plane)
Fall 1996: XP24 Disc 2 times. Subsoil @ 45° 2 times

1997 HISTORICAL DATA

DATE	FIELD	ACTION	MATERIALS	AMOUNT
2/24/97	XP3,XP10	Burndown (plane)	Roundup Ultra	1qt/acre
3/3/97	XP3,XP10	Burndown (plane)	Roundup Ultra	1qt/acre
3/11/97	XP1,XP2,XP8	Burndown (approx 90 acres out of water)	Roundup Ultra	1qt/acre
	XP9A,9B	COTTON		
5/14/97	XP3	Do-all , plant, & chemical application 19" band	Stoneville474 Cotoran Command Ammo Disyston Surfactant	11 lbs/acre 1pt/acre .4/acre 1gal/50/acres 5lbs/acre ¼%
5/17/97 6/20/97	XP10 XP3,XP10	Do-all , plant, & chemical application. 19" band Tractor boom 20" band	Stoneville 474 Cotoran Command Ammo Disyston Surfactant Baythroid	11 lbs/acre 1pt/acre .4/acre 1gal/50/acres 5lbs/acre ¼% 1gal/60/acre
6/27/97	XP3	Hooded sprayer with sensors	Roundup Ultra	1 qt/acre in 10 gal water
6/28/97	XP10	Hooded sprayer with sensors	Roundup Ultra	1qt/acre
6/27/97	XP3, XP10	Tractor boom 20" band	Baythroid	1gal/60/acres
7/2/97	XP10 , XP3	Tractor boom 20" band	Baythroid Pravado	1gal/60/acre 1gal/34/acres
7/24/97	XP3, XP10	Plane	Fury	1gal/35/acres
8/1/97	XP3,XP10	Plane	Tracer	1gal/64/acres
8/11/97	XP10,XP3	Plane	Fury Methyl Parathion Oil	1gal/35/acres 1 gal/16/acres 1gal/acre
9/14/97	XP10,XP3	Plane (defoliation)	Dropp Prep	1lb/8/acres 1gal/5/acre
		FERTILIZER		
5/13/97	XP3,XP10	Anhydrous Amonia knifed in pre plant	NH3	95.7lbs/acre
5-18-19/97 10/14/97 10/14/97	XP10 XP3 XP3 XP10	Sidedress lbs N/acre Sidedress lbs N/acre Fertilizer surface applied with spreader Fertilizer surface applied with spreader	Nsol (32%) Nsol (32%) K2O K2O	30 lbs/acre 30lbs/acre 200lbs/acre 150lbs/acre
		SOYBEANS		
5/2/97	XP2, XP9	Do-all, plant & chemical application	Asgro5801 Command Gramoxone	50lbs/acre .5AI/acre 19.2oz PR/acre
6/6/97	XP1,XP8,XP9A XP9B	Do-all, plant, & chemical application Less part of field under water.	Asgro 5801 Command Gramoxone	50 lb/acre .5AI/acre 19.2oz

				PR/acre
6/6/97	XP2 (W end)	Do-all, plant, & chemical application	Asgro5801&5601 Hartz 5088&6686	50 lb/acre 50lb/acre
5/19/97	XP1,XP2,XP8 XP9A,XP9B	Hooded sprayer with sensors	Roundup-Ultra	1qt/acre
6/5/97	XP1, XP2, XP8 XP9A,XP9B	Hooded sprayer with sensors	Roundup-Ultra	1qt/acre
5/19/97	XP1,XP2 ,XP8 XP9A, XP9B	Over top with 10” band	Roundup Ultra	1 qt/acre
6/5/97	XP1,XP2,XP8 XP9A, XP9B	Over top with 10” band	Roundup Ultra	1 qt/acre
6-23-25/97 6/23/97 7/17/97 11/16/97 11/17/97	XP1, XP2, XP8 XP9A,XP9B XP1,XP2,XP8,XP9A,XP9B XP1,XP2,XP8 XP9A,XP9B XP3,XP10 XP3,XP10	Spray over top with 10” band Hooded sprayer with sensors Hooded sprayer with sensors FALL PLOWING Disc, hip up, sub soil with rows Disc, hip up	Roundup Ultra Roundup Ultra Roundup Ultra	1 qt/acre, 1qt/acre 1qt/qcre
11/5/97	XP9A, XP9B	Wheat Spreader		100 lb/acre
11/6/97	XP8, XP1, XP2	Wheat Spreader		100 lb/acre
11/7/97	XP3, XP10	Wheat Spreader		100 lb/acre

Fall 1997: XP3, XP10 subsoil with rows
Fall 1997: XP2 (W side), XP3, XP10 hip up rows
Fall 1997: Plant wheat 100 lbs/acre (plane)
Fall 1997 XP24 Disc 2 times. Subsoil @ 45° 2 times

1998 HISTORICAL DATA

DATE	FIELD	ACTION	MATERIALS	AMOUNT
4/9/98	XP3	COTTON Fertilize	Nsol (33%)	103.3 lbs/acre
4/9/98	XP10	Fertilize	NSol (33%)	103.3 lbs/acre
3/10/98	XP, all except XP24	Burndown (plane)	Roundup Ultra	1 qt/acre
5/5/98 5/20/98 6/3/98 6/8/98 6/7/98 6/8/98 6/16/98 6/16/98	XP3 , XP10 XP3,(6.4AC) NOTIL XP3 XP10 XP10 XP3 XP3 XP10 XP3,XP10	Do-all , plant, & chemical application (1/4 % surfactant). 20" band Spray Boom on four wheeler Boom on tractor Boom on tractor Hooded sprayer with sensors Over the top 14'' band Sidedress 25 units/N/acre Plane	Stoneville 474 Gramaxone Cotoran Command Ammo Disyston Karate Fury Fury Round-up ultra Staple N-sol Tracer Crop Oil	11 lbs/acre 20 oz/acre 16 oz/acre (1.33 pt/acre) 1 to 6 acres 1 gal/80 acres 6.67lbs/acre 1gal/25 acres 1gal/35 acres 1gal/35 acres 1qt/acre 1.2oz/acre 25lbs/acre 1gal/45/acres 1pt/acre
6/25/98	XP3	Hooded sprayer with sensors	Round-up ultra	1qt/acre
6/25/98	XP3	Over the top 14'' band	Staple	1.2oz/acre
6/26/98	XP10	Hooded sprayer with sensors	Round-up ultra	1qt/acre
6/26/98	XP10	Over the top 14'' band	Staple	1.2oz/acre
7/1/98	XP3,XP10	Plane	Karate	8oz/acre
7/1/98 7/7/98	XP3,XP10 XP3, XP10	Layby Rig Plane	Bladex 4L MSMA 6.6 Karate	2.5pts/acre 2.4 pts/acre 1 gal/28acres
8/1/98	XP3,XP10	Plane	Fury	1gal/35acres
8/11/98	XP3,XP10	Plane	Decis	.019lbs ai/acre
8/20/98	XP3 XP10	Plane	Tracer	1gal/60/acres
9/3/98	XP3,XP10	Plane	Guthion	1gal/8acres
9/7/98	XP3,XP10	Plane(defoliation)	Def Prep	1gal/9.4acres 1gal/5.5/acres
9/13/98	XP3,XP10	Plane(2nd defoliation)	Sodium chlorate Starfire + surf	4.5lbs/acre 6oz/acre + ¼%
10/6/98	XP3,	Fertilizer, spreader	Phospate 0-30-0 Potash 0-0-120 Lime	65lbs/acre 100lbs/acre .5ton/acre
10/6/98	XP10	Fertilizer spreader 1/3 N end	Phospate0-30-0	65lbs/acre
10/6/98	XP10	Fertilizer spreader all	Potash0-0-60	100lbs/acre
10/6/98	XP10	Fertilizer spreader ½ N end	Lime	.5ton/acre
7/15/98 to	XP3, XP10	Irrigation, 6 times, furrow		

		SOYBEANS		
	XP1,XP2,XP8, XP9A,XP9B	1st Burndown Plane	Round-up Ultra	1qt/acre
	XP1, XP2, XP8, XP9A, XP9B	2ND Burndown (broadcast w/ tractor) (1/2% surfactant)	Gramoxone	3pts/acre in 10 gal water
4/22/98	XP1	Do-all, plant, & chemical application.	Hornbeck 49 Gramoxone Command	Soybeans 50 lb/acre 1qt/acre 10oz/acre
4/22/98	XP2 (W side)	Do-all, plant, & chemical application	Hartz 6191 Command Gramoxone	50 lb/acre 10oz/acre 1qt/acre
4/22/98	XP2 (E side)	Do-all, plant, & chemical application	Hornbeck 49 Command Gramoxone	50 lb/acre 10oz/acre 1qt/acre
4/23/98	XP8, XP9A, XP9B	Do-all, plant, & chemical application	Asgro RR Command	50 lb/acre 1/6 acres
5/26/98	XP1	Hooded sprayer with sensors	Roundup Ultra	1 qt/10 gal water
5/27/98	XP2	Hooded sprayer with sensors	Roundup Ultra	1 qt/10gal/acre
5/28/98 6/3/98 6/3/98 6/23/98 6/24/98 6/24/98 6/25/98 6/25/98 8/25/98 10/6/98 10/6/98	XP8 XP9A XP9B XP1 XP2 XP8 XP9A XP9B XP9A,XP9B XP1,XP2,XP8, XP2,XP1 XP2,XP1 XP2,XP9A,XP9B	Hooded sprayer with sensors Hooded sprayer with sensors Hooded sprayer with sensors Hooded sprayer with sensors Hooded sprayer post directed with Peptoil Hooded sprayer post directed with Peptoil Hooded sprayer with sensors Hooded sprayer with sensors Hooded sprayer post directed with Peptoil Hooded sprayer with sensors Hooded sprayer with post directed Peptoil Hooded sprayer with sensors Hooded sprayer with poat directed Peptoil Plane Fertilizer spreader XP2,1/2 W, XP1,1/3 N Fertlizer spreader XP2,1/3W,XP9A,XP9B all	Roundup Ultra Round-Ultra Round up-Ultra Round-up Ultra Conclude Xtra Conclude Xltra Round-up Ultra Round-up Ultra Conclude Xtra Round-up Ultra Conclude Xtra Round-up Ultra Conclude Xtra Larvin 3.2 Phospate 0-30-0 Potash 0-0-60	1 qt/acre, 10 gal/acre 1qt/acre,10gal/acre 1qt/acre,10gal/acre 1qt/acre,10gal/acre 38oz/acre 38oz/acre 1qt/acre,10gal/acre 1qt/acre,10gal/acre 38oz/acre 1qt/acre,10gal/acre 38oz/acre 1qt/acre,10gal/acre 38oz/acre 1gal/5/acres 65lbs/acre 100lbs/acre
10-14-98	XP9A, XP9B	Wheat (Plane)		100lb/acre
10-14-98	XP8, XP1, XP2	Wheat (Plane)		100 lb/acre
10-14-98	XP3, XP10	Wheat (Plane)		100 lb/acre
10-31-98	XP1, XP2, XP8	Wheat (reapply) (Plane)		50 lb/acre

1998Cotton & Soybean Yields

Field Number	**Acreage**	**Yield**	**Bu/acre**	**Lbs/Acre**	**Price/Unit**
COTTON					
XP3	50.2			933.0	$0.72
XP10	54.7			816.3	$0.72
TOTAL	104.9			929.36	$0.72
XP24	50.0			951.44	
DIFFERENCE				22.08	
SOYBEANS					
XP1	17.6	420	24.7		
XP2A	36.9	720	19.5		
XP2B	22.0	385	17.5		
XP8	8.0	215	26.9		
XP9A	12.6	374.2	29.7		
XP9B	10.6	258.6	24.4		
TOTAL	105.0		18.68		

OTHER BEANS	362.0	23.21
DIFFERENCE		4.53

SOYBEANS 4.53 BU/ACRE X 105.0 = 475.65 X 5.50= $2616.08
COTTON 22.08 LBS/ACRE X 104.9 =2296.32 X .72 =$1653.35
REBATES $190.80
TOTAL $4460.23

Fall 1998: XP3, XP10 subsoil with rows
Fall 1998: XP2 (W side), XP3, XP10 hip up rows
Fall 1998: Plant wheat 100 lbs/acre (plane)
Fall 1998: XP24 Disc 2 times. Subsoil @ 45° 2 times

1999 HISTORICAL DATA

DATE	FIELD	ACTION	MATERIALS	AMOUNT
4-30-99	XP3	Fertilize	NSol	91.4 lbs/acre
4-30-99	XP10	Fertilize	NSol	91.2 lbs/acre
4-1-99	XP, all except XP24	Burndown (plane)	Roundup Ultra	1 qt/acre
		COTTON		
5-9-99	XP3 S end, 3 acres XP10	Do-all , plant, & chemical application (1/4 % surfactant). 20" band	BXN 47 Stoneville Gramaxone Cotoran Command Ammo Disyston	11 lbs/acre 20 oz/acre 16 oz/acre (1.33 pt/acre) 1 to 6 acres 1 gal/50 acres
5-11-99	rest of XP3	Do-all , plant, & chemical application (1/4 % surfactant). 20" band	BXN 47 Stoneville Gramaxone Cotoran Command Ammo Disyston	11 lbs/acre 20 oz/acre 16 oz/acre (1.33 pt/acre) 1 to 6 acres 1 gal/50 acres
5-28-99	XP3B	Spot-spray on 4-wheeler	Roundup	1 qt/acre in 10 gal water (total 2 qts)
6-8-99	XP3C (5 acres S end)	Replant cotton. Chemical application in furrow.	BXN Stoneville 47 Disyston	11 lb/acre
6-10-99	XP3, XP10	2 men chopped pigweed & hemp sesbania		
6-10-99	XP10 (30 acres S end), XP3 (16 rows N end)	Spray over top	Fusion	10 oz/acre
6-11-99	XP3, XP10	Chemical application in middles (hooded sprayer)	Roundup Ultra	1 qt/acre in 10 gal water
6-22-99	XP3	Broadcast over top (1/4% surfactant)	Staple Buctril	8 oz/acre in 10 gal water 1 pt/acre
6-23-99	XP10	Broadcast over top (1/4% surfactant)	Staple Buctril	8 oz/acre in 10 gal water 1 pt/acre
7-1, 2-99	XP10	Broadcast over top (1/4% surfactant)	Staple Buctril	8 oz/acre in 10 gal water 1 pt/acre
6-25-99	XP3	Sidedress lbs N/acre	NSol	33.3 lbs/acre
6-25-99	XP10	Sidedress lbs N/acre	NSol	23.5 lbs/acre
		INSECTICIDES		
5-11-99	XP3	Spray behind planter, 19" band	Ammo	1 gal/50 acres
5-30-99	XP3B	Spray 6.4 acres on 4-wheeler (grasshoppers)	Karate	6 oz/acre
6-9-99	XP3, XP10	Spray w/ tractor, 20" band	Baythroid	1 gal/ 100 acres
6-15-99	XP3, XP10	Spray w/ plane 8:20 A.M. Wind NE 5mph. 85 °	Karate 1-30 acres	3 gal liquid/acre
6-24-99	XP3, XP10	Spray w/ plane 8:15 A.M. Wind SSW 4mph 80°	Furidan 1-16 acres Vegetable oil	5 gal/acre ½ pt/acre
7-1-99	XP3, XP10	Spray w/ plane 9:00 A.M. Wind SSW 6.7mph. 81°	Tracer 1 gal/150 acres	5 gal/acre

			Soy surfactant	½ %
7-17-99	XP3, XP10	Spray 7:00 A.M. Wind SSE 2.4mph. 73°	Curicron 1 gal/20 acres Baythroid 1 gal/50 acres Cottonseed oil	4 oz pix 2 qt/acre
7-24-99	XP3, XP10	Spray 10:00 A.M. Wind NNW .6 mph. 91º	Decis 1 gal/63 acres Curicron 1 gal/20 acres	3 gal/acre water
7-31-99	XP3, XP10	Spray 10:00 A.M. Wind SW 2 mph. 93º	Karate Z 1 gal/63 acres Orthene 1 gal/2 acres	3 gal water/acre, 4 oz Pix
8-14-99	XP3, XP10	Spray 8:00 A.M. Wind N 3 mph. 81º	Baythroid 1 gal/57 acres Fury 1 gal/30 acres Karate Z 1 gal/60 acres Meptichloron	5.7 oz
8-25-99	XP3, XP10	Spray 8:45 A.M. Wind ESE 4.5 mph. 80º	Tracer 1 gal/66 acres Asana XL 1 gal/16 acres Soy Surfactant	5 gal water 1 pt
9-2-99		Spray 10:00 A.M. Wind ENE 2.2 mph. 77º	Pirate 1 gal/22.2 acres Soy Oil	5 gal water 1 qt
7-12-99 to 9-2-99	XP3, XP10	Irrigation, 6 times, furrow		
9-20-99	XP3, XP10	Defoliation, Plane (5 gal water)	Def Prep	1 to 9.4 acres 1 to 5.5 acres
		SOYBEANS		
5-21, 22-99	XP1, XP2, XP8, XP9A, XP9B	2ND Burndown (broadcast w/ tractor) (1/2% surfactant)	Gramoxone	3pts/acre in 10 gal water
5-25-99	XP1	Do-all, plant, & chemical application.	Delta Pine Roundup Ready Command	Soybeans 50 lb/acre 1/6 acres (1.33 pt/acre)
5-25-99	XP2 (W side)	Do-all, plant, & chemical application	Delta Pine RR Command	50 lb/acre 1/6 acres (1.33 pt/acre)
5-27-99	XP2 (E side)	Do-all, plant, & chemical application	Asgro Roundup Ready Command	50 lb/acre 1/6 acres (1.33 pt/acre)
5-28-99	XP8, XP9A, XP9B	Do-all, plant, & chemical application	Asgro RR Command	50 lb/acre 1/6 acres (1.33 pt/acre)
6-8-99	XP2 (30 acres E side), XP9A, XP9B	Boom-spray	Roundup Ultra	1 qt/10 gal water
6-28-99	XP2 (E side), XP9A, XP9B	Spray, over top (Boom)	Roundup Ultra	1 ½ pt/acre, 10 gal/acre
7-1, 2-99	XP1, XP2, XP8	Spray over top (Tractor)	Roundup Ultra	1 qt/acre, 10 gal/acre
10-1-99	XP9A, XP9B	Wheat (Plane)		100 lb/acre
10-11-99	XP8, XP1, XP2	Wheat (Plane)		100 lb/acre
10-29-99	XP3, XP10	Wheat (Plane)		100 lb/acre
11-22-99	XP1, XP2, XP8	Wheat (reapply)		50 lb/acre

1999 Cotton & Soybean Yields

Field Number	**Acreage**	**Yield**	**Bu/acre**	**Lbs/Acre**	**Price/Unit**
COTTON					
XP3	44.8			1072.68	$0.72
XP10	37.1			1072.68	$0.72
TOTAL	81.9	87,583		1072.68	
XP24	63.9	77,438		1211.86	$0.72
DIFFERENCE				139.18	
	139.18 X 81.9 =	11,398.84 X .72 =	$8207.16		
SOYBEANS					
XP1	17.6	161	8.54		
XP2	59.1	737	11.35		
XP8	7.9	191	22.73		
XP9	23.2	503	19.42		
TOTALS	107.8	1592.0	14.76		
OTHER SOYBEANS	358.9	5285.35	14.73		
DIFFERENCE			.03 BU/ACRE		