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Management Research Unit
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Tifton, GA

Title
Water Quality Impacts of Best Management Practices and Conservation Buffers on Fields, Farms, and Watersheds**.**

Scientists

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Total Scientific Staff Years
2.25

Planned Duration
60 months

Pre-Peer Review

Signatures and Dates Must be Complete Prior Distributing this Project Plan to Peer Reviewers

[CRIS # 6602-13000-011; 6602-13000-015; 6602-13000-013; 6602-13610-006
Water Quality Impacts of Best Management Practices and Conservation Buffers on Fields, Farms, and Watersheds.**]**

This project plan was found to meet the peer review criteria, be in compliance with the Project Plan Instructions and Format, and demonstrate how the research team will conduct research in a manner appropriate for this area of research.

__Timothy C. Strickland_______________ ___Tuesday, October 02, 2001_____

Research Leader **Date**

This project plan was prepared by a qualified research team and demonstrates the research team's best effort towards achieving the assigned research objectives.

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Center, Institute, or Lab Director **Date**

This project plan is relevant to the Agricultural Research Service's National Program Water Quality and Management Action plan and was prepared in accordance with the outlined objectives, experimental approach, and project duration previously agreed to by the National Program Team and research team.

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National Program Leader **Date**

This project plan was prepared by a qualified research team and demonstrates the research team's best effort towards achieving the assigned research objectives. All internal review and approval requirements have been met. To validate the plan's readiness for implementation and gain recommendations for improvement, the project plan is now available for peer review.

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Area Director **Date**

These officials have not performed a scientific merit peer review. Their statements do not necessarily require expertise in the specific subjects associated with this research. The approval to implement this project plan cannot be made without a scientific peer review coordinated by the Office of Scientific Quality Review, ARS-USDA.

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TABLE OF CONTENTS

PROJECT SUMMARY

Water quality is generally assessed at the watershed scale but water quality Best Management Practices (BMPs) are typically applied at the field scale. Many BMPs have been tested at the small plot scale but very few have been evaluated at the farm or watershed scale. In many cases we do not know whether or how much water quality has been improved on a watershed or stream segment scale by the application of agricultural water quality BMPs. It is also poorly understood how in-field BMPs such as conservation tillage and chemical management techniques interact with off-field BMPs such as vegetated filter strips and riparian buffers. Through the proposed new research, we will provide new information on the effects of current and innovative BMPs on water quality and quantity at the field, farm and watershed scale. We will provide new tools to examine the effects of buffer systems on the transport of pesticides that might leave fields in runoff or groundwater flow. We will provide enhanced models of buffer system effects on sediment, nutrient, pesticide, and water transport to integrate with ongoing ARS watershed modeling efforts. We will provide more complete understanding of agriculture effects on water quality in important crop production regions of the southeastern Coastal Plain and in year-round crop production areas of South Florida. We will adapt and use the modeling and analysis tools developed in our research program to understand the effects of USDA Conservation Buffer Initiative programs on water quality in important agricultural regions of the U.S.

Objectives

1) Delineate water quality impacts of current conservation buffer management practices and water quality Best Management Practices (BMPs) at field, farm, and watershed scales;
2) Enhance existing models to quantify the impact of buffer systems on water quality (nutrients, sediment, pesticides) at multiple scales and in multiple regions;
3) Link models of pesticide attenuation and dilution in buffer systems with field-scale fate and transport models;
4) Improve the scientific basis for assessing the effects of USDA/state conservation initiatives (CRP, CREPs, EQIP) on water quality and the restoration and sustainability of agricultural landscapes;
5) Develop new concepts and enhance scientific understanding of the role of buffer ecosystems (including wetlands, riparian systems) and agroecosystems (including pastoral and agroforestry systems) within landscapes in processes such as carbon sequestration, aquatic and terrestrial habitat, and materials transport.

Need for Research

• Description of the problem to be solved

Water quality in many parts of the Southeastern Coastal Plain is impaired due to nonpoint source pollution from agriculture (Figure 1). In the Suwannee River Basin of Georgia and Florida, over 90% of the monitored streams have impairments due to low dissolved oxygen levels (SRWMD, 2000). Studies from farm-size watersheds and the larger gauging stations of Little River Watershed show similar trends (Lowrance, unpublished data). The low dissolved oxygen has been attributed to excess nutrients by state water quality regulatory agencies. Nutrient Total Maximum Daily Load (TMDL) assessments have been prepared for all the impaired stream reaches. These assessments indicate that an average of a 40% reduction in N and P load is needed in the impaired watersheds (GA-EPD,2000). Because in almost all cases these are rural watersheds with no point sources and only agriculture is using significant amounts of supplemental nutrients, TMDL implementation plans will require agriculture to make nonpoint load reductions up to 40% in the impaired watersheds. Other Coastal Plain agricultural watersheds in Georgia, Alabama, Florida, South Carolina and North Carolina are experiencing similar problems. When states are required by USEPA to set nutrient impairment criteria for streams (in 2002 or shortly after) many of these Coastal Plain streams that are listed as impaired due to dissolved oxygen will also be listed as impaired due to excess nutrients (USEPA, 2000).

Other non-point source contaminants strongly associated with agriculture in the region are pesticides. Use rates are high; this is in part due to crop types and high pest pressure. For example estimated total pesticide use rates for the dominant row crops, cotton and peanuts, are 8.5 and 7.7 lbs. acre^{-1} yr^{-1} of active ingredients, respectively. In comparison pesticide use on the corn and soybeans, which dominate mid-Western agricultural landscapes is 2.2 and 1.5 lbs. acre^{-1} yr^{-1} (USDA-NASS, 2000). In spite of their high use rate, available data do not indicate that pesticide contamination of surface and ground water is a cause for impairment. Less than 1 % of the impaired waters in Georgia identified pesticides as source of impairment (GA-EPD, 2000). This may be due in part to relatively high temperature and humidity during the growing season which contributes to rapid pesticide breakdown (Potter et al, 2001). While impairment is not widespread, pesticide contamination of surface waters is a concern. In the USGS NAWQA phase I survey of the Suwannee River Basin conducted in 1993-1996, 21 different compounds

Figure 1. Impaired streams in southwest Georgia.

were detected in surface water samples. At least one pesticide was detected in >94 % of all samples and 2 or more in >66 % of all samples (Potter and Wauchope, 2001). Although levels detected were low there are no harm-to- aquatic-life guidelines for some of the compounds found and the fact that mixtures of chemicals are frequently detected adds uncertainty to assessment of impacts.

In many parts of the Southeastern Coastal Plain there are significant interactions between surface water that may be contaminated from agricultural nonpoint source pollution and groundwater that is used for municipal and domestic drinking water supplies. The connections are both direct and indirect. The direct connections are where sandy agricultural soils and subsoils overlie sand and limestone aquifers that are relatively shallow (15-40m deep). Good examples of these types of connections are found in the Dougherty Plain of Georgia, the Middle Suwannee Region of Florida (SRWMD, 2000), and the shallow soils above the Biscayne Aquifer in South Florida where large springs or regional groundwater supplies are recharged by locally infiltrated rainfall. The indirect connections are where surface water in streams discharges into aquifers, typically where limestone aquifers outcrop after being confined by upslope aquicludes. Among other places, this situation occurs near the Georgia/Florida state line where flows from the Alapaha and Withlacoochee Rivers discharges into the Floridan Aquifer. Whether direct or indirect, there are significant interactions between water contaminated by agricultural chemicals or excess nutrients and drinking water supplies for the region. Although there are currently few cases where drinking water standards are violated, there are significant areas of nitrate contamination above 10 mg L^{-1} NO_3-N in both the Dougherty Plain of Southwest Georgia and the Middle Suwannee of North Florida (SRWMD, 2000). In addition, there is surface water mixing with the aquifer near Valdosta, GA (Plummer et al, 1998) that was connected to unacceptable disinfection byproduct contamination at drinking water treatment plants using chlorine.

- **Relevance to ARS National Program Action Plan**

The research is part of the ARS National Program in Water Quality and Management (NP 201). The research will allow us to understand the effects of watershed characteristics, water use, and management on the structure and function of riparian and wetland ecosystems (Goals 1.4.1, 1.4.2, 1.4.4). The research will provide better understanding of the effects of nutrient cycling, and nutrient and sediment transport processes on fate of pollutants in riparian and wetland systems in agricultural landscapes (Goals 3.1.2, 3.1.4 and 3.4.5). The research will provide new information to develop management practices that reduce losses of pesticides and synthetic organic chemicals into soil and water resources (Goal 3.2.4). The research will contribute to development and testing of models of chemical transport at the field, farm, and watershed scale and allow the development of environmental components of decision support systems for selecting on-field and off-field management practices (Goals 3.6.2 and 3.6.5). The research will provide new tools for evaluating and targeting agricultural conservation programs (especially buffers) for water quality improvement (Goal 3.8.1).

- **Potential benefits**

Results will allow landowners to improve and maintain water quality in the southeastern Coastal Plain and Florida - important areas for growing peanuts, cotton, other row crops, vegetables, citrus, tropical fruits, forage crops, for animal production, and for forest products. We will be able to provide customers with a better understanding of how specific in-field BMPs and conservation buffers will improve water quality in general and in certain impaired river basins such as the Suwannee (GA and FL), the Satilla (GA) and the South Dade Basin (FL). We will improve modeling efforts related to riparian wetlands and other conservation buffers and will develop new tools for more accurate assessments of the effects of cropland and associated landscape features on water quality. The research will contribute to the restoration of impaired streams and rivers in both the Southeastern Coastal Plain and in other parts of the country, especially where riparian buffers are being used or will be used to control nonpoint source pollution.

- **Anticipated products**

1) Quantification of the effects of water quality BMPs and the integrated farm scale and small watershed effects of BMPs and conservation buffers;
2) Estimates of the ability of specific BMPs and conservation buffers to achieve nutrient load reductions required for TMDL implementation plans.
3) Modifications of the Riparian Ecosystem Management Model (REMM) to account for regional and scale differences in riparian systems and wetlands;
4) Enhanced models of pesticide fate and transport in buffer systems and other portions of agricultural landscapes;
5) More accurate estimates of human and ecological risks of pesticide use;
6) New techniques and datasets to assess the effects of USDA/state conservation initiatives;
7) Data analysis tools and decision aids to describe multiple landscape scale benefits from buffers, agroforestry systems and/or pastoral systems.

- **Customers**

Our research products will be distributed to farmers, growers groups, technical agencies, consultants, environmental groups and the general public interested in protecting and enhancing environmental quality. Specific customers include: technical specialists at institutes and centers of USDA-NRCS (Watershed Science Institute, Water and Climate Center) and USDA-FS (National Agroforestry Center, State and Private Forestry); USEPA regional offices involved in TMDLs, pesticide registration, and nonpoint pollution control programs; USEPA-Office of Pesticide Programs -Environmental Fate and Effects Division (OPP-EFEP); state environmental protection agencies in Georgia and Florida (Ga-Environmental Protection Division and FL Dept of Agriculture and Dept. of Environmental Protection); the Water Resource Divisions of Water Management Districts (WMD) in Florida including South Florida WMD and Suwannee River WMD; and NGOs such as the Upper Suwannee River Watershed Initiative and the Altamaha River Keeper. Customers are included in formulation of general research objectives and plans and in review of results. We propose to co-locate at SEWRL a technical specialist from the National Agroforestry Center to receive training on REMM and to provide customer guidance on new technology development efforts related to conservation buffers and agroforestry systems.

Scientific Background

Agriculture and Environmental Quality

Environmental quality in agricultural landscapes depends on a combination of field-scale BMPs and ecosystem based conservation practices that buffer the environment against potential off-site effects of agriculture (Lowrance, 1990). In the Southeastern U.S. and the Suwannee River Basin in particular, these off site effects are typically from irrigated crops receiving high levels of pesticides and nutrients (primarily cotton, peanuts, and vegetables); animal production generating high levels of nutrients and potential pathogens (swine, poultry, beef cattle, and dairy), and animal production damaging the physical and biological condition of riparian ecosystems, streams, and wetlands (swine, beef cattle, and dairy). Buffers (e.g riparian systems, wetlands, forests, vegetated filter strips) are the unmanaged or less-managed portions of the landscape. Because buffers may compete with production systems for land and other resources and because field scale BMPs are used to modify the external effects of agriculture, it is necessary to quantify the integrated effects of production oriented BMPs and ecosystem based conservation practices. To protect water quality, the appropriate scale for understanding integrative effects is at the level where a full suite of BMPs and conservation practices can be implemented. This is typically at the farm or small watershed scale. At the small watershed scale, the effects of BMPs and conservation practices on a limited number of farms can be analyzed. This has generally not been done in the research used to develop the BMPs. New knowledge, enhanced models, and new decision support systems are needed for the analysis of the integrated effects of BMPs and conservation practices, especially buffer ecosystems. New concepts of how to manage agroecosystems as buffers in multiple use landscapes (including grazing lands, forestry, and urban lands) are also needed.

In many agricultural regions of the U.S. there has been a wide spread conversion of riparian ecosystems to cropland. This is generally in conjunction with ditching or draining of depressional or riparian wetlands. In some parts of the country, notably the Mid-West and Coastal Plain areas of North Carolina, the loss of this wetland and riparian habitat is directly linked to nitrogen enrichment of streams, reservoirs, and downstream receiving waters. Restorations of riparian, floodplain, and wetland habitats for nitrogen retention are among the cornerstones of water quality restoration strategies for the Gulf of Mexico Hypoxia Program, The Chesapeake Bay Program, and estuaries such as Tar-Pamlico Sound, NC (Mississippi River/Gulf of Mexico Watershed Nutrient Taskforce, 2001; Chesapeake Bay Council, 1997; Gilliam et al., 1997). Although the "vegetated or forested buffers established along rivers and streams of priority watersheds" is a programmatic indicator to be tracked in these large basin scale restoration efforts (Mississippi River/Gulf of Mexico Watershed Nutrient Taskforce, 2001) understanding the direct benefits of these buffers for reduction of nonpoint source pollution is a better way to account for their effects. Robust, process based models are needed for the evaluation of the success of these strategies. By testing and modification of the Riparian Ecosystem Management Model (REMM, Lowrance et al., 2000) we will be able to provide direct estimates of the masses of nutrients, sediments, and pesticides not reaching streams and other aquatic ecosystems due to the buffer establishment strategies pursued in the watershed restoration projects.

Unlike other agricultural regions, there is currently very little cropland along streams in the Southeastern Coastal Plain. Row-crop production is typically concentrated on the most productive land. These are typically not riparian areas due to seasonal flooding or water logging; seasonal drought due to low water holding capacity; and pH and fertility problems. Although there is very little riparian cropland, there are only a few areas of continuous riparian forest for more than a few kilometers of stream because of the prevalence of riparian pastures. For instance in the Little River Watershed (334 km^2) there are only three stream reaches with more than a kilometer of continuous riparian forest (Perry et al.,1997). Riparian pastures lead to increased water temperatures and increased input of bacterial and other potential pathogens to streams. These impacts are associated with the principal surface water quality impairments of low dissolved oxygen and increased fecal coliform bacteria found in water quality monitoring (SRWMD, 2000). Restoration of these riparian pastures under USDA programs such as the Conservation Reserve Program (CRP) Continuous Sign-Up is vital to water quality improvement in the Southeastern Coastal Plain. Coordinating research on water quality improvement and ecosystem health with the restoration of these areas through USDA and state programs will provide essential information on the actual environmental quality benefits of restoring marginal pasture through CRP.

Water Quality BMPs as Part of Agronomic Management

Conservation tillage has significant potential as a management tool for cotton production on sandy soils that are drought-prone and susceptible to erosion. Planting directly into a residue cover (no-till) or in narrow rows tilled into a residue cover (strip-till) has been shown to reduce erosion and conserve water by enhancing infiltration and increasing soil-water holding capacity. This can reduce irrigation requirements and runoff which transports sediment, nutrients, pesticides and other agrichemical residues into surface waters (Potter et al., 1995; Reeves, 1997, Truman et al., 2001). While potential benefits of conservation tillage are widely recognized, actual benefits in terms of water conservation and quality vary, depending on numerous factors including soil characteristics, topography, pest pressure, agrichemical use and weather. There is a continuing need for systematic research to provide growers with the best available information on benefits of different tillage systems so that they can make informed choices which will enhance profitability and sustainability while minimizing adverse environmental impacts (Bosch et al., 2000).

Many agricultural areas in the Southeast are on lands with little or no relief where leaching of chemicals to groundwater is the main environmental concern. The C-111 basin, located in the southern portion of Miami-Dade County, FL, includes about 100 square miles of land in agricultural production and the entire Taylor Slough basin within Everglades National Park (ENP). The large scale hydrologic restoration of the Everglades includes modifications of the existing surface water management system that will restore historic freshwater flows in Taylor Slough and the Eastern Panhandle areas of ENP (SFWMD 2000a, 2000b). Increased freshwater deliveries to ENP are designed to restore more natural hydrologic patterns in the area and contribute to ENP ecosystem restoration. Total costs of the 20-year restoration project are estimated to be $8 billion dollars. There is a growing recognition among ENP managers that retention of farmland is critical to restoration efforts because land in agricultural production provides a buffer for urban sprawl from the City of Miami. However, it also appears that vegetable and tree-fruit production in the area may be a significant source of non-point source pollution to surface and ground waters. This could impact restoration efforts since current plans include pumping water, which drains from the cropland, to the ENP. NPS pollutants could negatively impact the sensitive Everglades ecosystem. There is a consensus among all parties that the design, evaluation and implementation of agricultural Best Management Practices to protect water quality are a critical component of restoration efforts and promoting agricultural sustainability in the southern Everglades (SFWMD 2000a, 2000b).

Use of Buffer Systems to Reduce Chemical and Sediment Loading to Receiving Waters

The best-studied aspects of buffer ecosystem effects on water quality are nitrate removal and sediment retention. Reports of nitrate removal in riparian buffers were first published in the 1980s (Lowrance et al, 1984; Peterjohn and Correll, 1984, Jacobs and Gilliam, 1985). Recent literature has provided a better understanding of the interactions among hydrology, vegetation, and soils in reducing nitrate transport through riparian forest buffers (Addy et al., 1999; Bosch et al., 1996; Correll, 1997; Simmons et al., 1992). Although there are as many as 284 papers on nitrate removal functions of riparian forest buffers (Correll, 2000) there is no generally accepted way of determining removal rates or even estimating the range of removal rates. Recent reviews and synthesis efforts to do this without well-tested riparian ecosystem models have lead to a better conceptual framework but no real increase in our ability to quantify the effects (Hill, 1996; Lowrance et al., 1997). Sediment removal has been studied in a variety of buffer experiments that lead to general conclusions concerning general buffer functions (Arora et al, 1996; Dillaha et al., 1989; Lowrance et al., 1986). Although sediment and sediment borne chemical removal in buffers have been studied in a variety of systems, there is still no generally accepted method for estimating this effect and no means to deal quantitatively with the effects of concentrated flow through buffers. Other functions of buffer ecosystems such as phosphorus removal, pesticide removal, pathogen removal, provision of energy sources to aquatic ecosystems, provision of coarse woody debris, and effects on aquatic habitat structure are more poorly understood than the nitrate removal and sediment retention functions. Furthermore many of the studies of these functions have been done on mature buffers rather than developing buffers and very few studies have been done on the watershed scale. Clearly there are needs for new knowledge and technology to assess buffer ecosystem functions on the field, farm and watershed scales.

All pesticide tolerances are currently undergoing re-assessment by USEPA. The process was initiated after passage of the Food Quality Protection Act (FQPA) in 1996. A key feature of FQPA is use of multi-pathway exposure risk assessment models. Ingestion of contaminated drinking water is one of the exposure pathways. EPA has addressed this route of exposure using relatively simple and highly conservative models to estimate potential pesticide concentrations in drinking water reservoirs vulnerable to contamination by runoff from agricultural land. Because estimates in this modeling approach are highly conservative, it is possible that the exposure estimates are overstated (Hetrick et al. 2000; USEPA, 1999). EPA has proposed use of more monitoring data to increase the “realism” of FQPA drinking water assessments. However, it does not appear monitoring data will replace the need for or use of models because robust data sets suitable for drinking water exposures assessments are not routinely available and are expensive to develop.

To date, EPA has focused modeling efforts on two models- the Generic Estimated Environmental Concentration (GENEEC) and the Pesticide Root Zone Model/Exposure Analysis Modeling System (PRZM-EXAMS). GENEEC provides an extremely conservative first-tier assessment by generating worst-case “edge-of-field” concentrations. Refined “edge-of-field” concentration estimates are obtained with PRZM for use in Tier-two assessments. With EXAMS, in-stream attenuation of pesticide after chemicals enter streams is simulated. The suite of models has no capability to evaluate the effects of buffer systems on pesticides before they reach streams, rivers or reservoirs.

Studies show that buffers are needed to reduce other pesticide loadings to waters in the Southeast. Atrazine and alachlor were effectively retained in mature buffers along a Coastal Plain stream (Lowrance et al., 1997b). A study conducted in crop-year-1999 at a site on the Coastal Plain region in Southern Georgia found that up to 15 % of the mass of the active ingredients in two widely used cotton defoliants was lost in runoff during a single post-application storm event. One of the defoliant active ingredients, tribufos, has been reported to be highly toxic to aquatic life. Thus, negative impacts on streams and rivers could result if a storm event occurs soon after defoliant application. There are also concerns about runoff of pre-emergence herbicides and nutrients and pathogens from cotton fields amended with poultry-litter. One of the most commonly detected pesticides in surface waters in the cotton producing regions in the Southeastern USA is Fluometuron, a compound widely used for pre-emergence weed control (Coupe et al., 1998). Grower use of poultry litter is also rapidly increasing. Numerous studies have shown that the concentration of pesticides and other agricultural chemicals dissolved in runoff can be substantially reduced as it flows through conservation buffers like grass filter-strips (NRCS, 1999). Their effective and efficient use requires that design features be systematically evaluated for crop type, local climatic conditions, vegetation, and contaminant-type.

Buffers are increasingly accepted as a means to achieve water quality improvement goals on farms of all sizes. Buffers are the main component of the Conservation Reserve Program Continuous Sign-Up and are included in most states Conservation Reserve Enhancement

Programs. Because of limited acreage, buffers might be of less use on small or medium size farms than on larger farms. Conversely, because of the acceptability of buffers to regulatory and management agencies and the government payments often available for buffers, they might be of more importance for achieving water quality goals on small sized, medium sized, and limited resource farms. If buffer ecosystems can be integrated with sustainable farming practices and if the water quality benefits can be well quantified, they will allow small, medium, and limited resource farmers to meet their conservation needs. If farmers and farm operators have limited financial resources to apply advanced production technology that will lead to water quality improvements, then buffers that are cost-shared through state and federal programs may be the most cost-effective approach. In addition, as small, medium, and limited resource farmers are required to be part of watershed based water quality improvement programs, the use of buffer ecosystems will be a simple and direct way to show that these farms are contributing to watershed scale solutions.

Buffer designs and specifications are based on concepts developed in buffer system research over the past two decades (Welsch et al., 1991, Lowrance et al., 1997a; Schultz et al., 1995) . The research programs have ranged from highly controlled conditions on engineered buffer systems to natural rainfall conditions on unmanaged riparian ecosystems. Although the research designs and experimental procedures have varied, these research programs have had a common goal: to understand how various buffers work to control nonpoint source pollution from a variety of sources. On the whole, these research programs provide a large number of general concepts to apply in designing buffer ecosystems to control nonpoint source pollution. Among the general concepts are: 1) minimize channelized flow; 2) store polluted water in either surface detention, floodplains or soil water; 3) store nutrients in woody biomass; 4) maximize contact between pollutant laden water and the biologically active root zone; 5) maintain high roughness and leaf litter; 6) maintain a large number of stiff upright stems; 7) use multiple zone systems which provides multiple functions based on distance from aquatic ecosystem and distance from the source area. These general principles have been used by various USDA agencies to achieve general standards and specifications for multiple zone buffer systems (Welsch, 1991). Other groups have used similar design principles to provide variations on multiple zone buffer systems for specific parts of the country (Isenhart et al., 1997; Schultz et al., 1995). Although general design principals are derived from these studies, they are not sufficient to provide either detailed designs of buffers for specific water quality problems or an evaluation of the water quality benefits to be expected from particular buffer designs. As with any conservation practice, the results achieved for water quality improvement will vary based on site, region, pollutant loading, hydrologic conditions, soils, vegetation, and numerous other factors.

The Riparian Ecosystem Management Model (REMM) was developed by SEWRL scientists and cooperators. REMM is designed to evaluate the effects of different buffer conditions and management practices and different pollutant loads entering the buffer ecosystems from upslope agriculture (Lowrance et al., 2000; Inamdar et al 1999a, 1999b). REMM simulates a buffer system of 1-3 zones that can include vegetated filter strips (annual or perennial herbaceous), managed forest, permanent forest, and shrubs (woody understory). REMM has been tested for Coastal Plain conditions (Inamdar et al, 1999a, 1999b, Gerwig et al, 2001). REMM has developed a significant user community and is unique in its potential to represent and predict the potential of a wide range of stream- and pond-side nonpoint pollution remediation zones in agricultural landscapes. REMM does not currently include algorithms for pesticide and other toxic organic chemical behavior in such systems. Research into the pesticide "filtering" capabilities of grassed waterways and other buffer strips has had conflicting results (Lickfeldt and Branham, 1995; Patty, et al., 1997; Cole, et al., 1997; Benoit, et al., 1999; Poletika, et al., 1995; Dozier and Senseman, 1998; Misra et al., 1996), but on balance it appears that riparian systems can, through hydrologic rerouting and sediment trapping, remediate agrichemical discharges into surface waters (NRCS, 1999; Lowrance, et al., 1997b; Baker, et al., 1995; Shankle, et al., 2000).

Multiple purpose agroecosystem management will include multiple objectives such as water quality, water supply, carbon sequestration, wildlife management, biological diversity, recreation, and other uses that society demands (Hart, 1984). Among the multiple benefits of agroecosystem management are to buffer the effects of more intensive development such as cities and to sequester carbon that would otherwise contribute to greenhouse gases. Carbon storage in agricultural systems can take place in soil and vegetation of cropped fields and in the non-cropped portion of a landscape – areas such as buffers, wetlands, and riparian zones. The estimate of carbon sequestration in conservation buffers, especially riparian forest buffer ecosystems, is highly uncertain. The only estimates available are described as “probably an underestimate” (Lal et al., 1998). Because of two decades of research on riparian ecosystems in the headwaters of the Suwannee River Basin, a large data set is available to provide a more detailed estimate of carbon storage in riparian buffers.

A number of “full-text” searches of the National Agriculture Library CRIS project databases were done in order to document some of the ongoing research in the areas covered by this proposed project. These searches showed that as many as 94 projects were in the CRIS system (nationwide) with the words water quality and buffers. For the southern region there were 78 projects in the CRIS system with the words BMPs and water quality. These findings represent a very wide range of projects from in-house ARS projects to cooperative agreements. One finding form the CRIS search is that we are cooperating with a large number of the investigators in the region and nationally who are doing research in these areas. As an example, there were at least 10 projects not including our own that had REMM somewhere in the full text of the project.

ARS National Collaboration

The research program of the CRIS will be done in conjunction with the ARS Total Maximum Daily Load (TMDL) Monitoring and Research National Initiative and the ARS Coastal Water Quality Protection National Initiative. The testing and modification of REMM at multiple ARS locations will be done in conjunction with the ARS River and Stream Corridor Restoration and Management National Initiative. The primary ARS locations with which we will collaborate are Ames, IA; Beltsville, MD; Corvallis, OR; Florence, SC; Oxford, MS; and University Park, PA. The specific deliverables will be 1) new scientific knowledge to evaluate the effects of production agriculture systems on specific water quality parameters that are used to evaluate stream, lake, river and coastal water quality for TMDL and other assessment programs; 2) new modeling tools based on REMM to evaluate the water quality functions of buffer systems in important agricultural regions of the U.S.; 3) integration of riparian ecosystem functions into existing watershed scale water quality models developed by ARS and other agencies. The specific contributions from this project will be 1) understand the effects of agronomic BMPs on agrichemical transport potential to streams in Coastal Plain production systems; 2) coordinate a national effort to test, modify, and apply REMM; 3) provide scientific leadership in incorporating riparian ecosystem functions into existing watershed scale models. This project, and associated projects at SEWRL in NP201 **(Bosch et al,), NP202 (Wauchope et al.), and NP206 (Hubbard et al.),** play key roles in achieving these national program collaborative goals due to our leadership in understanding and modeling the water quality functions of riparian ecosystems and our combination of field experimental and laboratory analytical capabilities to support these efforts. We will use a combination of replicated field experiments, small watershed monitoring, model testing, model modification, and data sets collected by ARS and other cooperators to accomplish the collaborative research. The National Program problem areas and goals that are addressed in the project are shown in Appendix B.

Approach and Research Procedures

The research described in this project plan is being done in coordination with the overall research mission of the SEWRL. In particular, this research is closely integrated with a secon projct in the Water Quality and Management National Action Program "Impacts of Land Use on Hydrologic and Environmental Processes for Watersheds in the Coastal Plain." Specific aspects of the project described in this proposal are also done in conjunction with the two other CRIS projects in SEWRL entitled "Soil Resources in the Coastal Plain: Process Characterization, Management Impacts, and Assessment Tools" and "Whole Farm Management of Agricultural Effluents."

Objective 1 - Hypothesis: Water quality BMPs will provide improvements in water quality from agricultural land uses by reducing the movement of chemicals to receiving waters. Plot experiments will be used to examine the effects of BMPs on pesticide and nutrient transport.

Experiment 1 (Potter, Bosch, Truman): Plot scale watersheds, instrumented to collect surface runoff and subsurface flow, will be used to quantify the effects of conservation tillage on water storage and pollutant transport. Soil processes and quality aspects of this experiment are addressed a companion project in National Program 202- Soil Quality and Management entitled "Soil Resources in the Coastal Plain: Process Characterization, Management Impacts, and Assessment Tools." Surface and subsurface water samples will be collected to characterize water and chemical losses from plot size watersheds. A 2 ha parcel on the University of Georgia Gibbs Farm located in Tift County, GA will be used to study the effects of conservation tillage on runoff, infiltration, and water quality. The site is divided into six 0.2 ha plots with a seventh 0.4 ha plot set aside for companion rainfall simulation studies (Fig. 2). The soil is a Tifton loamy sand with a 3 to 4 % slope. Past agronomic practices resulted in substantial soil erosion. The soil is a loamy-sand to a depth of 25 to 50 cm underlain by dense sandy clay loam and sandy clay whose plinthite concentrations increase with depth. Plots 1 to 6 are surrounded by 0.6 m earthen berms. Metal runoff flumes concentrate surface runoff for automated sample collection and flow monitoring. Five cm (i.d.) PVC groundwater monitoring wells and soil-water monitoring access tubes on the down-slope side of each plot allow monitoring and sampling of the groundwater. A 15 cm (i.d.) tile drain installed across the slope between the lower boundary of plot 7 and the upper berm of plots 1 and 2 (Fig. 2) intercept upslope lateral flow. Two loops of drain tile capture and separate the subsurface flow from the conservation till plots from that of the conventional till plots (Fig. 2). Flumes installed at the tile drain outlets measure flow and provide a point for manual water sample collection.

Plots 1, 3 and 5 will be conventionally tilled while plots 2, 4 and 6 will be maintained in strip-tillage. Plot 7 will be half strip and half conventional. A rye grass cover crop will be planted each fall. The cover crop will be disked each spring on the conventional till plots and killed with a contact herbicide on the strip till plots. Chicken litter will be applied at a rate of 4.5 Mg/ha each plot each spring. A representative sample of the chicken litter will be analyzed for N and P content. A crop rotation of three years cotton - one year peanuts will be followed for all plots. A solid set irrigation system will be used to supply additional water needs. Precipitation, soil temperature, soil-water content, surface runoff, lateral subsurface flow (tile drain), and water table elevations will be

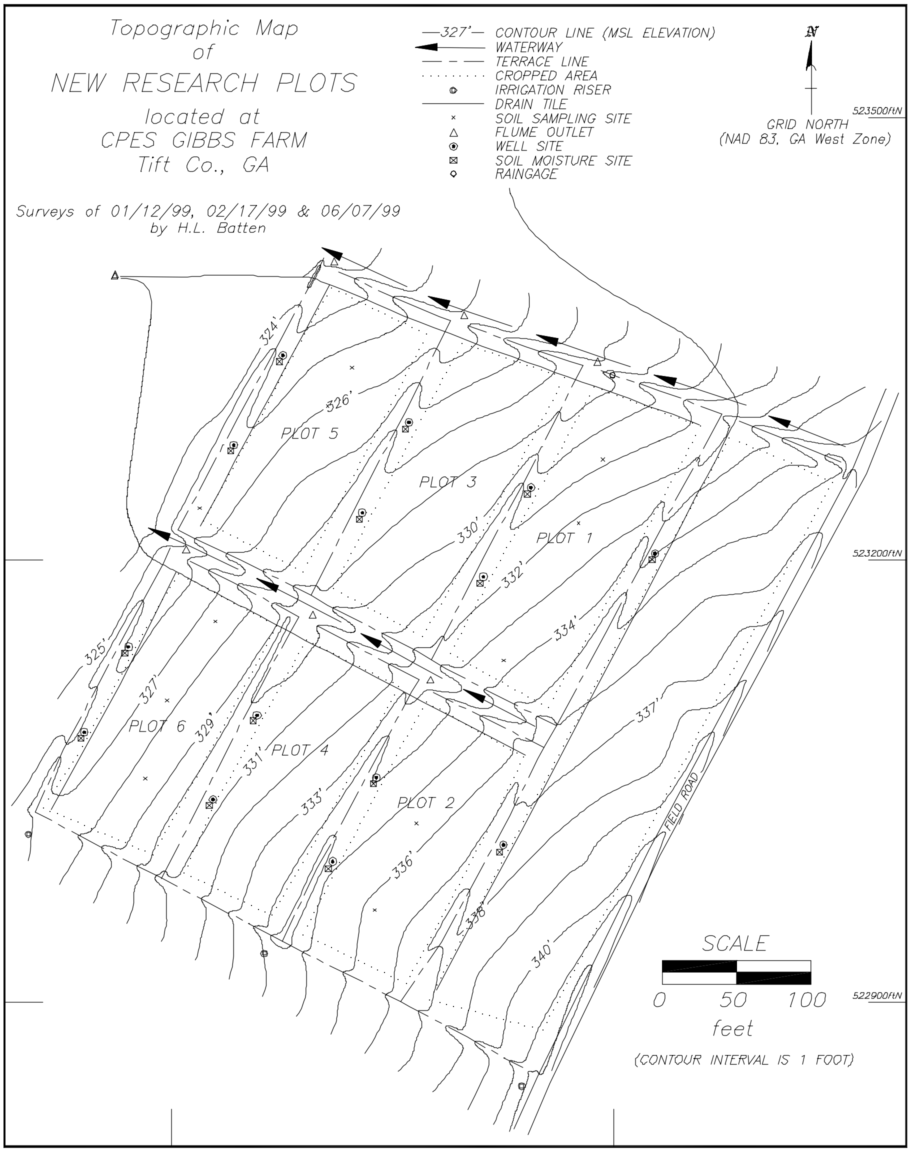

Figure 2. Map of Gibbs Farm Plots

monitored. Precipitation will be measured with an on-site tipping bucket rain gage. Soil temperature and soil-water will be measured every half-hour at depths of 5, 13, and 30 cm within plots 1 and 2. Additional bi-weekly soil-water measurements will be taken in the perimeter of each plot in 15 cm increments to 3 m. Water table elevation readings will be collected manually.

During each storm event composite surface runoff samples will be collected from plots 1 - 6 for water quality analysis. The surface water samples will be analyzed for suspended solids and nitrate by standard methods. Pesticides will be determined using methods developed by Potter et al, (2000). Daily samples of the tile outflow and monthly well samples will be collected. The tile and well samples will be analyzed for nitrate and pesticide residues. Composite soil samples will be collected from each plot at four depth increments, 0-1, 0-2, 2-8, and 8-15 cm. The soil samples will be collected at approximately 1, 4, 7, 14, 21, 30, 43, 57, 74, 86, and 100 days after pesticide application, with the most intensive sampling immediately after application. Soil samples will be frozen after collection until analyzed. Selected sub-samples will be tested for organic matter content and other physical and chemical properties. Nutrient and pesticide losses associated with surface runoff, sediment, and lateral subsurface flow on event, seasonal, and/or annual time periods will be used to isolate and study processes influencing chemical and sediment fate and transport. Data will be used to evaluate the effect of reduced tillage as a BMP to increase SOC and plant available water and decrease sediment delivery and water quality problems in Coastal Plain landscapes. Standard statistical techniques will be used to identify treatment differences, correlations,and cause/effect relationships.

Experiment 2 (Potter, Bosch):   This project, which was developed through a cooperative effort between the South Florida Water Management District (SFWMD), the University of Florida (UF), and ARS, was designed to: evaluate the fate and transport of indicator pesticides, i.e. compounds detected in surface water monitoring programs; evaluate the efficacy of summer cover crops in controlling pesticide and fertilizer contamination of surface and ground water; and evaluate contaminant attenuation during transport in the upper Biscayne aquifer. Results will contribute to risk reduction strategies for pesticide use, enhance water quality and promote agricultural sustainability. A 4-ha block of land was dedicated for the study at the University of Florida Tropical Research and Education Center in Homestead, FL. Within this block, six 0.16-ha plots were delineated and 21 monitoring wells constructed (Figure 3) data-loggers are installed in 3 wells located at the boundaries of the block to continuously monitor water table elevation. Sweet-corn

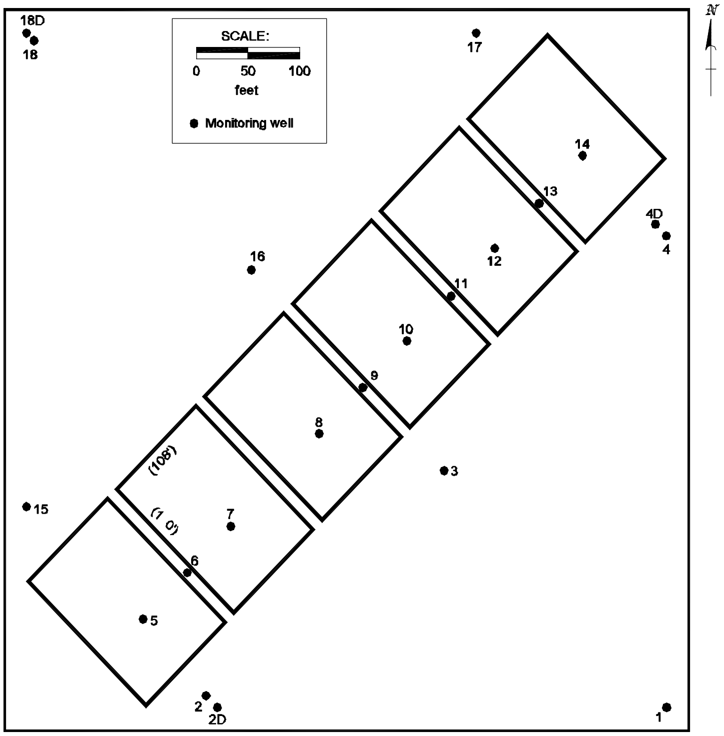

Figure 3. Map of Homestead, FL plots

(Zea mays) is being produced on the plots following standard grower practices for fertilizer an pesticide use. Water samples are collected biweekly from the wells and analyzed for nitrogen, phosphorus and pesticide residues. Nitrogen and phosphorus are analyzed by standard colorimetric methods. The pesticides atrazine, chlorpyrifpos and their principal environmental degradation prodcuts are analyzed using methods developed in-house. The analytical approach involves solid-phase extraction as described by Potter et al (2000) followed by HPLC-DAD-APCI-MS. Quality control plans require the analysis of matrix spikes with each sample set. Quantitative recoveries are achieved. In the Spring of each year, three plots are planted with *Crotalaria juncea* L. (Sun Hemp) as summer cover crop and three left fallow. The cover crop is mowed and disked into the soil prior to Fall Sweet Corn planting. To enhance the ability to detect agri-chemical leaching on these plots, groundwater sampling will also be coupled with soil water monitoring with a multi-sensor capacitance probe system. When the probes indicate soil saturation, data-loggers in monitoring wells will be checked for changes in the water table elevation. If a change is noted, water quality samples from all monitoring wells will be collected. The high porosity of the soils, the proximity of underlying Biscayne aquifer to soil surface and the aquifer's high permeability indicate that very rapid leaching of pesticides and nutrients may be taking place and that calendar-based sampling programs may not effectively capture peak pesticide and fertilizer loading of groundwater. The sampling scheme described is designed to address this question.

Ground water flow patterns and velocity in the aquifer will be defined by conducting tracer injection experiments during Spring and Summer. This is at the end of the dry and the end of the wet seasons in this humid sub-tropical environment. The aquifer's geologic matrix consists of weakly cemented limestone whose permeability, both vertical and tranverse is poorly defined. These studies will be performed by saturating water with sulfur hexafluoride (SF_6), pumping the water into the aquifer through a monitoring well and periodically monitoring the compound in the site's well network. To enhance the ability to measure both vertical and horizontal water flux, a series of "nested" multi-level, piezometers will be installed prior to beginning the tracer work. These studies will contribute to more accurate estimates of groundwater flow velocity and direction and field-scale contaminant dispersion. Hydraulic and water quality data from the Homestead site will be combined to develop a multi-year data set which will be used to calibrate vadose zone chemical transport models. Models tested will include RZWQM, GLEAMS 3.0, PRZM 3.0 and LEACHMP. Model outputs will be compared on the basis of the root-mean square error of predicted concentrations to determine which performs most effectively under the hydrogeologic conditions in the region.

Experiment 3 (Potter, Hubbard): Different grass buffer lengths will be evaluated to determine their impacts on nutrients and pesticides in runoff from cotton production areas. A 0.37-ha parcel located on the University of Georgia Ponder Farm in Tift County Georgia was divided into eighteen plots, which run up and down the slope. Plots are 45.6 m in length and 6.4 m wide. Each plot, for the full 45.6-m length, was bounded by plastic borders inserted into the soil to 0.15 m and extending to 0.15 m high above the soil surface. Borders were installed to confine runoff within individual plot boundaries. A 1-m wide walkway was left between the plots. The soil is Tifton loamy sand with 2 to 3 % slope. Crop-year 2000 was an establishment year. Plots were subdivided at their midpoints on the lengthwise dimension. The upper half of each was reserved for cotton production following common grower practices. This includes use of 2 tons/acre of poultry litter per year, the pre-emergence herbicides, fluometuron and pendimethalin, and chemical defoliation with tribufos and thidiazuron, prior to machine picking. The lower half of 9 plots each was sprigged with common Bermuda grass (*Cynadon dactylon* L. Pers.) and 9 with Tifton 85 Bermuda grass. Tifton 85 is a very productive hybrid with rapid and robust growth and excellent value as a forage crop. It must be planted with vegetative planting material, representing a substantial cost of establishment. Common Bermuda grass is indigenous to most field edges throughout the Coastal Plain, is less productive, but is easily established and often volunteers at field edges. The overall experimental design consisted of two grass and three grass-filter lengths, 0, 11.4 and 22.8-meter treatments. Each had three replicates and plot assignment was randomized. Surface runoff collectors (Sheridan et al., 1997) were installed at the bottom edge of the cotton crop area, mid-way through the grass filter strips (11.4-m) and at the bottom edge of the filter-strips (22.8-m). The runoff collectors provide a single flow-weighted sample for each runoff event. Samples will be analyzed for residues of the defoliants (tribufos and thidiazuron) and herbicides (fluometuron and pendimethalin) using methods developed by Potter et al, (2001). Nitrogen, phosphorus, and sediment will be analyzed using standard methods. We will use a combination of parametric and non-parametric statistics to determine whether or not concentrations in edge-of-field samples are significantly different from samples collected after flow through grass filter strips.

Contingencies – Because all experiments described under this opbjective involve intensive collection of field dat from plot size areas, field and laboratory procedures witll be continually evaluated for adequacy to meet project goals. Data will be analyzed after each field season to determine if data are adequate to teast hypotheses. Adjustments will be made to field and laboratory techniques as necessary.

Collaborations - Effects of water quality BMPs on nitrogen cycling processes in farms of the Middle Suwannee River Basin will be measured. A University of Florida (UF) study of farms in the Middle Suwannee River Basin (319 project) is designed to determine the source of nitrate contamination in major springs that are connected to the Suwannee River and the Floridan Aquifer system. SEWRL will cooperate with scientists at UF to determine the effects of nitrogen management techniques on the loss of N through denitrification from soils and subsoils. Existing methods for estimation of denitrification (Lowrance and Hubbard, 2001) using the acetylene inhibition technique will be used to determine the effects of N application techniques on denitrifcation. The sampling done by UF scientists is designed to look at inorganic N application through center pivot irrigation systems, liquid manure applicationfrom a dairy lagoon , and poultry litter application to cropland. As part of the overall N budget being developed in these projects, we will cooperate by estimating soil and subsoil loses via denitrifcation. Samples will be taken every other month over a 12 month period from depths determined by soil and subsoil profile characteristics. Donald Graetz, Bruce Schaffer (U. of Florida) and Craig Bednarz (U. of Georgia) are involved in the crop production aspects of the experiments.

Objective 2 - Hypothesis: Watershed models will provide more accurate representations of watershed chemical loads and concentrations when they include buffer areas as well as source areas in spatially explicit simulations. (Lowrance, Bosch, Sheridan, Hubbard)

Because of the widerspread need to achieve water quality improvements using vegetated streamside buffers, there is a need to test and modify REMM for use in other parts of the country and for other conditions in the Coastal Plain. We will do this testing and modification in conjunction with ARS research projects in Ames, IA; Beltsville, MD; Corvallis, OR; Florence, SC; Oxford, MS, **Coshocton, OH**, and University Park, PA. These are multi-objective projects testing the use of riparian buffers to meet critical regional needs. Each of these projects has as a sub-objective to work with SEWRL scientists on testing and modification of REMM for regional conditions. Completed and ongoing studies of buffer systems in the Coastal Plain, the Corn Belt, the Mississippi Delta, the glaciated Northeast, the North Appalachians, and the Pacific Northwest will be used to test the hydrology, sediment, and nutrient components of REMM. In each case, SEWRL scientists will serve as cooperators on REMM testing projects being carried out by the investigators responsible for the primary data collection at the above sites. Testing of REMM will follow procedures used in previous publications where both continuous and annual summary data (observed and simulated) are compared (Inamdar et al., 1999a; 1999b). Observed and simulated summary data are compared to see if the simulated is within one standard deviation of observed. Continuous data such as water table depth are compared to determine if the pattern and values are similar. Based on these comparisons, we will use detailed information from the cooperating studies to modify parameters and/or processes in REMM to achieve better agreement between observed and simulated data. To enhance the use of REMM in Coastal Plain systems, such as those in the Neuse River Basin, NC and other areas receiving high loadings of manure, REMM will be tested with surface runoff, and shallow groundwater data from a three year study of application of swine lagoon wastewater via overland flow. A three-year study was conducted to determine the feasibility of using riparian buffer systems to assimilate N and P from swine lagoon effluent (Hubbard et al., 1998; Lowrance and Hubbard, 2001). Replicated 30X4 m plots were established at the interface of a pasture and riparian forest. Three different vegetative buffer treatments were evaluated; (1) 10 m grass buffer draining into 20 m existing riparian zone vegetation; (2) 20 m grass buffer draining into 10 m existing riparian zone vegetation; and (3) 10 m grass buffer draining into 20 m maidencane (*Panicum hematomon* L. Pers.). The effects of the wastewater on surface runoff and groundwater quality were evaluated by transects of surface runoff collectors, suction lysimeters, and shallow groundwater wells which extended from the top to the bottom of each plot. Data analyses showed differences due to wastewater application rate and distance downslope from the wastewater application pipe. Nitrogen concentrations increased over time at the top ends of the plots but showed little increase at the bottom ends of the plots. The same pattern was observed with P, although soluble orthophosphate concentrations at the bottom ends of the plots was higher than anticipated, indicating that soluble orthophosphate will leach with time in sandy Coastal Plain soils.

REMM will be used to estimate the N removal capacity of riparian buffers in Coastal Plain areas of the Neuse River in North Carolina in conjunction with USEPA and North Carolina State University. The model will be used as parameterized for Coastal Plain conditions (Inamdar et al., 1999a; 1999b) to estimate the effects of buffers on loadings estimated for typical agricultural areas of the Neuse Basin using the loading models HSPF and GLEAMS.

Small watersheds in the Coastal Plain where REMM has been tested (Inamdar et al., 1999a; 1999b) will be used to test the linkages between the AnnAGNPS model and REMM. AnnAGNPS is part of a suite of models (AGNPS 2001) developed by ARS and cooperators to model various water quality functions in small; agricultural watersheds (Bingner, et al, 2001; Bosch et al., 1998). REMM will be used as the basis for integrating riparian functions into the AGNPS 2001 suite of models. Data on shallow groundwater, streamflow stage, and streamflow water quality has been collected at the Gibbs Farm site since 1997 (Figure 4). Streamflow water quality sampling on two streams and groundwater sampling in the watershed will be used in testing the model linkages. The area forms two small watersheds drained by two second order streams. Each has a drainage area of 140-160 acres. Both streams drain into a farm pond just below the study area after passing through a wide mature riparian forest. The upstream areas of the small watersheds have little riparian forest in place. Field surface runoff data from an earlier record period is available from the site (Sheridan et al, 1999). Each stream was instrumented at upstream and downstream sites (four sites total) in 1997. Both upstream sites are at culverts. Both downstream sites have temporary wooden control structures (broad-crested v-notch weirs). Each of the four stations has instrumentation to measure water depth (with a pressure transducer), water temperature, specific conductivity, and a composite water sampler (ISCO autosampler). Autosamplers, pressure

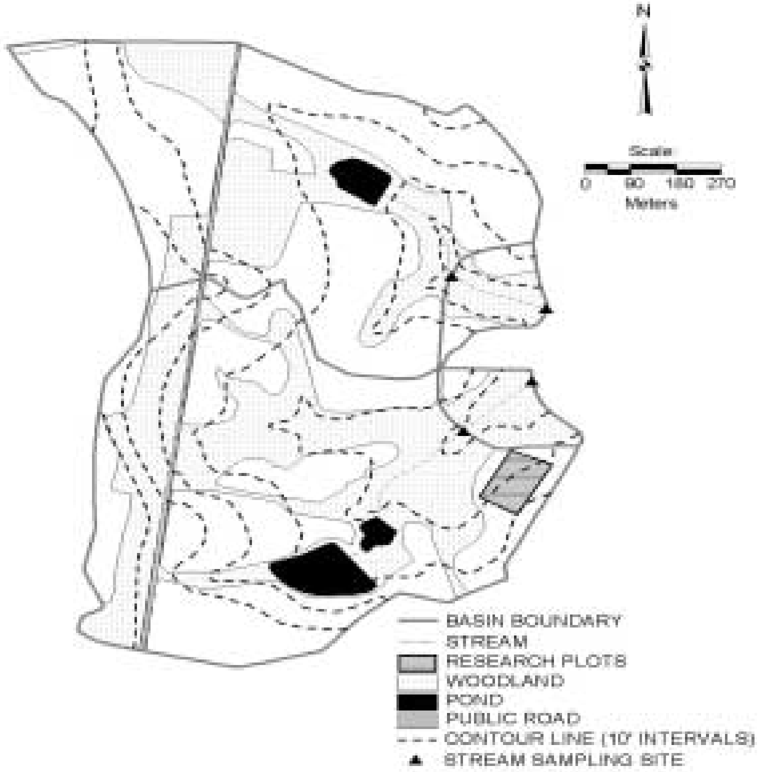

Figure 4. Gibbs Farm Watershed showing location of Gibbs Farm Plots and stream sampling sites.

transducers, and temperature conductivity probes will be connected to and/or controlled by CR-10 data loggers. Flow proportional composite water samples from the small watersheds are analyzed for N and P species and total suspended solids. Data from the Gibbs Farm watersheds will be used to test the linkage of REMM and AnnAGNPS by comparing AnnAGNPS simulations to observed data. AnnAGNPs will first be run without riparian components and compared to observed data. Next, the model will be run with riparian components based on REMM and compared to observed data. Differences in the outputs will be quantified and related to existing information on riparian fuctions at the Gibbs Farm site (Lowrance et al., 2000, Sheridan et al., 1999). Differences in calibration procedures for AnnAGNPS will be documented and added to the suite of tools available in AGNPS 2001. The test of the model linkages will be used to guide implementation of a version of AnnAGNPs with capability to model the effects of riparian systems on water, chemical, and sediment transport in agricultural watersheds. **Model testing data will be archived at SEWRL.**

Contingencies - Test of the model linkages may indicate needs for new data collection atr the Gibs Farm watershed experimental site. These new field data will be collected as needed. If new field data are needed for model tesing at the other sites, collaborators will be responsible for collection of the new field data.

Collaborations - Ali Sadeghi, Steve Griffith, Tom Moorman, Carlos Alonso, Ron Bingner, Ken

Stone, Pat Hunt, Andrew Sharpley, **Martin Shipitalo** (all ARS). Greg Ruark, National Agroforestry Center. In addition to the ARS collaborations, there are currently at least 6 university based research groups that need SEWRL cooperation to help with testing REMM. Outside funds are being sought to test REMM with university collaborators in the Midwest in conjunction with a North Central Regional Project and with other cooperators in other regions. These tests will increase the scope where REMM can be applied to help design riparian buffers for water quality improvement and quantify the actual load reduction associated with riparian buffers installed under conservation programs. Outside funds are being sought to enhance existing tools for application of REMM via Microsoft Access and STELLA based user interfaces.

Objective 3 - Hypothesis: Estimates of pesticide exposure in aquatic ecosystems will be more accurate if existing transport models are combined with a model of pesticide transport in buffer ecosystems. (Wauchope, Potter, Truman, Bosch, Lowrance)

Enhancing and evaluating the role of riparian buffers in reducing pesticide transport is important to the proper evaluation of pesticide exposures. Existing pesticide transport algorithms will be incorporated into REMM to simulate the transport of pesticides in conservation buffers. REMM will be linked with the USEPA fate and transport models PRZM-EXAMS to provide a more complete model of the interface between agricultural land and buffer systems that can be used in pesticide risk assessments. Data from plot experiments will be used to test the pesticide transport components added to REMM. We will add algorithms to the REMM model that will utilize the environment supplied by the model (soil and plant characteristics, weather, hydrologic events) and combine them with organic pollutant characteristics (degradation kinetics, solubility, volatility, soil sorptivity) to describe and predict the transport and dissipation of the organics within a riparian buffer system. The level of complexity of the algorithms will be appropriate to the level of complexity of the REMM model: daily time step, single-valued sorption coefficient, two-phase degradation kinetics, simplified volatilization. We will include temperature and soil moisture effects on chemical persistence, in keeping with current practice (FOCUS, 2000). The modified REMM will be applied to watershed water quality projects of the SEWRL including integration with larger-scale watershed models such as AnnAGNPS. It will also be coupled to the field-scale edge-of-field models GLEAMS and PRZM. In the latter case we will work in cooperation with USEPA/OPP/EFED to develop REMM as a second-tier model for pesticide re-evaluation under FQPA as well as new pesticide risk assessment under FIFRA. Pesticide loadings from the coupled models will be compared to the uncoupled edge-of-field models and differences related to the known effects of buffers and compared to data from completed plot experiments (Lowrance et al., 1997b). Ongoing buffer system experiments described above (Objective 1) will be used to test the pesticide transport components added to REMM.

Contingencies – If necessary, ongoing buffer experiments will be modified to provide appropriate test data for REMM. The procedures for testing REMM with the EPA models will be modified based on test results and the structure of REMM will be changed if necessary to accommodate testing needs.

Collaborations - Ron Parker (USEPA-OPP), Steve McCutcheon, Christina Wright (USEPA-ORD),. Because of the need to provide technology of direct usefulness to USEPA we will maintain close contacts with scientists in appropriate USEPA divisions involved with both pesticide fate modeling and TMDL modeling.

Objective 4 - Hypothesis: The relative effects of different types of water quality BMPs (on-field and off-field) can be determined more accurately if they are evaluated concurrently as part of farm and watershed scale water quality improvement programs. (Lowrance, Truman, Hubbard).

Very little is known about the actual stream water quality effects of the application of water quality Best Management Practices in agriculture. One reason for the lack of knowledge of the effects of BMPs on streams is the inabilitiy to do landscape level or farm scale manipulations as part of a research program. The Nonpoint Source Pollution Program (319 Program) funded by USEPA in most states is one way to demonstrate and monitor the effects of BMPs applied at a larger scale in order to improve water quality.

We will compare specific concentration and load reduction data from plot experiments, field experiments, farm size watersheds, and modeling studies to determine the relative impacts of BMPs and conservation buffers. Data from ongoing water quality sampling in farms and watersheds of both Little River Watershed and Piscola Creek Watershed (tributaries of the Withlacooche R.) will be used to examine specific field and farm scale practices related to manure management, chemical management, and buffer systems. Two riparian buffers will be installed on commercial farms and water quality impacts will be monitored in conjunction with an ongoing USEPA 319 project.

SEWRL scientists will cooperate with scientists from the University of Georgia to determine the water quality effects of BMPs in two 319 projects. One project, focused on animal waste management will be done on the Animal & Dairy Science (ADS) Farm watershed, part of the Coastal Plain Experiment Station. The ADS watershed is about 400 acres, located in the headwaters of a long term monitoring site on a tributary of Little River (Station O). Water quality changes at the outlet of the ADS watershed will be monitored as changes are made in waste management and animal management on the watershed. N and P species, dissolved oxygen, conductivity, pH, and fecal coliform and fecal strep will be monitored at the watershed outlet. These data will be compared to an earlier unpublished data set and to ongoing measurements of the same parameters approximately two km downstream at Station O, a permanent watershed gauging site operated by SEWRL.

On a second 319 project, SEWRL scientists will cooperate with University of Georgia scientists to estimate the water quality effects of two large scale riparian buffer restoration projects done as part of a state-wide Georgia Buffer Initiative. Upstream and downstream sampling sites will be established on two buffer demonstration projects. The first, on a major tributary of TyTy Creek (Kelly Farm, Worth Co, GA) will involve restoration of approximately 25 ha of riparian forest in an abandoned pasture. The second, along a large field ditch (Tony Smith Farm, Early Co., GA) will provide seasonal wetlands through the use of removable control structures on the ditch. In both cases, we will monitor water quality before and after the restoration and at upstream and downstream sites. N and P species, dissolved oxygen, conductivity, pH, and fecal coliform and fecal strep will be monitored at the watershed outlets and downstream from the actual BM<P implementation. Before and after data will be compared for concentrations of contaminants or water quality indicators.

Contingencies – Research done on actual farms in conjunction with demonstration projects is subject to changes in farm management, landowner objectives, and ownership. Our monitoring of these demonstration projects, if done on priovate property will be done after execution of contracts for demonstration project BMPs. Adjustments of monitoring will be done in conjunction with landowners and demonstration project managers as needed.

Collaborations - David Radcliffe, Larry Newton, George Vellidis (U. of Georgia). Evaluating the effects of field and farm scale BMPs on a watershed scale requires collaboration with projects such as the 319 demonstration projects. These projects typically require university or non-federal participation because of the ned for non-federal matching funds.

Objective 5 - **Hypothesis: Ancillary benefits of water quality BMPs will be greater for buffer ecosystem technology when buffers are integrated with whole farm and watershed management programs for multiple purposes**. **(Lowrance, Strickland)**

Agroecosystem conservation programs may focus on water quality, soil erosion, and water supply but can simultaneously provide ancillary benefits such as carbon sequestration, wildlife habitat, biological diversity, recreation, and other uses that society demands. In the southeastern U.S., the USDA Conservation Reserve Programs to establish streamside buffers and to restore long-leaf pine ecosystems will have multiple ancillary benefits. Because of two decades of research on riparian ecosystems in the headwaters of the Suwannee River Basin, a large data set is available to provide a more detailed estimate of carbon storage in riparian buffers. We will use existing data on carbon storage and transport in Coastal Plain watersheds to estimate C sequestration in conservation buffers in the headwaters of the Suwannee River Basin. Data on dissolved organic carbon (DOC) in streamflow, a major C transport mechanism in these blackwater streams is available from the late 1970s to the present. Studies from the early 1980s on sediment deposition, aboveground and below ground net primary productivity, and soil carbon are also available. More recent studies have examined soil carbon, root biomass, and soil microbial biomass for a variety of riparian systems in the watershed and adjacent landscapes. Techniques used in Little River Watershed riparian system N and P budgets will be used to develop carbon budgets for the same riparian ecosystems (Lowrance et al., 1985). **Error terms for each pool or flux will be estimated and the overall error for the mass balances will be estimated based on the individual error terms.** The synthesis conducted using the existing data will provide multiple benefits in understanding the potential role of riparian systems in carbon storage and sequestration. Among the expected outcomes are: 1) more complete understanding of the carbon pools and waterborne inputs/outputs for riparian ecosystems in the Southeastern Coastal Plain; 2) more complete understanding of the effects of managed riparian systems on net carbon storage and transport in agricultural watersheds; 3) analysis of gaps in data to determine effects of riparian ecosystems on carbon fluxes; 4) application of watershed and riparian zone nutrient budgeting techniques to carbon budgets.

Contingency: Part of this objective is to identify gaps in knowledge about multiple benefits of buffer ecosystems. Identification of these gaps will lead to other possible avenus of analysis to estavlish these ancillary benefits.

Collaborations - Greg Ruark (National Agroforestry Center)

Water Quality Research and Monitoring Techniques

Water quality research and monitoring is central to all of the field experimental components of this project. The water quality research and monitoring is done with a common set of techniques based on standard and/or published methods and standard Quality Assurance procedures. All water quality monitoring will be done in accordance with a Quality Assurance/Quality Control Plan (QA/QCP) developed by the scientists and technical staff of SEWRL. The QA/QCP covers standard operating procedures for a wide range of practices including sample collection, sample storage, sample processing, equipment blanks, field blanks, field spikes, matrix spikes, analytical precision, and data handling. Prior to implementation of this CRIS project, the scientists in charge of each objective of the project that requires water quality monitoring will document all procedures being used as part of the standard operating procedures (SOPs) of the QA/QCP. In most cases the SOPs are shared among all water quality research projects but in some cases special procedures will be used that will be documented in the QA/QCP.

The water quality sampling is of three general types – fixed time interval sampling (typically done for groundwater, although groundwater sampling at Homestead site will be tied to leaching events); runoff event sampling; and flow proportional sampling. Runoff event sampling is typically done on small plot experiments when rainfall induces direct surface runoff. SEWRL scientists have developed a number of techniques to use estimates of flows at open channel gauging sites to take flow proportional samples of streamflow. These techniques, deployed at a number of small stream sampling sites in the Suwannee River basin are provide a composite sample with higher flows represented by higher volumes of sample collected for the composite.

All streamflow samples are analyzed for suspended solids based on the material that does not pass a 0.45-micron type A/E glass fiber filter. The filtrates from the sediment analysis are analyzed for dissolved nitrate+nitrite ($NO_3^-N + NO_2^-N$), ammonium (NH_4^+-N), total kjeldahl N (TKN), ortho phosphate (ortho-P), and total P (TP) by standard methods (APHA, 1989). Sediment borne TP and TKN are determined by difference between the bulk sample and the filtered sample. Chemical analyses are done using two Flow Injection Analyzers (Lachat Analytical, Mequon, WI) with Lachat methods 10-107-06-2-D (TKN), 10-115-01-1-C (TP), 10-107-06-2-A (NH4$^+$-N), 10-107-04-1-A (NO_3^--N), and 10-115-01-1-A (SRP). Other water quality parameters including dissolved oxygen, conductivity, temperature, field ammonium, and redox potential are measured using a YSI multi-prode data sonde in the field.

Pesticide analyses are carried out using a multi-residue approach developed by Potter et al (2000). The method is based on Sollid Phase Extraction with a divinylbenzene-n-vinylpyrrolidine (DVBVP) copolymer solid phase. Gas chromatography with thermionic nitrogen/phosphorus detection (GC-NPD), GC-mass spectrometry (GC-MS), and HPLC-diode array detection (DAD)-MS are used to analyze extracts. The procedure was orginally developed for a suite of agrichemicals used on cotton. It included the non-polar organophosphates, tribufos and methylparathion, the phenyl-ureas, diuron and thidiazuron, and moderately polar herbicide, dimethipin. Unpublished spike recoveries studies in soil and water have confirmed that this analytical approach is highly effective in the analysis of a wide range of other active ingredients and degradates. This includes atrazine, and its principal environmental degradation products, desethylatrazine, desisopropylatrazine and hydroxyatrazine; the fungicide chlorothalonil and its main degradate, 4-hydroxychlorothanonil; the organo-phosphate, chlorpyrifos and its degradate, trichloropyridinol; the herbicide, fluometuron and its degradates, desmethyl fluometuron and trifluoromethylaniline and the herbicide, pendimethalin.

On-going efforts include evaluation of the procedure for other active ingredients of regional interest. This follows the QA/QC protocols described above. Quantitative recoveries of all target compounds in monitoring and research programs are verified by matrix-spikes before they incorporated into SOP's. To address the need for data which will permit comprehensive human and ecological risk assessments of pesticide exposure due to many common use chemicals, our laboratory has developed a sensitive multiresidue procedure required for the analysis of residues of three cotton defoliant chemicals, tribufos, thidiazuron, and dimethipin, in water. The rationale for the multiresidue approach is that defoliant chemicals are often applied in tank-mix combinations. Thus one or more active ingredients have the potential to occur in water samples following a single defoliation treatment. Two other compounds, diuron and methyl parathion, were included in the target compound list.Work which lead to development of a sensitive, method detection limit (MDL) < 0.1 g L-1, multiresidue method for tribufos, methyl parathion, dimethipin, diuron, and thidiazuron dissolved in water is described in Potter et al., 2000. The suite of target compounds required the use of both GC and HPLC techniques. During GC analysis, the phenyl-urea compounds, diuron and thidiazuron, decompose in the heated GC inlet. Tribufos does not exhibit significant absorption of the wavelength range 200-600 nm and is thus not detectable by photodiode array. The method has been applied to a series of surface runoff and tile drainage samples collected from a cotton research plot after defoliation with a tank mixture of thidiazuron and dimethipin. It was also applied to surface runoff samples collected in a commercial cotton field which had been defoliated with tribufos. Concurrent analysis of quality control samples has indicated that the data were accurate and precise.

Physical and Human Resources

Category I scientists are listed in the front of proposal. In addition, appropriate levels of support are available from three Category 3 Scientists (L. Hargett, L. Marti, and R. Williams). Other technical support for field, laboratory, and computer modeling activities are available from existing staff. All necessary laboratory support is provided by the Analytical Chemistry Laboratories of SEWRL. The SEWRL laboratories are equipped with modern analytical equipment including liquid chromatograph/mass spectrometer (LC/MS); gas chromatograph/mass spectrometer (GC/MS); high pressure liquid chromatographs (HPLC,2); gas chromoatographs (GC,3); ion chromatograph (IC); flow injection analyzers (FIA, 2); dissolved organic carbon analyzer (DOC); and carbon & nitrogen analyzer (CAN). All associated sample preparation and storage equipment are available. All necessary field sampling equipment are available. Other field and laboratory equipoment and support personnel are shared with University of Georgia cooperators including Dr. George Vellidis (Biological and Agricultural Engineering); Dr. Craig Bednarz (Crop and Soil Science); and Dr. Larry Newton (Animal and Dairy Science).

Milestones and Expected Outcomes

Milestone Time Line

Objective	Months of Study			
	15	30	45	60
1. BMP Experiments	Continue field data collection and sample analysis	Continue field data collection and sample analysis	Data synthesis	Studies complete, final publications complete
2. REMM Testing	Preliminary testing at other ARS sites with existing data	Testing for liquid manure site complete, testing at all ARS sites underway	Modify model and paramters based on other ARS sites	Studies complete, final publications complete
3. Pesticide Modeling	Modification of REMM based on documented existing pesticide algorithms	Validation of revised model complete	Testing of pesticide components with SEWRL data	Studies complete, final publications complete
4. Farm scale BMPs	Establish monitoring of ADS watershed, begin sample collection and analysis	Continue monitoring of ADS watershed, establish monitoring of individual BMPs	Continued monitoring, data synthesis	Studies complete, final publications complete
5. Ancillary Benefits	Carbon budget systhesis complete	Carbon budget synthesis published, proposals submitted for outside funding to expand program	Contingent on increased funding	Contingent on increased funding

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Past Accomplishments of R. Richard Lowrance (Lead Scientist)

Education:

1975	University of South Alabama, B.S. Biology
1981	University of Georgia, Ecology, Ph.D.

Experience:

1982- 1983	Post-Doctoral Associate , Institute of Ecology, Univ. of Georgia,
1983- Present	Ecologist, USDA-ARS, Southeast Watershed Research Lab., Tifton, GA

Accomplishments:

Dr Lowrance conceived, directed, and conducted studies that discovered that nitrate removal in Coastal Plain riparian forests depended on woody vegetation bringing nitrogen to the surface in litterfall and root sloughing. Determined that denitrification in surface soils was limited by nitrate availability in the high organic carbon riparian soils. Subsurface samples, taken from the top of the saturated zone, showed no significant response to either nitrate or carbon additions for either soil. These results showed that in these riparian forests, direct denitrification from the shallow aquifer was not likely to be important due to low denitrification potential. This low potential was due to either low numbers of denitrifying organisms or low activity of the organisms or both. Furthermore, the results indicate that denitrification in riparian areas requires the high organic matter surface soils provided by forest vegetation.

Dr. Lowrance led two team efforts to determine the effectiveness and sustainability of riparian buffer systems on a regional scale. At the invitation of the Chesapeake Bay Program and USDA-Forest Service, Dr. Lowrance led a team of scientists in a research synthesis and best professional judgement process to determine where riparian forest buffers could best be used to control nonpoint source pollution in the Chesapeake Bay Watershed. The synthesis was based on understanding of the hydrology, nutrient cycling, and nonpoint source pollution problems of physiographic subregions of the watershed. The scientific team produced a series of summary tables and best professional judgements which provide estimates of the nonpoint source pollution control capacity of riparian buffers in each of the physiographic provinces of the Chesapeake Bay Watershed.

Dr. Lowrance leads an interdisciplinary research team in the development of the Riparian Ecosystem Management Model (REMM). REMM is a simulation model designed to provide both a management/design tool and a research tool to examine the water quality functions of riparian buffer systems of various sizes, soil, vegetation, and adjacent land uses. REMM simulates ecosystem processes such as plant growth and nutrient cycling and water quality parameters such as nutrients and sediment in surface runoff and nutrients and dissolved organics in shallow groundwater. REMM provides the only tool for simulation of the water quality impacts of riparian buffer systems. Additionally, REMM can be used to simulate a variety of non-riparian edge-of-field buffer systems.

Publications: Peer reviewed in past 5 years and other relevant in past 10 years [R. Richard Lowrance]:

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Past Accomplishments of Thomas L. Potter

Education:
1990 University of Massachusetts, Environmental Chemistry, PhD

Experience:

1980 1984	Senior Chemist, Maine Dept. Environmental Protection, Augusta, ME
1980 1985	Research Chemist, Univ. of Mass., Amherst, MA.
1998-Present	Research Chemist, USDA-ARS, Southeast Watershed Research Lab., Tifton, GA

Accomplishments:

Developed trace residue analysis methods for pesticides and other contaminants and natural products in environmental matrices

Implemented environmental fate studies of anthropogenic pollutants including pesticides, petroleum, trace metals, and chemicals which have been implicated as environmental estrogens. Measured long the range transport and deposition of pesticides and trace metals at remote sites in Northeastern USA and evaluated biormediation of soil contaminated by petroleum during the 1991 Gulf War.

Evaluated human and ecological risks of environmental releases of toxic chemicals and pesticides.

Provided complete mass spectral characterization of environmental degradation products of alachlor and chlorothalonil, two of the world's highest volume use pesticide.

Determined rate of degradation of alkyl-phenol ethoxylate surfactants and complex petroleum mixtures in estuarine waters and sediments, identified products that formed and their rate of formation and decay. Showed that the principal environmental breakdown products of the surfactants were carboxylates rather than alkylphenols. Work lead to re-evaluation of the risks of use of alklphenol ethoxylate surfactants using bioassays . Work demonstrated that under aerobic conditions estrogenically active products are not formed.

Served on U.S. EPA FIFRA and Food Quality Protection Act Science Advisory Panels. Provided guidance to the agency on ecological risk assessment and watershed scale assessment and modeling of pesticide residues in surface waters.

Most significant Publications in last 10 years [Thomas L. Potter]:

Potter, T.L., Wauchope, R.D.; Culbreath, A.K., 2001. Accumulation and decay of chlorothalonil and selected metabolites in surface soil following foliar application to peanuts. *Environ. Sci. Tech.* (in press)

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Salama, A.A., Mohamed, M.; Duval, B.; Potter, T.L.; Levin, R. 1998. PCB concentration in raw and cooked North Atlantic Bluefish (Pomatomus saltatrix) fillets. *J. Agric. Food Chem.* 46:1359-1362.

Mohamed, M.A.M; Osman, M.A.; Potter, T.L.; Levin, R.E. 1998. Lead and cadmium in Nile River water and finished drinking water in greater Cairo, Egypt. Environ. Intl. 24, 767-772.

Calabrese, E.A.; Baldwin, L.A., Potter, T.L.; Kostecki, P.T. 1997. A toxicologically-based weight-of-evidence methodolgy for the relative ranking of chemicals for endocrine disrupting potential. *Reg. Tox. Pharm.* 26:36-40.

Potter, T.L. Analysis of petroleum contaminated water by GC-FID with direct aqueous injection. *Ground. Mon. & Remed*. 16, 157-162.

Potter, T.L., Carpenter, T.L. 1995. Occurrence of alachlor environmental degradation products in ground water. *Environ. Sci. Tech.* 29:1557-1563.

Past Accomplishments of David D. Bosch

Education:

University of Arizona, Hydrology, PhD

Experience:

1982-1986	Research Assistant, U.S. Department of Agriculture, Agricultural Research Service, Morris, MN
1986-1990	Graduate Research Associate, U.S. Department of Agriculture, Agricultural Research Service, Southwest Watershed Research Laboratory, Tucson, AZ.
1990 – Present	Research Hydrologist, USDA-ARS, Southeast Watershed Research Laboratory., Tifton, GA

Accomplishments:

AGNPS model. Co-developer of the AGNPS water quality model used by public service agencies as a tool for prioritizing watersheds according to non-point source pollution level. The model is used throughout the world to examine watershed management alternatives and their impact on flow and transport.

Shallow groundwater characterization. Characterized the interactions between shallow groundwater and low-gradient streams of the Southeastern U.S. This work is important for understanding the mechanics of riparian buffers and for transferring this information into management alternatives .

REMM model. Co-developer of the Riparian Ecosystem Management Model (REMM) for assessing the impact of riparian zone management on stream and groundwater quality. REMM is the first process based model to describe flow and transport through riparian buffer areas.

Rainfall Variability. Developed methods for quantifying the seasonal and spatial variability of rainstorms in the Southeastern Coastal Plain region of the U.S. This information is important for agricultural management in this area.

Most significant Publications in last 10 years [David D. Bosch]:

BOSCH, D.D. 1991. Error associated with point observations of matric potential in heterogeneous soil profiles. *Trans. Am. Soc. Agr. Eng.* 34:2427-2436.

BOSCH, D.D., R.K. HUBBARD, L.T. WEST, and R.R. LOWRANCE. 1994. Subsurface flow patterns in a riparian buffer system. *Trans. Am. Soc. Agr. Eng.* 37:1783-1790.

BOSCH, D.D., J.M. SHERIDAN, and R.R. LOWRANCE. 1996. Hydraulic gradients and flow rates of a shallow coastal plain aquifer in a forested riparian buffer. Trans. Am. Soc. Agr. Eng. 39:865-871.

BOSCH, D.D., and F.M. DAVIS. 1997. Methods for calculating flow from observed or simulated hydraulic head data. *Advances in Engineering Software.* 28:267-272

. LOWRANCE, R.R., G. VELLIDIS, R.D. WAUCHOPE, P. GAY, and D.D. BOSCH. 1997. Herbicide transport in a managed riparian forest buffer system. *Trans. Am. Soc. Agr, Eng.* 40:1047-1057.

BOSCH, D.D., 1997. Constant head permeameter formula dependence on alpha parameter. *Trans. Am. Soc. Agr. Eng.* 40:1377-1379.

BOSCH, D.D., and L.T. WEST. 1998. Hydraulic conductivity variability for two sandy soils. *Soil Sci. Soc. Am. J.* 62:90-98.

SHERIDAN, J.M., R.R. LOWRANCE, and D.D.BOSCH. 1999. Management effects on runoff and sediment transport in riparian forest buffers. *Trans. Am. Soc. Agr. Eng.* 42:55-64.

BOSCH, D.D., R.K. HUBBARD, R.A. LEONARD, and D.W. HICKS. 1999. Tracer studies of subsurface flow patterns in a sandy loam profile. *Trans. Am. Soc. Agr. Eng.* 42:337-349.

BOSCH, D.D., J.M. SHERIDAN, AND F.M. DAVIS. 1999. Rainfall characteristics and spatial correlation for the Georgia Coastal Plain. *Trans. Am. Soc. Agr. Eng.* 42:1637-1644.

INAMDAR, S.P., J.M. SHERIDAN, D.D. BOSCH, R.G. WILLIAMS, R.R. LOWRANCE, L.S. ALTIER, AND D.L. THOMAS. 1999. Riparian ecosystem management model (REMM): I. Hydrology Evaluation. *Trans. Am. Soc. Agr. Eng.* 42:1679-1689.

LOWRANCE, R.R., L.S. ALTIER, R.G. WILLIAMS, S.P. INAMDAR, J.M. SHERIDAN, D.D. BOSCH, R.K. HUBBARD, and D.L. THOMAS. 1999. REMM: The riparian ecosystem management model. *J. Soil and Water Cons.* 55:27-24.

SHAW, J.N., L.T. WEST, D.E. RADCLIFFE, and D.D. BOSCH. 2000. Preferential flow and pedotransfer functions for transport properties in sandy kandiudults. *Soil Sci. Soc. of Am. J.* 64(2):670-678.

TUCKER, M.A., D.L. THOMAS, D.D. BOSCH, and G. VELLIDIS. 2000. GIS-based coupling of GLEAMS and REMM Hydrology: 2) Field test results. *Trans. Am. Soc. Agr. Eng*. 43(6): 1535-1544.

TUCKER, M.A., D.L. THOMAS, D.D. BOSCH, and G. VELLIDIS. 2000. GIS-based coupling of GLEAMS and REMM hydrology: 1) Development and sensitivity. *Trans. Am. Soc. Agr. Eng.* 43(6): 1525-1534.

BOSCH, D.D., C.C. TRUMAN, and R.A. LEONARD. 2000. Atrazine and Carbofuran transport through the vadose zone in the Claiborne Aquifer recharge area. *Trans. Am. Soc. Agr. Eng.* 43(6):1609-1620.

SHAW, J.N., D.D. BOSCH, L.T. WEST, C.C. TRUMAN and D.E. RADCLIFFE. 2001. Lateral flow in loamy to sandy kandiudults of the upper coastal plain of Georgia (USA). *Geoderma*. 99:1-25.

Past Accomplishments of Timothy C. Strickland, RL

Education:
1985 Univ. of Georgia, Microbiology, PhD

Experience:

1985- 1987	Post-Doc, Dept. of Forest Science, Oregon State Univ., Corvallis, OR
1987-1992	Project Scientist, USEPA, Environmental Research Lab., Corvallis, OR
1992-1997	Program Director, USDA-NRI Competitive Grants Program, CSREES, Washington, DC
1994-2000	Special Assistant for Science and Technology to the Under Secretary for Research, Education, and Economics (USDA), Washington, DC
1999-2000	National Program Leader (Water Quality), USDA-CSREES, Washington, DC
2000-Present	Research Leader, USDA-ARS, Southeast Watershed Research Lab., Tifton, GA

Accomplishments:
Developed laboratory procedures to determine the importance of biological processes in mitigating the potential negative impacts of acidic sulfate deposition in the U.S. The basic premise of this research was that soil inorganic chemical processes do not constitute the sum total of buffering capacity in soils exposed to sulfate from atmospheric deposition and that microbial communities are responsible for the buffering potential in forest soils. Radioisotopic procedures were used to determine that active microbiological process work in concert with soil chemical adsorption to result in a large soil organic-S pool.

Developed methodologies to evaluate the relative importance of soil physical structure in the incorporation of added nitrogen into active and passive pools of soil OM. Central theory relating to the ageing of soil OC attributed the decomposition recalcitrance of "old" soil OC solely to complex poly-aromatic chemical structures associated with humic and fulvic acids. This research culminated in the finding that newly introduced nitrogen is rapidly incorporated into "recalcitrant" OM. Subsequent mineralization studies indicated that at least some of this material was "physically protected" from decomposition by its relationship to inorganic soil particles within micro-aggregates (<250 micrometers in diameter).

Lead a team effort that developed a procedure to establish critical loads for atmospheric deposition of sulfur and nitrogen to sensitive ecosystems in the northeastern United States. This project was successful in demonstrating that policy-relevant information can be presented in a scientifically-defensible manner and that ecosystem specific regulations can reasonably be established using the current state of scientific knowledge.

Collaborated on two teams defining the research and development priorities for the Clinton Administration: 1) developed an integrated set of ecosystem R&D priorities and objectives that reflect to common goals of multiple federal agencies; and 2) developed a strategy to construct a national framework for integration and coordination of environmental monitoring and related research through collaboration and building upon existing networks and programs.

Most significant Publications in last 10 years [Timothy C. Strickland]:

STRICKLAND, T.C., P. SOLLINS, N. RUDD, and D.S. SCHIMEL. 1992. Rapid stabilization and mobilization of 15N in forest and range soils. *Soil Biol. Biochem.* 24:849-855.

STRICKLAND, T.C., G. R. HOLDREN, P.L. RINGOLD, D. BERNARD, K. SMYTHE, and W. FALLON. 1993. A national critical loads framework for atmospheric deposition effects assessment: I. Method summary. *Environ. Management.* 17:329-334.

HUNSAKER, C.T., R. GRAHAM, P.L. RINGOLD, G. R. HOLDREN, and T.C. STRICKLAND. 1993. A national critical loads framework for atmospheric deposition effects assessment: II. Defining regulatory endpoints, indicators, and functional subregions. *Environ. Management.* 17:335-341.

HICKS, B.B., R. McMILLEN, R.S. TURNER, G. R. HOLDREN, and T.C. STRICKLAND. 1993. A national critical loads framework for atmospheric deposition effects assessment: III. Deposition characterization. *Environ. Management.* 17:343-353.

HOLDREN, G.R., D. MARMOREK, C.T. HUNSAKER, D. BERNARD, C.T. DRISCOLL, R.S. TURNER, and T.C. STRICKLAND. 1993. A national critical loads framework for atmospheric deposition effects assessment: IV. Model selection, application, and critical loads mapping. *Environ. Management*. 17:355-363.

HOLDREN, G.R., T.C. STRICKLAND, P.W. SHAFFER, P.F. RYAN, P.L. RINGOLD, and R.S. TURNER. 1993. Sensitivity of critical load estimates for surface waters to model selection and regionalization schemes. *J. Environ. Qual.* 22:279-289.

ROSENBAUM, B.J., T.C. STRICKLAND, and M.K. McDOWELL. 1994. Critical levels of ozone, sulfur dioxide, and nitrogen dioxide for crops, forests, and natural vegetation in the United States. *Water, Air, and Soil Pollution.* 74:307-319.

MULTIPLE AUTHORS. 1995. Building a Scientific Basis to Ensure the Vitality and Productivity of U.S. Ecosystems. National Science and Technology Council Special Report. White House Publications Archives. http://www.cop.noaa.gov/pubs/ewgfn2.txt

MULTIPLE AUTHORS. 1997. Integrating the Nation’s Environmental Monitoring & Research Networks & Programs – A Proposed Framework. National Science and Technology Council Special Report. White House Publications Archives. http://www.epa.gov/cludygxb/Pubs/framewrk.wp5

Norton, S. J. Kahl, I. Fernandez, T. Haines, L. Rustad, S. Nodvin, J. Scofield, T. Strickland, H. Erickson, P. Wigington, J. Lee Jr. 1999. The Bear Brook watershed, Maine (BBWM), USA. Environmental Monitoring and Assessment 55: 7-51.

Past Accomplishments of Clinton C. Truman

Education:

Purdue University, Soil Physics, PhD

Experience:

1990—1991	Post-Doc, USDA-ARS, Southeast Watershed Research Lab., Tifton, GA
1991-Present	Soil Scientist, USDA-ARS, Southeast Watershed Research Lab., Tifton, GA

Accomplishments:

Ground-penetrating Radar. Developed and adapted ground-penetrating radar as an efficient, cost-effective tool for nondestructively describing spatial variability of selected subsurface soil features.

Erosion Processes. Identified and characterized parameters affecting erosion processes controlling sediment delivery, thus improving current simulation model technologies. Provide C-factors for peanuts grown in the Coastal Plain soil province.

Pesticide Fate and Transport. Described and quantified effects of intrinsic soil, pesticide, and rainfall characteristics on pesticide fate and transport, thus improving the understanding of how pesticides are transported to and by surface and subsurface flow.

Phosphorus Transport. Continuous application of commercial fertilizer and/or poultry litter can cause build up of P (STP) in the 0-1 cm and 0-15 cm soil layer within 2-5 yrs. Soluble P (SP) and sediment-transported P (SedP) losses tend to be greater from poultry litter applications than from commercial fertilizer applications. During the growing season, SP losses were greatest 1 day after fertilization, while percent of total P transported from Coastal Plain fields as SedP increased during the growing season. Majority of P lost during any given year is in the SedP form. Variation in annual P losses can be explained by the occurrence of major storms near the day of fertilization.

Event-based Models. Developed and altered event-based models for improved risk assessment technologies and ag-managemnent decision aids, thus extending the ability to simulate agrichemical contamination of sensitive water bodies. Used 50-yr GLEAMS simulations to show that SP and SedP losses from poultry litter applications were 0.2-0.4 and 25-29%, respectively. Created Gumbel extreme-value (probability) plots for poultry litter applications to determine “recurrence intervals” for the average time within which a value/loss of specific magnitude will be equaled or exceeded.

Most significant Publications in last 10 years [Clinton C. Truman]:

TRUMAN, C.C., and J.M. BRADFORD. 1990. Effect of antecedent soil moisture on splash detachment under simulated rainfall. *Soil Sci.* 150:787-798.

TRUMAN, C.C., and R.A. LEONARD. 1991. Effects of pesticide, soil, and rainfall characteristics on potential pesticide loss by percolation – A GLEAMS simulation. *Trans. ASAE.* 34:2461-2468.TRUMAN, C.C., L.E. ASMUSSEN, and H.D. ALLISON. 1991. Ground-penetrating radar: A tool for mapping reservoirs and lakes. *J. Soil and Water Cons.* 46:370-373.LEONARD, R.A., C.C. TRUMAN, W.G. KNISEL, and F.M. DAVIS. 1992. Pesticide runoff simulations: Long-term annual means vs. event extremes? *Weed Technology.* 6:725-730.

TRUMAN, C.C., and J.M. BRADFORD. 1993. Relationships between rainfall intensity and the interrill soil loss-slope steepness ratio as affected by antecedent water content. *Soil Sci.* 156:405-413.

TRUMAN, C.C., G.J. GASCHO, J.G. DAVIS-CARTER, and R.D. WAUCHOPE. 1993. Seasonal phosphorus losses in runoff from a Coastal Plain soil. *J. Prod. Agric.* 6:507-513.

TRUMAN, C.C., and J.M. BRADFORD. 1994. Laboratory determination of interrill soil erodibility. *Soil Sci. Soc. Am. J.* 59:519-526.

SUMNER, H.R., R.D. WAUCHOPE, C.C. TRUMAN, and C.C. DOWLER. 1996. A rainfall simulator for mesoplot runoff studies. *Trans. ASAE.* 39:125-130.

SHAW, J.N., L.T. WEST, C.C. TRUMAN, and D.E. RADCLIFFE. 1997. Morphologic and hydraulic properties of soils with water restrictive horizons in the Georgia Coastal Plain. *Soil Sci.* 162:875-885.

TRUMAN, C.C., R.A. LEONARD, and F.M. DAVIS. 1998. GLEAMS-TC: A two-compartment model for simulating temperature and soil water content effects on pesticide losses. *Soil Sci.* 163(5):362-373.

TRUMAN, C.C., R.A. LEONARD, and A.W. JOHNSON. 1998. Fenamiphos transport, transformation, and degradation in a highly weathered soil. *Trans. ASAE.* 41(3):663-671.

TRUMAN, C.C., P. STEINBERGER, R.A. LEONARD, and A. KLIK. 1998. Laboratory determination of water and pesticide partitioning. *Soil Sci.* 163:556-569.

WAUCHOPE, R.D., H.R. SUMNER, C.C. TRUMAN, A.W. JOHNSON, C.C. DOWLER, J.E. HOOK, G.J. GASCHO, J.G. DAVIS, and L.D. CHANDLER. 1999. Runoff from a corn field as effected by tillage and corn canopy: A large scale simulated-rainfall hydrologic data set for model testing. *Water Resources Research.* 35:2881-2885.

TRUMAN, C.C., and R.G. WILLIAMS. 2000. Peanut cropping practices effects on event and seasonal runoff and soil losses. *J. Soil and Water Conservation.* (ACCEPTED).

TRUMAN, C.C., R.D. WAUCHOPE, H.R. SUMNER, J.G. DAVIS, and G.J. GASCHO. 2000. Slope-length and crop growth effects on runoff and sediment delivery. *J. Soil and Water Conservation.* (ACCEPTED).

SHAW, J.N., L.T. WEST, D.D. BOSCH, C.C. TRUMAN, and D.S. LEIGH. 2000. Parent material uniformity and soil distribution and genesis in a Kandiudult association. *Soil Sci. Soc. Am. J.* (ACCEPTED).

SHAW, J.N., D.D. BOSCH, L.T. WEST, C.C. TRUMAN, and D.E. RADCLIFFE. 2000. Evidence of lateral flow in SE (USA) upper Coastal Plain kandiudults with loamy to sandy argillic horizons. *Geoderma.* (ACCEPTED).

Past Accomplishments of Joseph M. Sheridan

Education:

1968	University of Georgia, Agricultural Engineering, MS
1966	University of Georgia, Agricultural Engineering, BSAE

Experience:

1968 - 1969	Agricultural Engineer, USDA-ARS, SEWRL, Athens, GA
1969 - 1974	Hydraulic Engineer, USDA-ARS, SEWRL, Tifton, GA
1974 - present	Research Hydraulic Engineer, USDA-ARS, SEWRL, Tifton, GA

Past accomplishments:
Previous research by this investigator and collaborators has demonstrated the impact of extensive floodplain/riparian areas and the surficial stream-channel depositional aquifer systems in determining the hydrologic response, and hence, the potential for transport of sediment and nutrients in streamflow from low-gradient, humid region watersheds. This work has explained the extreme range of seasonal storm response characteristics observed on Coastal Plain watersheds, and has demonstrated the impact of stream channel aquifer systems on the volume of storm runoff, peak rate of discharge, and relative timing of runoff peaks.

Evaluations of the effect of heavily-vegetated floodplain and other nearstream riparian areas on rates of sediment transport and delivery observed within Coastal Plain watersheds demonstrated that riparian areas in the region function essentially as sinks for deposition of materials eroded from adjacent upland agricultural areas, significantly reducing levels of suspended constituents transported in streamflow from Coastal Plain watersheds.

Recent investigations of hydrograph time parameters for flatland watersheds have provided relationships for determining hydrograph time parameters required for engineering design applications in low-gradient drainage basins. Other recent research has provided rainfall-streamflow relations needed by Federal action agencies for water quality screening and assessment required for water resource planning and management responsibilities in Coastal Plain region of the southeastern US.

His most recent research showed that riparian forest buffer systems under standard forestry management and harvest practices significantly reduce water and sediment movement from agricultural areas, thereby providing economic return to the landowner while maintaining the intended environmental enhancement function of the buffer system. He is a co-developer of Riparian Ecosystem Management Model (REMM) developed for assessing the impact of riparian zone management on stream and groundwater quality.

Most significant publications in last 10 years [Joseph M. Sheridan]:

HUBBARD, R.K., J.M. SHERIDAN, and L.R. MARTI. 1990. Dissolved and suspended solids transport from Coastal Plain watersheds. *J. Environ. Qual.* 19:413-420.

KNISEL, W.G., R.A. LEONARD, F.M. DAVIS, and J.M. SHERIDAN. 1991. Water balance components in the Georgia Coastal Plain: A GLEAMS model validation and simulation. *J. Soil and Water Conserv.* 46(6):450-456.

WILLIAMS, R.G., and J.M. SHERIDAN. 1991. Effect of rainfall measurement time and depth resolution on EI calculation. *TRANS. of ASAE.* 34(2):402-406.

SHERIDAN, J.M. 1994. Hydrograph time parameters for flatland watersheds. *TRANS. of ASAE* 37(1):103-113.

HUBBARD, R.K. and J.M. SHERIDAN. 1994. Retention of solutes by clayey Coastal Plain soils. *J. Soil and Water Conserv.* 49(1):90-96.

HUBBARD, R.K. and J.M. SHERIDAN. 1994. Nitrates in Groundwater in the Southeastern USA. p.303-345. In: D.C. Adriano, A.K. Iskandar, and I.P. Murarka. (Editors) *Advances in Environmental Science: Contamination of Groundwater.*

SHERIDAN, J.M., W.C. MILLS, and L.H. HESTER. 1995. Data management for experimental watersheds. *APPLIED ENGINEERING IN AGRICULTURE*. 11(2):249-259.

BOSCH, D.D., J.M. SHERIDAN, and R.R. LOWRANCE. 1996. Hydraulic gradients and flow rates in a shallow Coastal Plain aquifer in a forested riparian buffer. *TRANS. of ASAE.* 39(3):865-871.

SHERIDAN, J.M., R.R. LOWRANCE, and H.H. HENRY. 1996. Surface flow sampler for riparian studies. *APPLIED ENGINEERING IN AGRICULTURE.* 12(2):183-188.

SHERIDAN, J.M. 1997. Rainfall-streamflow relations for Coastal Plain watersheds. *APPLIED ENGINEERING IN AGRICULTURE.* 13(3):333-344.

SHERIDAN, J.M., D.D. BOSCH, and R.G. WILLIAMS. 1999. Hydrologic response of Coastal Plain watersheds. ASAE Paper No.99-2121. Annual Meeting ASAE. Toronto, Ontario, Canada.

BOSCH, D.D., J.M. SHERIDAN, and F.M. DAVIS. 1999. Rainfall characteristics and spatial correlation for the Georgia Coastal Plain. *TRANS of ASAE* 42(6):1637-1644.

SHERIDAN, J.M., R. LOWRANCE, and D.D. BOSCH. 1999. Management effects on runoff and sediment transport in riparian forest buffers. *TRANS of ASAE* 42(1):55-64.

INAMDAR, S., J.M. SHERIDAN, R.G. WILLIAMS, D.D. BOSCH, R.R.LOWRANCE, L.S. ALTIER, and D.D. THOMAS. 1999. The Riparian Ecosystem Management Model (REMM): I. Testing of the Hydrologic Component for a Coastal Plain riparian system. *TRANS of ASAE* 42(6):1679-1689.

LOWRANCE, R.R., L.S. ALTIER, R.G. WILLIAMS, S.P. INAMDAR, J.M. SHERIDAN, D.D. BOSCH, R.K. HUBBARD, and D.L. THOMAS. 2000. REMM: The Riparian Ecosystem Management Model. *J. of Soil and Water Conserv.* 55(1):27-34.

Past Accomplishments of R. Don Wauchope

Education:

North Carolina State University, Physical Chemistry, PhD

Experience:

1971-1972	Post-Doc, Oregon State Univ., Corvallis, OR
1972-1984	Research Chemist, USDA-ARS, Southern Weed Science Lab., Stoneville, MS
1984-1988	Research Chemist, USDA-ARS, Southeast Watershed Research Lab., Tifton, GA
1988-1999	Research Chemist, USDA-ARS, Nematodes, Weeds, and Crop Unit, Tifton, GA
1999-Present	Research Chemist, USDA-ARS, Southeast Watershed Research Lab., Tifton, GA

Accomplishments:

Pesticides in runoff. We have demonstrated the utility of small-plot simulated rainfall experiments to provide worst-case pesticide runoff measurements as a function of formulation and antecedent environmental conditions.

The RZWQM model pesticide module. The ARS RZWQM model has been re-released this year. The components, pesticide process theory and pesticide parameters database, used by the model came from this research. The model contains the most complete description of pesticide fate and dissipation in the environment available, and has been shown to represent "real" scenarios. It has the potential to be the next generation model for dealing with complex pesticide and nutrient processes and transport in the environment.

The ARS Pesticide Properties Database. The book "Pesticide Properties in the Environment" by Hornsby, Wauchope, and Herner is an important product of recently completed research, and is used globally with its first printing selling out. The book gives a complete set of property values for all major pesticides in existence at the time, and allows modelers/risk assessors to make a wide range of "first-tier" risk calculations. Data provided within it has been made the default data set for the PRZM, GLEAMS, and RZWQM models. The database has been placed on NRCS's web site.

Most significant Publications in last 10 years [R. Don Wauchope]:

R.D. WAUCHOPE, R.G. WILLIAMS, and L.R. MARTI. 1990. Runoff of sulfometuron-methyl and cyanazine from small plots: Effects of formuation and grass cover. *J. Environ. Qual.* 19:119-125.

R.D. WAUCHOPE, J.R. YOUNG, R.B. CHALFANT, L.R. MARTI, and H.R. SUMNER. 1991. Deposition, mobility, and persistence of sprinkler-irrigation-applied chlorpyrifos on corn foliage and in soil. *Pesticide Sci.* 32:235-243.

R.D. WAUCHOPE, T.M. BUTLER, A.G. HORNSBY, P.W.M. AUGUSTIJN-BECKERS, and J.P. BURT. 1992. The SCS/ARS/CES pesticide properties database for environmental decision-making. *Rev. Environ. Cont. Toxicol.* 123:1-164.

R,D. WAUCHOPE. 1992. Environmental risk assessment of pesticides: Improving simulation model credibility. *Weed Technol.* 6:753-759.

A. G. HORNSBY, R.D. WAUCHOPE, and A.E. HERNER. 1995. Pesticide properties in the

environment. New York: Springer-Verlag New York, Inc., 1995. ISBN 0-387-9453-6: disk ISBN 3-540-94353-6.

A.W. JOHNSON, R.D. WAUCHOPE, and H.R. SUMNER. 1996. Effect of simulated rainfall in efficacy and leaching of two formulations of fenamiphos. *J. Nematology.* 28:374-388.

R. F. DAVIS, R.D. WAUCHOPE, A.W. JOHNSON, B. BURGOA, and A.B. PEPPERMAN. 1996. Release of fenamiphos, atrazine, and alachlor into flowing water from granules and spray deposits of conventional and controlled-release formulations. *J. Agr. Food Chem.* 44:2900-2907.

R. D. WAUCHOPE, H.R. SUMNER, and C.C. DOWLER. 1997. A measurement of the total mass of spray and irrigation mixtures intercepted by corn and cotton seedlings. *Weed Technol.* 11:466-472.

R.D. WAUCHOPE, R.G. NASH, L.R. AHUJA, K.W. ROJAS, G.H. WILLIS, L.L. MCDOWELL, T.B. MOORMAN, and Q.L. MA. Pesticide Processes. Ch. 6, In Ahuja, L.R., J.D. Hanson, and M.J. Shaffer (eds). 1999. Root Zone Water Quality Model: Modeling Management Effects on Water Quality and Production. Water Resources Publications, LLC, Englewood, CO. (In Press).

R. D. WAUCHOPE R. D., SUMNER, H. R., TRUMAN, C. C., JOHNSON, A. W., DOWLER, C. C.. HOOK, J. E, GASCHO, G. J., DAVIS, J. G. AND CHANDLER, L. C. 1999. Runoff from a cornfield as affected by tillage and corn canopy: a large-scale simulated-rainfall hydrologic data set for model-testing . Water Resources Res. 35:2882-2885 (1999).

Past Accomplishments of Robert K. Hubbard

Education:

1971 University of Illinois, Agriculture, BS
1975 Michigan State University, Soil Science, MS
1979 Michigan State University, Soil Science, PhD

Experience:

1979-1980 Asst. Prof., Environ. Science, Wm. Paterson College of NJ, Wayne, NJ.
1980-1984 GS-11, Soil Scientist, USDA-ARS, SEWRL, Tifton, GA
1984-1990 GS-12, Soil Scientist, USDA-ARS, SEWRL, Tifton, GA
1990-1999 GM-13, Soil Scientist, USDA-ARS, SEWRL, Tifton, GA
1999 GS-14, Soil Scientist, USDA-ARS, Southeast Watershed Research Laboratory (SEWRL), Tifton, GA.

Accomplishments:

Discovered that recommended Coastal Plain fertilizer rates including application of animal wastes resulted in nitrate concentrations that exceeded public health standards for drinking water. First to show that nitrate leaching in the Coastal Plain under recommended N rates is negatively impacting shallow groundwater quality and that rates and quantities of nitrate leached depend on N application rate, method of application, and time of year.

Characterized properties of Coastal Plain soils and determined their effects on solute transport. Determined that the physical and chemical properties of Coastal Plain soils are dominated by the relative proportions of sand and clay, and that on the sandier soils percolation rather than surface runoff is the major loss pathway for solutes. Discovered that some phosphorus will leach through sandy Coastal Plain soils, but not through clayey ones.

Discovered that nitrate will leach through plinthite and Hawthorn Formation materials to contaminate groundwater as deep as 4 m in the Tifton Upland physiographic region. Senior authored the book chapter entitled “Nitrates in groundwater in the southeastern United States”.

Investigated spatial and temporal patterns of solute transport through a riparian forest and discovered that agrichemicals applied upslope of a riparian area may take several seasons to completely leave the upslope area and move through the riparian forest.
Conceived, developed, and tested an overland flow- grass-riparian forest buffer system for utilizing nutrients contained with animal lagoon wastewater. The system combines inexpensive application of wastewater via overland flow with nutrient uptake and filtering by grasses, forest and/or planted wetland vegetation.

Prepared an invited book chapter on dairy cattle manure management. It provides an overview of management and utilization of dairy cattle manure and emphasizes strategies for utilizing the nutrients in the waste without negatively impacting the environment.

Most significant Publications in last 10 years [Hubbard RK]:

ENTRY J.A., HUBBARD R.K., THIES J.E. and FUHRMAN J. 2000. Influence of vegetation in riparian filterstrips on coliform bacteria: I. Movement and survival in surface flow and groundwater. Accepted by J. Environ. Qual.

ENTRY J.A., HUBBARD R.K., THIES J.E. and FUHRMAN J. 2000. The influence of vegetation in riparian filterstrips on coliform bacteria: II. Survival in soils. Accepted by J. Environ. Qual.

BOSCH D.D., HUBBARD R.K., LEONARD R.A. and HICKS D.W. 1999. Subsurface flow patterns identified through tracer studies in a sandy loam profile. TRANS of ASAE 42(2):337-349.

HUBBARD R.K. RUTER J.M., NEWTON G.L. and DAVIS J.G. 1999. Nutrient uptake and growth response of six wetland/riparian plant species receiving swine lagoon effluent. TRANS of ASAE 42(5):1331-1341.

HUBBARD R.K., NEWTON G.L., DAVIS J.G., LOWRANCE R., VELLDIS G. and DOVE R. 1998. Nitrogen assimilation by riparian buffer systems receiving swine lagoon wastewater. TRANS of ASAE 41(5):1295-1304.

HUBBARD R.K. and LOWRANCE R.R. 1997. Assessment of forest management effects on nitrate removal by riparian buffer systems. TRANS of ASAE 40(2):383

LOWRANCE R.R., VELLIDIS G. and HUBBARD R. 1995. Denitrification in a restored riparian forest wetland. J. Environ. Qual. 24:808-8.

HUBBARD R.K. and LOWRANCE R.R. 1994. Riparian forest buffer system research at the Coastal Plain Experiment Station, Tifton, GA. Water, Air, and Soil Pollution 77:409-432.

HUBBARD R.K. and SHERIDAN J.M. 1994. Retention of solutes by clayey coastal plain soils. J. Soil Wat. Conserv. 49:356-362.

VELLIDIS G.R., LOWRANCE R., SMITH M.C. and HUBBARD R.K. 1992. Methods to assess the water quality impact of a restored riparian wetland. J. Soil Wat. Conserv. 48:223-230.

HUBBARD R.K., LEONARD R.A. and JOHNSON A.W. 1991. Nitrate transport on a sandy Coastal Plain soil underlain by plinthite. TRANS ASAE 34:802-808.

Health, Safety, and other Issues of Concern Statement

Animal Care – Not Relevant
Endangered Species – Not Relevant
Environmental Impact Statement – The research project has been examined for potential impacts on the environment and has been found to be categorically excluded under ARS regulations for the National Environmental Policy Act.
Human Study Procedure – Not Relevant
Laboratory Hazards – Safety training and appropriate equipment are provided fopr all laboratory employees. All laboratory employees and their supervisors are respppponsible for laboratory safety in their performance plans.
Occupational Safety and Health – All appropriate procedures are followed to ensure safety and healthA Recombinant DNA Procedures – Not Relevant