National Program 201 – Water Quality and Management

Dates October 2004

CRIS Project Numbers
This new project will be affiliated with the following continuing projects:
1902-13000-009D, 3602-12000-011D, 3602-12220-005D, 3604-13000-007D, 3622-12130-002D, 3625-12000-011D, 3625-12130-003D, 3625-13000-008D, 3625-13000-006D, 5342-66000-004D, 5358-21410-002D, 5402-13660-006D, 5402-66000-004D, 5402-66000-005D, 6206-11120-003D, 6206-13610-005D, 6218-13000-009D, 6408-12130-012D, 6408-13000-012D, 6408-13660-004D, 6602-13000-019D, 6602-13000-020D, 6602-13000-021D

Research Management Units and Locations
1902-05-00 Pasture Systems and Watershed Management Research, Univ. Park, PA
3602-15-00 National Soil Erosion Research, West Lafayette, IN
3604-05-00 Soil Drainage Research, Columbus, OH
3622-15-00 Cropping Systems and Water Quality Research, Columbia, MO
3625-15-05 Agricultural Land Management Research, Ames, IA
3625-15-10 Soil and Water Quality Research, Ames, IA
5342-45-00 Southwest Watershed Research, Tucson, AZ
5358-05-00 Forage Seed and Cereal Research, Corvallis, OR
5402-15-00 Great Plains Systems Research, Ft. Collins, CO
6206-05-05 Natural Resources Systems Research, Temple, TX
6218-05-20 Great Plains Agroclimate and Natural Resources Research, El Reno, OK
6408-05-10 Channel and Watershed Processes Research, Oxford, MS
6408-05-15 Water Quality and Ecological Processes Research, Oxford, MS
6408-05-30 Upland Erosion Processes Research, Oxford, MS
6602-05-00 Southeast Watershed Research, Tifton, GA

Title
Conservation Effects Assessment Project – The ARS Watershed Assessment Study

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Participating Scientists: See Appendix A

Total Scientific Staff Years
Sixty ARS scientists will contribute to the project with a fulltime equivalent of about 38 SYs.

Planned Duration 60 months

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Project Summary

U.S. Department of Agriculture (USDA) conservation initiatives are conducted through several programs. The Farm Security and Rural Investment Act of 2002 (the 2002 Farm Bill) authorized an increase in funding levels for the Environmental Quality Incentives Program (EQIP) and the Conservation Reserve Program (CRP), authorized continued funding for other conservation programs, and established new conservation programs. Overall, the 2002 Farm Bill authorized federal expenditures for conservation practices on farms and ranches in the U.S. at a level about 80 percent above the level set under the 1996 Farm Bill. It is widely recognized that these conservation programs will protect millions of acres of agricultural land from degradation and will enhance environmental quality. The environmental benefits of the programs, however, have not been quantified. Tracking the environmental benefits of the programs will allow policy-makers and program managers to implement and modify existing programs and design new programs to more effectively and efficiently meet the goals of Congress.

The Natural Resources Conservation Service (NRCS) and Agricultural Research Service (ARS) are leading a project to quantify the effects of the USDA conservation programs. The project, known as the Conservation Effects Assessment Project (CEAP), has two major components: 1) a National Assessment and 2) a Watershed Assessment Study. The National Assessment will be conducted using NRCS data and watershed-scale models developed by ARS and will provide estimates of conservation benefits at the national scale. The ARS Watershed Assessment Study (WAS), designed to provide detailed assessment of conservation programs on selected watersheds, is the subject of this project plan.

Previous research has established effects of conservation practices at the plot or field-scale. The results are limited in that they have not captured the complexities and interactions of conservation practices, landscape characteristics, and other land uses at watershed and landscape scales. The WAS will assess effects and benefits of conservation practices at the watershed scale. The results will advance our knowledge of how watershed scale assessments might be done to capture impacts at multiple scales. They also will improve our understanding of effects of conservation practices beyond the edge of the farm field. Ultimately, the assessments conducted at the watershed scale will be used to improve the performance of the models that will be used in the National Assessment.

Twelve ARS Benchmark Watersheds will support watershed-scale assessment of environmental effects of USDA conservation program implementation. The ARS Benchmark Watersheds represent primarily rainfed cropland, although some of the watersheds also contain irrigated cropland, grazingland, wetlands, and confined animal feeding operations. Conservation practices (or best management practices, BMPs) to be emphasized will include NRCS CORE 4 practices for croplands (conservation buffers, nutrient management, pest management, and tillage management), drainage management systems, and manure management practices. Environmental effects and benefits will be estimated primarily for water and soil resources, with some assessment of wildlife habitat and air quality benefits in some watersheds.

The goal for the WAS is to provide detailed assessments of conservation programs in a few selected watersheds, provide a framework for improving the performance of the national assessment models, and support coordinated research on the effects of conservation practices across a range of resource characteristics (such as climate, terrain, land use, and soils).

The comprehensive analysis of resources, the quality of the environment, and social and economic benefits that accrue to rural communities and the nation from implementing conservation programs will benefit those responsible for developing conservation policy and managing the USDA Farm Bill conservation programs.

Objectives

The primary purpose of CEAP is to produce a national assessment of environmental benefits of USDA conservation programs. The national assessment will provide estimates of conservation benefits at a national scale. The primary objectives of the WAS component of CEAP are to support the national assessment by providing detailed research findings for a few intensively studied watersheds and to provide a framework for evaluating and improving the performance of models for future national assessments. National assessments of USDA conservation programs are expected to continue well into the future. The need to support the national assessments with watershed studies is also expected to continue over a long time period. This project plan describes the research objectives and plans for the first five years of what is expected to be a much longer project.

Within the two primary objectives there are five specific objectives of CEAP-WAS. The objectives are:

1. Develop and implement a data system to organize, document, manipulate and compile water, soil, management, and socio-economic data for assessment of conservation practices.

2. Measure and quantify water quality, water quantity, soil quality, and ecosystem effects of conservation practices at the watershed scale in a variety of hydrologic and agronomic settings.

3. Validate models and quantify uncertainties of model predictions at multiple scales by comparing predictions of water quality to measured water, soil and land management effects of conservation practices.

4. Develop and apply policy-planning tools to aid selection and placement of conservation practices to optimize profits, environmental quality, and conservation practice efficiency.

5. Develop and verify regional watershed models that quantify environmental outcomes of conservation practices in major agricultural regions.

Need for Research

Description of the problem. The 2002 Farm Bill re-authorized the USDA's existing conservation programs, including the Conservation Reserve Program (CRP) and the Environmental Quality Incentive Program (EQIP), and created a new Conservation Security Program (CSP). The Bill also increased funding levels for these programs by 80% above the 1996 level. The CRP is the Federal Government's single largest environmental improvement program; at the end of FY 2002 34 million acres were enrolled in the CRP involving annual rental payments of $1.6 billion. The EQIP will provide as much as $5.8 billion for five years, 2002 to 2007, to address conservation and environmental stewardship on "working agricultural land."

The CSP defines eligible conservation practices more broadly than defined by EQIP and is the first program that allows for payment based on existing conservation management, rather than cost sharing for application of new practices. Conservation practices eligible under CSP include nutrient management; integrated pest management; water conservation (including irrigation and drainage management) and water quality management; grazing, pasture, and rangeland management; soil conservation, quality and residue management; invasive species management; fish and wildlife habitat conservation, restoration, and management; air quality management; energy conservation measures; biological resource conservation and regeneration; contour farming; strip cropping; cover cropping; controlled rotational grazing; resource-conserving crop rotation; conversion of portions of cropland from a soil-depleting use to a soil-conserving use including production of cover crops; partial field conservation practices; and native grassland and prairie protection and restoration.

The 2002 Farm Bill mandates that education, monitoring, and assessment of the programs be provided. Further, the Department of Agriculture Reorganization Act of 1994 requires USDA to conduct a thorough analysis of the risks to human health, safety, and environment from such federal programs, determine alternative ways of reducing risk, and conduct cost-benefits assessments.

Additionally, conservation planners and land managers need information on alternative cost-effective conservation practices and tools for planning and implementing conservation measures. These needs include a variety of conservation objectives such as protection and enhancement of soil, water, and air quality; carbon storage; wildlife habitat; and other environmental needs and benefits.

The Conservation Effects Assessment Project (CEAP) was created to assess and quantify the effects and benefits of USDA conservation programs. CEAP is a multi-agency effort led by NRCS; ARS is a major partner in this effort. The principle focus of the CEAP is a national assessment of environmental benefits of conservation programs to support policy decisions and program implementation. It is recognized, however, that the benefits of conservation practices may be understood only by studies on specific watersheds. Therefore, CEAP has two major components: 1) a National Assessment of effects of conservation practices and systems for all major watersheds in the U.S. and 2) a Watershed Assessment Study (WAS) focusing research on specific watersheds. The National Assessment will provide broad estimates of conservation benefits at the national scale, using existing models adapted for the national analysis. The WAS is needed to: 1) provide more detailed assessments in a few selected watersheds; 2) provide a framework for scaling results at watershed scale up to regional levels using data from specific watersheds; 3) provide data to evaluate and improve the performance of the national assessment models; and 4) provide credible research results on the effects of specific conservation practices or combinations of practices for different hydrology, soils, climates, topographies, and land uses. The research requires enhanced data systems to support assessment of cost-effectiveness of conservation practices, and evaluate uncertainty and risk. New regionalized watershed models need to be developed to provide more efficient tools for future assessments.

Pollution resulting from intensive crop and animal production continues to threaten water resources despite significant investments in conservation practices implemented at the farm scale. Watershed-scale assessments are needed to address agricultural impacts on water resources and soil. The spatial complexities of landscapes, land use, soils, and hydrology require new approaches to develop knowledge that can guide policy-making and management decisions. Watershed management challenges that include excess freshwater nutrient loads, sedimentation, pathogen movement, and hypoxia in coastal waters will be more easily confronted with an integrated understanding of watershed processes and new analytical tools and improved mechanistic models to quantify responses to conservation practices. The impacts of livestock and cropping systems on water quality are not sufficiently understood to guide improved conservation practices and their strategic location within watersheds. Intensive cropping systems have produced surpluses of nitrogen and phosphorus and mobilized soil in fields and streams banks that contaminate streams and aquifers. Concentration of animal feeding operations has been accompanied by intensive manure applications in localized areas that exceed the capacity of those areas to retain the nutrients. There is increasing evidence that repeated applications of manure can result in increased movement of nitrogen (N), phosphorus (P) and pathogens into stream and river waters, with significant consequences for downstream water quality.

Relevance to ARS National Program Action Plan. The CEAP project is part of the ARS National Program 201, Water Quality and Management. The proposed research addresses the following specific goals of ARS National Program 201: 1) Predict impacts of changes in land use and management on watershed response based on hydrologic processes, watershed variability, and watershed characteristics (Goal 1.2.1); 2) Develop methods to determine input model parameters, values, and state variables for multiple scales to account for the effect of management practices (Goal 1.7.2); 3) Test and improve models by comparing results against field data bases for different conditions at the field, farm, and watershed scale (Goal 3.6.2); and 4) Determine the impact of management practices developed at the field and farm scales on water quality within watersheds (Goal 3.7.3). This research also addresses the following goals of the ARS National Program 202, Soil Resource Management: 1) Develop quantitative approaches for evaluating the environmental and economic benefits of site-specific soil management strategies; and 2) Develop science-based tools and decision aids that enable land managers to understand the effects of various combinations of management practices. This research also will serve a fundamental role in addressing components of the new ARS NP 201 Water Quality Management initiatives on: Water Supply and Drought (A1), Total Maximum Daily Loads (A5), Remote Sensing Applications (A6), and Water Resource Models (A8).

Potential benefits expected from attaining objectives. The CEAP is expected to benefit the USDA Farm Bill conservation programs by providing a comprehensive analysis of resources, the quality of the environment, and social and economic benefits that accrue to rural communities and the Nation from implementing conservation programs. The WAS, as a part of CEAP, will specifically:

1. Quantify on-site and off-site effects of conservation practices on water quality and quantity, air quality, soil quality, and aquatic and terrestrial wildlife habitats at a watershed scale in a manner that enables a more accurate CEAP National Assessment.
2. Develop and validate watershed and regional scale models that are useful to NRCS and other stakeholders for assessing the effects of conservation practices.
3. Develop and provide watershed scale data for the validation of national/regional models that are assembled for use in the CEAP National Assessment.
4. Provide policy-relevant analyses of the threshold at which conservation practices can be shown to have measurable benefits within a watershed through sensitivity and uncertainty analysis of the quantity and scale of implementation in specific watersheds.
5. Provide policy-relevant analyses of where in the watershed conservation practices may be deployed to achieve targeted reductions in pollutants at minimum costs.

6. Provide policy-relevant analyses of the net cumulative effects of conservation practices within a watershed.
7. Provide policy-relevant analyses of economic and environmental effects and benefits to rural communities and the nation that are derived from USDA conservation programs.
8. Demonstrate and promote conservation practices and programs to the public using the watershed research system.

Anticipated products of the research. The purpose of the WAS is to provide a scientific basis for the annual reports to be delivered by the National Assessment. Five specific products, or deliverables, are to be provided to NRCS and other stakeholders to meet the demands of the National Assessment and other similar activities designed to quantify the effects of USDA conservation programs. The five deliverables relate directly to the five specific objectives of this project. The deliverables are:

1. Water, soil, management, and socio-economic data system to document effects of conservation practices.
2. Quantification, at multiple scales, of the effects of conservation practices on water quality, water quantity, soil quality, and ecosystems.
3. Validation of model performance through quantifying uncertainties of model predictions at multiple scales.
4. Planning tools to evaluate environmental and cost effectiveness of selection and placement of conservation practices at multiple scales.
5. New regional software tools (Object Modeling Systems) that can be used to quantify environmental outcomes of conservation practices in major agricultural regions.

These five deliverables are the basis of an agreement between ARS and NRCS in which ARS has committed to delivering the products to NRCS on a mutually agreeable schedule.

Customers of the research and their involvement. This research is being undertaken by ARS to meet the needs of the natural resource community, and in particular, the specific needs of USDA to respond to the demands of the 2002 Farm Bill. Within each watershed, a diverse group of local partners, such as state agencies, conservation districts, education institutions, businesses, municipalities, landowners, and watershed alliances, are engaged in watershed conservation activities. The research will be facilitated by NRCS as they 1) implement conservation programs on benchmark watersheds, 2) provide access to data on specific programs installed including acreage, locations, costs, and other information, 3) participate in the planning of the experimental design, 4) provide guidance on the kind of experimental data to be obtained and assistance on interpreting the results, and 5) provide other assistance as appropriate. NRCS participation will come from all levels of the agency from National Headquarters to State Offices to Field Offices within the benchmark watersheds.

Scientific Background

Environmental Effects of Conservation Programs and Practices. From the 1980's to present, U.S. farm policy has focused conservation programs on an expanding array of natural resource issues (from soil as the primary focus to now also include water quality, water conservation, habitat and ecosystem protection, and air quality as high priority resource concerns). *A Geography of Hope* (NRCS, 1996) articulated a new vision that encompassed the broad scope of the agency's mission to produce multiple environmental benefits from management of America's agricultural lands. The traditional focus of conservation for the purpose of developing and managing soil and water resources for production purposes has been expanded to also address the role of agriculture in environmental performance (SWCS, 2001). Similar evolution toward a broad environmental focus has occurred in agriculture policy in many other countries (e.g., Coote and Gregorich, 2000; McRae et al, 2000; and Bernstein et al. 2004).

In the 2002 Farm Bill, there was a continued evolution of farm policy (Classen, 2004) that included a renewed commitment to conservation on working lands (e.g., while an 80% funding increase was authorized for total conservation spending through 2007, funding for the primary working lands conservation program, EQIP, was authorized at more than five times the spending levels of the 1996 Farm Bill.). Additionally, the Conservation Security Program, a new working lands conservation program was authorized that for the first time authorized payments to landowners for practices that were installed prior to application for the program. Contrary to recommendations of many in the environmental-farm policy arena, the 2002 Farm Bill moved away from targeting of conservation programs (Classen, 2004; SWCS, 2002 & 2004).

While there have been economic assessments of conservation programs (Feather et al, 1999; NRCS, 2003) and assessments to quantify agricultural impacts on water quality within a watershed context, (e.g., Baker, 1993) a quantitative assessment of environmental outcomes of agriculture conservation practices and programs has not been attempted at the farm-policy scale.

Open data systems for scientific and policy analyses. The need for high-quality, long-term data records of hydrologic systems to address issues such as future water scarcity and potential implications of climate change has been emphasized in recent scientific reports (NRC, 2001; Hornberger et al., 2001). Kinzig et al. (2000) and Kinzig (2001) highlighted the need for increased interdisciplinary research in the area of communicating scientific information, emphasizing potential benefits of information technology (IT) on flows of scientific information to diverse citizen and stakeholder groups. There is a growing international recognition that use of research data is only maximized when the data access, management, and preservation are addressed as an inherent part of the research process, and that publicly funded research should be openly available (Arzberger et all, 2004).

The ecological research community has supported a strong thrust to develop cutting-edge information technologies to transform the research process in support of multi-location, synthetic analyses. The Long Term Ecological Research Network (LTER, http://www.lternet.edu/data) has provided leadership to develop these technologies (Baker et al. 2000). One aspect that has required considerable effort is development of metadata systems (Porter and Brunt 2001). The metadata are "data about data" and provide descriptive information to enable researchers who weren't involved in collecting or processing the data to understand the details of how the data were collected and processed. Recent and ongoing efforts focus on systems to electronically search data libraries to aid research teams in compiling appropriate data sets to address a particular scientific question. To successfully tackle such problems requires expertise from the data information and computing disciplines as well as expertise in the ecological and natural resources sciences (Baker et al. 2000). The NRC (2003) report "Frontiers in Agricultural Research" identified research in environmental stewardship and integration of leading-edge science concepts and techniques, of which informatics is an example, as an opportunity for USDA research to better address societal needs. Futrell et al. (2003) recently identified the need for design, development, and implementation of a “suite of critical enabling tools for storing, finding, analyzing, and synthesizing a diverse array of data” to enable study of complex systems. The goals of this project, quantitative assessment of environmental outcomes of conservation practices distributed within landscapes and watersheds on an array of soil, water, and other natural resource concerns, constitute such a complex system that will require development of “cyber-infrastructure”.

Water resources. Water resources face growing pressure globally, and with the prospect of possible future climate change, the water cycle (changes in precipitation frequency and intensity; evapotranspiration, runoff, snowmelt) will likely pose severe societal challenges (Gleik 1998). Within the U.S., severe multi-year drought coupled with changing demographics has let to establishment of the Water 2025 Initiative to address long-term needs for cities, farms, ranches, tribes, and wildlife. Equally complex issues must be addressed in humid regions of the U.S. (e.g., south Florida). Wherever concerns about adequacy of regional water resources arise, agricultural water use and impacts of agriculture on the water resource are critical issues.

In addition to critical issues of water quantity, water quality posed equally complex challenges. There are two principal pathways of nutrient movement into streams: movement in runoff resulting from storms or snowmelt or transport via base flow comprised of natural groundwater discharge or subsurface artificial drainage. Nitrate is transported to streams primarily through base flow under natural conditions or subsurface drainage, with critical consequences such as excessive nitrate in public water supplies (Kross, et al, 1990, Des Moines Water Works, 2002) and eventual transport to the Gulf of Mexico where nitrate plays a role in development of hypoxia in the Gulf of Mexico (Rabalais et al, 2001). Excessive phosphorus causes eutrophication of fresh water systems and possibly coastal estuary systems. Total phosphorus concentrations of 50 µg l^{-1} are sufficient to sustain chlorophyll concentrations of 10 µg l^{-1}, the lower boundary for a trophic state in temperate streams (Dodds, et al. 1998) and eutrophy in lakes (Smith, 2003). Using the Redfield ratio (Redfield, 1958) P concentrations exceeding 65 µg l^{-1} are sufficient to support algal growth in many water bodies when nitrate-N concentrations exceed 10 mg l^{-1}. It has been shown that these concentrations of total phosphorus can be from ground water in intensive agricultural regions (Burkart et al. 2004a).

Nitrogen and phosphorus translocations to stream waters are likely to have spatially different sources and pathways (Heathwaite et al., 2000) that should be considered in selecting and locating conservation practices. The differences may result from interactions between patterns of agricultural production and patterns of biophysical processes (e.g., nitrogen mineralization, phosphorus sorption, pathogen survival) in the soil and flow system. Watersheds provide an appropriate scale for measuring water quality and contaminant loads and their relationships to conservation practices.
A variety of conservation practices have been designed using hypotheses that link soil and vegetation conditions to flows of water, solutes and sediment across and through landscapes. However analyses of conservation practice systems at the watershed scale to explicitly evaluate water-quality effects are complex and rare. Management practices on agricultural lands are known to impact hydrology and water quality (Burkart and Stoner 2001; Castillo et al. 2000; Sauer et al 2001; Schilling and Libra 2000). It is also widely accepted that in-field and edge-of field practices can be modified to improve water quality, through nutrient management (Dinnes et al 2002; Kitchen and Goulding 2001), crop rotation (Bolton et al. 1970; Owens *et al*. 1995; Randall *et al*. 1997), and the

use of biological filters (e.g., Devito et al., 2000; Gold et al., 2001; Nelson *et al*. 1995; Peterjohn and Correll, 1983; Rosenblatt et al., 2001; and Spruill, 2000). While a variety of these kinds of practices are available, strategies to effectively optimize agricultural management systems to meet environmental goals are not commonly available to resource management agencies. This project seeks to develop tools that can be used to plan agricultural conservation systems in the context of water resource management needs within watersheds

Extensive agricultural areas in the Midwest are dominantly flat and require subsurface drainage (tile drains) in order to be productive. However these drainage systems transport significant amounts of nitrate to streams and rivers (Randall et al., 1997). Subsurface drainage can also transport particulate and dissolved P (Hergbert et al., 1981; Laubel et al., 1999; Addiscott et al., 2000; Uusitalo et al., 2001). Hergbert estimated that subsurface drains transported about 10% of the phosphorus lost to streams. Bacterial pollution accounts for 12 to 39% of impaired streams listed by state agencies in Iowa, Minnesota, and Indiana. Agriculture is viewed as a major source of these impairments through the movement of bacteria from manured fields and feedlots to streams. Contamination of public water supplies causes infrequent, but significant outbreaks of disease, such as the recent outbreak reported in Walkerton, Ontario. Bacterial pathogens addressed in this project include the enterotoxigenic *Escherichia coli* and species of *Salmonella*, *Campylobacter*, and *Listeria*. Public health microbiologists have used total coliforms, fecal coliforms or total *E. coli* as indicators of fecal contamination, and we propose to use *E. coli* as a pathogen indicator. The risk of fecal bacterial movement in runoff water has long been known for pasture systems and manured cropland. Culley and Phillips (1982) reported increased fecal coliforms in drainage from manure treatments, and the leaching of fecal coliforms or *E. coli* has been documented in other studies. However, the long-term impact of repeated manure applications on the bacterial pathogen populations in soil and drainage waters is unknown. Short-term studies show that *E. coli* populations in soil decrease rapidly from high initial levels (10^6 to 10^8 cells/g soil), but stabilize around 10^3 cells/g soil (Cools et al., 2001; Gagliardi and Karns, 2000). However, the relationship between soil populations and populations in runoff water has not been described. An additional complicating factor is the contribution of wild animals to the soil and water *E. coli* populations. Impacts of conservation practices on bacterial persistence and movement are poorly understood. In addition to bacterial pathogens, antibiotics have been found in surface waters at low concentrations in rivers (Kolpin et al. 2002). These chemicals may originate from animal feeding operations or from non-agricultural sources and are of concern because they may induce or maintain genes conferring antibiotic resistance in microbial populations. Antibiotic resistance in human bacterial pathogens is a growing human health concern and the contribution of agriculture via antibiotic use for growth promotion (in contrast to therapeutic use) remains a topic of intense controversy. Non-therapeutic use of antibiotics in swine production has been estimated to be as much as 10 million pounds annually in the USA. Persistence of antibiotics in the environment increases the risk from antibiotic-resistant pathogens, but relative risk from animal feeding operations compared to human uses or other agricultural uses is not clearly understood. The movement of antibiotics into surface waters involves transport in runoff water, but may also involve transport in subsurface drainage water.

Soil Quality. While there has been controversy amongst researchers about the concepts and terminology of soil quality (Karlen et al., 2003 and Letey et al., 2003), there is agreement that management has critical effects on soils and that soils can either move toward or away from a condition that is favorable for the defined use of that soil (Delgado and Cox, 2003). Within watersheds, soil condition, along with storm characteristics, controls the basic hydrologic process of infiltration, retention, and runoff of precipitation. In addition, soil condition controls the ability of soils to retain, bind, and transmit solutes and contaminants that flow with waters. Many conservation practices, by explicit design of otherwise, impact soil condition. Therefore, to understand hydrologic and water quality processes at a watershed scale, it is essential to quantify responses across a range that address field, edge-of-field, landscape, stream and channel processes and interactions. The Soil Quality Index Software Tool (Andrews et al., 2004) has been developed to quantify trends in soil condition at the field level, using measurements that are simple and relevant to farmers. Application of this tool within the benchmark watershed sites can provide data about management responsive soil condition as it impacts the hydrologic response to conservation practices.

Watershed models. Numerous models can predict runoff, sediment yield, and water quality processes, but none effectively integrate surface, subsurface, channel, and reservoir processes for use in detailed watershed-scale evaluation of conservation management practices. Available watershed models include some that are applicable for plot-size fields, others for field-size areas, and still others applicable for basin size areas. Examples of some models that can be considered both field-size and basin-size are SWAT (Arnold et al., 1998), AnnAGNPS (Bingner and Theurer, 2001), APEX (Williams et al., 1998; Williams et al., 2000), AGNPS (Young et al., 1989), and ANSWERS (Beasley et al., 1980). Each of these models uses different modeling techniques to compute runoff and sediment yield. Another model currently in the developmental stage is the WEPP model (Flanagan et al., 2001). The WEPP model is intended to eventually replace the USLE (Wischmeier and Smith, 1978) and RUSLE (Renard et al., 1997) that are currently used by NRCS as best management practice evaluation tools. Studies by Bingner et al. (1989), Bingner (1990), and Bingner et al. (1992) have shown the effectiveness of several models used for various conservation practices. The selection of appropriate spatial scales in the application of erosion models was shown in a study by Bingner et al. (1997).

There is a large body of literature on fluvial geomorphology that provides much of the information used for stream classification and channel design (Chang, 1988; Dunne and Leopold, 1978; Rosgen, 1994; Simon, 1989). Although these methods are useful for estimating average stable channel dimensions and alignment, detailed predictions of the evolution of a channel following land use change or stream corridor management activity are not possible. The long-term impact of channel erosion on ecological integrity can be far greater than point and non-point source pollution (Karr and Schlosser, 1977). This recognition led to new efforts in recent years to develop fully dynamic, physically-based stream models capable of tracking geomorphic changes. Early efforts include the one-dimensional models FLUVIAL-12 (Chang, 1990), HEC-6 (HEC, 1993), and GSTARS 2.0 (Yang et al., 1998). These models cannot address channel widening due to mass wasting of cohesive banks following bed lowering, a very destructive mode of channel erosion (Galay, 1983). The CONCEPTS model (Langendoen, 2000) is the first to simulate channel width adjustment in streams where bank retreat is the result of combined fluvial entrainment of bed and bank material and mass failure under gravity. CONCEPTS can also account for other variables that affect bank stability such as variations in groundwater table, vegetative roots, unsaturated soils, partial failure of the bank, and grade control structures.

The Riparian Ecosystem Management Model (REMM) (Lowrance et al, 2000) simulates hydrology, nutrient dynamics and plant growth for land areas between the edge of fields and a water body, allowing simulation of riparian forest buffer system effects on pollutant loadings. This provides users the ability to evaluate the conservation impact from various riparian systems. In order to completely investigate watershed systems with riparian buffers, the capabilities of REMM are needed within watershed models.

Model validation tools. In its standard for evaluating environmental fate models the American Society for Testing and Materials (1984) listed five components of model evaluation: model examination, algorithm examination, data evaluation, sensitivity analysis, and validation. The first two components ensure the model simulates the necessary processes and verifies that appropriate numerical techniques were used and coded correctly. The third component seeks to evaluate the availability and quality of data for model inputs and for model evaluation. The forth, sensitivity analysis, identifies those parameters having the most influence on the model estimates. The final component, validation, determines if the model adequately represents the system by comparing model predictions to independent**,** observed data.

Often there is a tradeoff between data collection and model validation costs and increasing confidence in the level of accuracy of the models. Tests or checks used to evaluate the reliability of models range from a simple assessment of the reasonableness of model outputs to sophisticated statistical techniques.

Modular models. Module libraries have been successfully used in several domains, such as manufacturing, transport, and other systems (Ziegler, 1990; Praehofer, 1996; Top et al., 1997; Breunese et al., 1998; Panagiotis et al., 1998; and Pidd et al., 1998). One of the earliest modular model developments was done for SHE, the European Hydrologic System Model (Abbot et al., 1986 and Ulgen et al., 1991). Leavesley et al. (1996, 1997) reported the conversion of the USGS Precipitation Runoff Modeling System (PRMS) to a Unix-based Modular Modeling System (MMS) for hydrologic modeling. Leavesley et al. (2002) presented some successful applications of this concept.

In 1997, an ARS-NRCS-USGS Interagency Workshop reviewed the MMS and other similar approaches and unanimously endorsed the development of an advanced Modular Modeling Framework for Agricultural and Natural Resource Systems to reduce duplication, improve quality and currency of code, facilitate maintainability, and enhance responsiveness of the modeling community to user needs.

No commercially available software exists to automatically extract scientific modules from legacy monolithic models, build new modeling tools, and verify the interoperability of the various modules that have been integrated. Some technology is available which uses a common interface for running different pre-built models, such as groundwater and surface water models. These systems cannot build models from modules.

Most current investments in model development by universities (e.g., University of Florida DSSAT Modeling Group), other government agencies (Corps of Engineers, Environmental Protection Agency), and foreign countries (e.g., the Cooperative Research Centre (CRC) for Catchment Hydrology in Australia and the European Commission Framework Programme 5: Harmon IT) are in the area of modular or object modeling, all of which use a basic concept of providing proven and sound scientific modules from existing models for use in custom-designed integrated analyses.

In 2001, several federal agencies (e.g., Nuclear Regulatory Commission (NRC), NOAA, EPS, COE, USGS, and USDA) entered into a Memorandum of Understanding (Interagency Steering Committee on Multimedia Environmental Models, www.iscmem.org) to collaborate in developing and using a modular approach to models.

These agencies enthusiastically endorsed the development and deployment of the Object Modeling System to meet the above criteria.

Terrain models. There are a variety of physical processes that are influenced by terrain and have a major impact on site hydrology and ecology. The influence of terrain on the distribution of energy and water by terrain can now be modeled using terrain analyses (Wilson and Gallant 2000). Hydrologic variables can be derived from terrain data providing opportunities for analysis at a variety of scales for which digital elevation models (DEM) are available. Many of these variables as well as other terrain variables can be calculated from two primary topographic attributes, slope and specific catchment area as proposed by Moore et al. (1991). Accurate determination of flow direction and calculation of catchment areas can accomplished by applying the method of Tarboton (1997) using triangular facets representing slope vectors between the elevation of each cell center and its eight neighbors. Channel heads where streams initiate can be defined using thresholds of specific catchment and slope (Montgomery and Dietrich, 1992). Derivation and application of indices of erosion, wetness, and other secondary topographic variables (Wilson an Gallant, 2000; Moore et al., 1993) have been shown to be useful in mapping the location of shallow saturation, erosion, sediment accumulation, catchment areas, soil properties and a variety of other interpretations using primary topographic variables. Experimental mapping of these interpreted variables (Bren 1998; Fried et al. 2001; Tomer et al., 2003 and Burkart et al., 2004b) have been used to develop strategies for riparian buffer placement and will be useful to develop strategies for implementation of other in-field and edge-of-field conservation practices.

Policy planning tools. There is a growing consensus that environmental and economic goals must be pursued as compatible, rather than opposing, goals of individuals, enterprises, and societies. A large body of knowledge on multiple objective decision making for land, water, and environmental management, including considerable discussion of agricultural issues, was presented in El-Swaify and Yakowitz (1998). A planning tool for evaluation of conservation effect at the watershed and national level will include three objectives: profit maximization at the farm level, maximization of environmental quality and program efficiency. These three goals will be specified as separate objective functions for the optimization calculation.

It is difficult to find a previous study where all three objectives are considered together. Two goals, revenue maximization and environmental quality, are used by Qiu and Prato (1998). They propose a crop yield index based on soil, hydrologic, and topographic field conditions. The index would be used to identify places in the field where revenue lost due to placement of conservation practices was lower. There is another line of literature, which attempts to value agricultural emissions (externalities), with the goal of making the producer bear the costs of the emissions. Studies include analysis of productivity (Archibald, 1988), where externalities are included in the calculation of productivity to identify problem areas. Calculation of a price for nonmarket emissions (Färe et al., 1993) allows the cost of the externality to be charged to the producer, resulting in the optimum based on profit and environmental quality. The environmental efficiency measure proposed by Reinhard, et al. (2000) includes emissions as well as inputs and outputs to produce a measure of efficiency that may be used to compare policies.

The combination of a physical model with economic analysis is the approach that will be taken in this study. Many previous studies linking biophysical and economic models use field scale models such as EPIC (Williams, et al., 1990). The most common strategy is to construct a "representative farm" based on cross-tabulated physical data on soil texture, slope, precipitation and crops. For example, a representative farm might be 200 acres growing pasture on sandy loam with a 1% slope. The data needed for economic modeling are input and output prices and their amounts. These data have been obtained from extension service budgets (McCarl, et al., 1999), state (Huang et al., 1996) or regional (Taylor et al., 1992; Mapp et al., 1994) estimates of production budgets, or estimated production functions based on physical model with regional prices (Johnson et al., 1991; Larson et al., 1996). SWAT has been linked to economic behavior using a budget generator to produce the required data for each watershed analyzed (Qiu and Prato, 1999). There are two studies that contain elements of the research proposed here; Whittaker et al. (2003) used spatial statistics to link SWAT to a Data Envelopment Analysis economic optimization to compare policy efficiency of two alternative nutrient reduction policies, and Gitau, et al. (2003) analyzed placement and cost effectiveness of conservation practices in a New York watershed using a genetic algorithm with values from SWAT and a BMP assessment tool.

Approach and Research Procedures

The underlying approach to the research is the acquisition, analysis, and interpretation of data from 12 ARS Benchmark Watersheds (Figure 1) and the testing and evaluation of models that will be used in the National Assessment. Conservation practices have been, or will be, applied on the 12 watersheds. The Benchmark Watersheds are at different stages of research implementation, ranging from little or no existing data to fully implemented experiments in place and water quality and discharge monitoring ongoing at several scales. Development and testing of regional watershed models will be associated primarily with the 12 benchmark watersheds.

The 12 watersheds provide a cross-section of climate, soils, land use, topography, and crops across major rainfed production regions of the U.S. The priority measurements and conservation practices to be evaluated for each watershed are summarized in Table 1. A more complete description of each watershed, including watershed specific objectives and approaches, is given in Appendix B.

The five objectives of this project are highly integrated. The field research will be conducted on the 12 watersheds using a carefully coordinated approach. Six multi-location teams will analyze and interpret the data as well as develop, validate, and apply models. The teams are: 1) Data Management, 2) Watershed Design for Determining Environmental Effects, 3) Model Validation, Evaluation and Uncertainty Analysis, 4) Economic Analysis, 5) Model Development and Regionalization, and 6) Data Quality and Assurance. Teams 1 through 5 will be primarily responsible for leading research conducted under objectives 1 through 5, respectively. It is essential that compatible date be obtained across all field sites and laboratories in order to make valid comparisons of the effects of conservation practices across regions. Team 6 will support the other five teams by providing QA/QC guidelines for methods and procedures to be used for data collection and analysis. Team 6 will also lead an effort to develop standard procedures for data collection and analysis consistent with recommendations of the National Water Quality Monitoring Council that is co-chaired by EPA and USGS (GAO, 2004). An inventory will be developed specifying data types to be collected at all watersheds and data needs that may be specific to one or more of the watersheds. The inventory will include climatic, geomorphic, and management data as well as data necessary for the resource measurements identified in Table 1 and the parameters required for the selected models. Where differences exist between watersheds or laboratories regarding how parameters are quantified, the scientists involved will identify a standard and develop relationships to normalize to the standard. Team 6 will lead the development of an inter-watershed data comparison program for QA/QC purposes that will involve representatives from each watershed and Teams 1 through 5.

The ***Experimental Design*** for each objective is given below. Specific responsibilities and tasks for Teams 1 through 6 are defined in the **Milestones and Expected Outcomes** section of this plan.

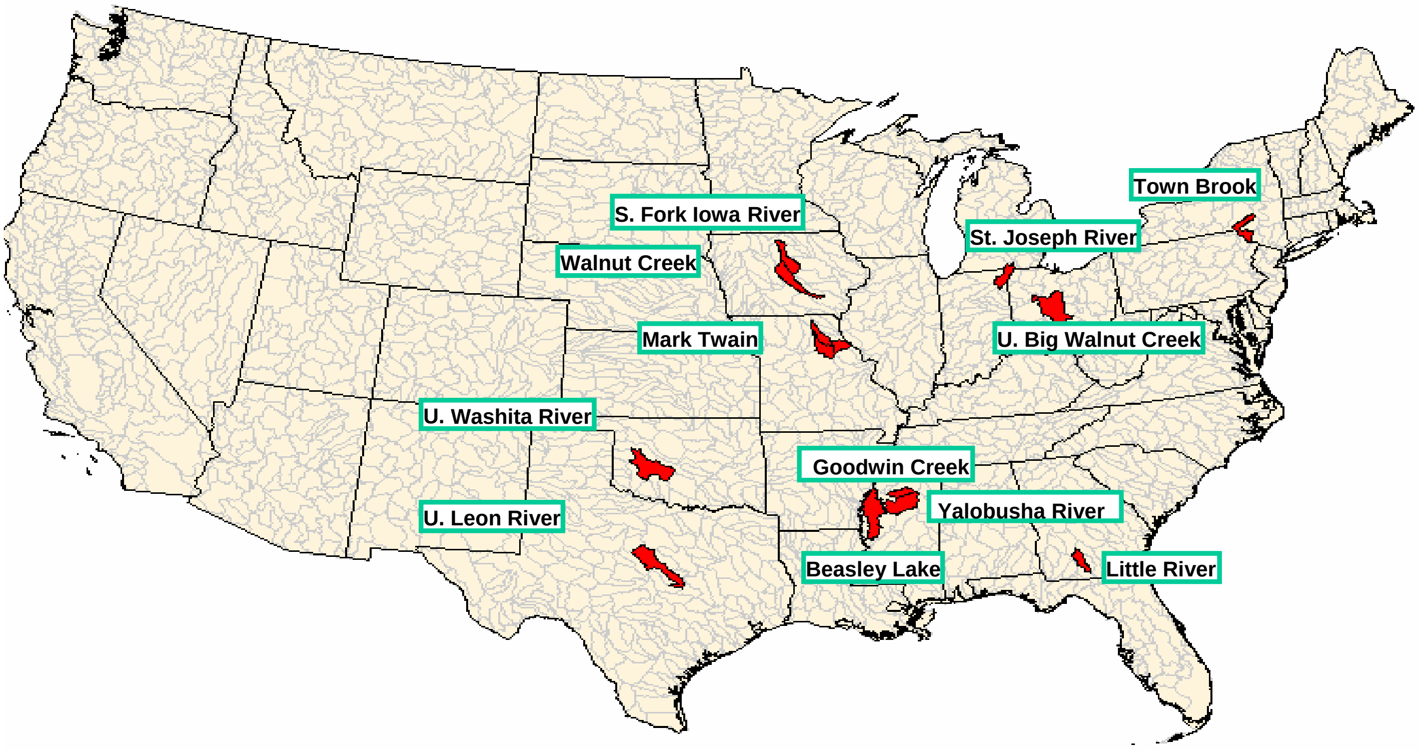

Figure 1. Location of ARS Benchmark Watersheds.

Table 1. Resource Measurements and Conservation Practices Underway or Planned for ARS Benchmark Watersheds for CEAP Watershed Assessment Study.

Watershed	Resource Measurements					Conservation Practices
	Water Quality[1/]	Water Quantity[2/]	Soil [3/]	Ecosystem [4/]	Economics [5/]	
S. Fork, Iowa River, IA	N, P, S, Pa, T, DO	D, A, P, G,	AS, B, O, E, total N, P		E, O, P	M, N, T
Walnut Creek, IA	N, P, Pe, S	D, A, P			E	N, D
Salt River, Mark Twain Lake, MO	N, P, Pa, Pe, S	D, G, P	AS, E, O, P, AM, D		O, P	B, N, P, T
Upper Washita River, OK	N, P, S	D, G, P, I, S, C	AS, AW, B, O, N, P	H		C, L
Goodwin Creek, MS	N*, P*, Pa*, S*	C, D, P, S	AS, E, O, P	C*, D*, H*, R*		B, C, N, T, L
Yalobusha, MS	N, P, S,	D, C, P, S, G	AW, B			B, C, T
Beasley Lake, MS	N, P, S, DO, Pa, Pe, T	D, P	O	C, D, R		B, D, N, T, L
Upper Leon River, TX	N, P, S, Pa	D, P	AS, B, E, O, P			B, N, M, R, T
Little River, GA	N, P, Pe, DO, S, T	D, G, P, S	AW, B, M, O			B, C, M, N, P, R, T
Town Brook, NY	P, S	D, G, P	AW, B, P		E, O, P	B, C, M, N, T
St. Joseph River, IN	N, P, S, Pe		AS, AW, B, C, E, M, N, O, P		E, P	B, D, M, N, P, T
Upper Big Walnut Creek, OH	N, P, S, Pe	A, D, P	AW, B, E, O, P	H, D, C	E	B, D, L, N, P, T

[1/] Water Quality Measurements:
DO - dissolved oxygen
N - nitrate-nitrogen
P – phosphorus
Pa – pathogens
Pe – pesticides
S – sediments
T – temperature

[4/] Ecosystem Measurements:
C – Community Structure
D – Species Diversity
H – Habitat Quality
N – Native vegetation Cover
P – Patchiness Index
R – Species Richness
S – Soil flora and fauna

[2/] Water Quantity Measurements:
A – Artificial drainage
C – Channel geomorphology
D – Discharge
I – Irrigation
G – Groundwater
P – Precipitation
S – Soil Water

[6/] Conservation Practice Categories:
B – Buffers
C – Channel Management
D – Drainage Management
M – Manure Management
N – Nutrient Management
P – Pest
R – Range
T – Tillage
L – Land conversion

[3/] Soil Measurements:
AS – Aggregate Stability
AW – Available Water Holding Capacity
B – Bulk Density
C – C mineralization potential
E – Electrical Conductivity
M – microbial biomass Carbon
N – N species and min. potential
O – Organic Carbon
P – Soil-test Phosphorus
AM – Microbial Activity
D – Microbial Diversity

[5/] Economic Measurements:
E – Program Efficiency
O – Optimal Placement
P – Profit

* From previously collected data.

Experimental Design

<u>Objective 1.</u> Develop and implement a data system to organize, document, manipulate and compile water, soil, management, and socio-economic data for assessment of conservation practices.

A common platform will be developed to provide access to watershed data from the 12 Benchmark Watersheds to increase the utility of these data for the CEAP National Assessment and the Watershed Assessment Study, as well as other applications. Successful implementation of the database will provide access to the watershed data for internal and external researchers while retaining local control of and responsibility for the data. The data system will be called STEWARDS (Sustaining the Earth's Watersheds: Agricultural Research Data System).

Approach: Working groups identified and coordinated by the CEAP Data Management Team Leaders will complete critical tasks/steps. Roles and responsibilities of individuals or groups are described in Table 2. Some of the tasks must be completed in sequence, while others can proceed simultaneously, as described below. An incremental approach will be taken to develop the data system.

The team leaders have identified a set of working groups who will accomplish specific tasks (Figure 2). Groups have been established to address tasks 1 through 4. Subsequent groups will be activated in future years. Throughout the multi-year process, electronic communication will be used to gain consensus for the plan across the planning groups, other CEAP participants, and ARS watershed research sites. The primary communication tools to be supported by the ARS Office of the Chief Information Officer (OCIO) are MCI Netconferencing and Sharepoint. Data policies for the project will be developed in compliance with Agency policies and federal data policies, e.g., http://globalchange.gov/policies/diwg/. The team leaders will monitor progress, and ensure that each step adequately addresses the charge, including documentation and training requirements throughout each phase of the project.

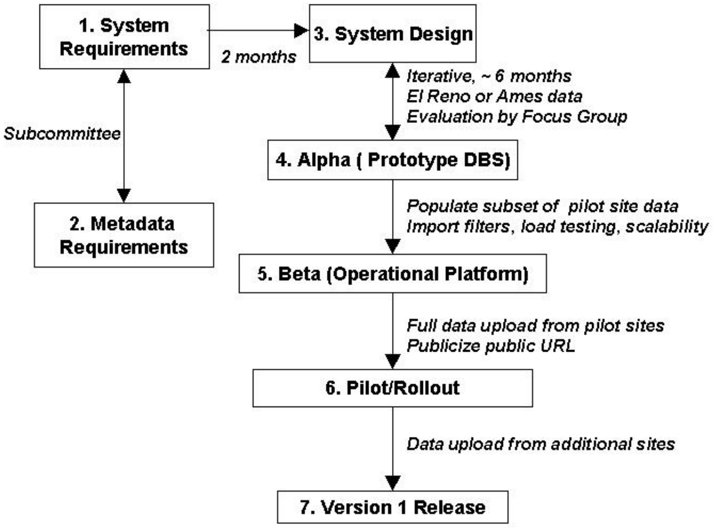

Figure 2. Tasks required for data system development.

The critical tasks, charges, and approaches are:

1) Define system requirements
   a) Charge: Define the system requirements, including for the operational phase, and prepare a written document that will provide the basis for System Design.

  b) Approach: The group will review system requirements documents from other data management systems (e.g., MSEA, U.S. Forest Service Hydrological Data Access Project http://www.fsl.orst.edu/hydrodb/). They will incorporate information from the: 1) inventory of data compiled from ARS watershed research programs, 2) inventory of methodologies used to measure particular fields (described under objective 2), and 3) input and output requirements for the models to be used. The group will define the capacity/functionality of the data system (e.g. data fields, data access, analysis, visualization). After a draft of the system requirements is completed, they will utilize Sharepoint to develop consensus, involving watershed site Research Leaders, Scientists, Support Staff, and Data Managers; the Object Modeling System Team, and the CEAP-WAS Model Validation Team, and other stakeholders. The data system will serve as a repository where diverse end-users can access, search, analyze, visualize, and report various types of integrated watershed data contributed from the multiple locations. Types of data will be diverse, including biophysical data (i.e., point-based in time and/or space, spatially variable data, time series), data about land use, management, and conservation practices; and economic data. The system should be interoperable with the NRCS data warehouse. Where applicable, data from the Economic Research Service (ERS) Agricultural Resources and Environmental Indicators database, other ERS sources of data on costs of conservation practices, and land use and management data of NASS or other agencies will be utilized to compile the needed data for analyses. A written document, incorporating metadata standards information from Task Group 2, will be prepared as the basis for design of the system by Task Group 3, identifying requirements for: data models, user interface, modules (data management/visualization tools), system administration and security needs, processes and data flows.
  c) Group members: Sadler, Hatfield, Bonta, Amerman, Moran, D. James, Chen, Ross, Lombardo, Ahuja (OMS), Carlson (NRCS), SWAT member.

2) Develop metadata standards
  a) Charge: Develop metadata requirements and provide a written report to Task Group 1, system requirements. They will also work with Task Groups 3 and 4, who will provide programming and other technical support required to develop a template and support system for development of metadata files. The group will develop a plan to train and offer technical support to locations in compilation of metadata files.
  b) Approach: The team will review metadata requirements from other database systems (e.g., http://www.icasa.net/data_exchange/index.html, http://badger.state.wi.us/agencies/wlib/sco/metatool/mtools.htm, http://knb.ecoinformatics.org/morphoportal.jsp) and adapt or create the standards for this database. The consensus-based approach, as in Task 1, will be utilized to develop the metadata standards for the watershed database. The 1998 Federal Geographic Data Committee's Content Standard for Digital Geospatial Metadata, FGDC-STD-001-1998, http://www.fgdc.gov/standards/standards.html, will guide the group's work. Each data element will include metadata to allow diverse end-users to evaluate the quality and suitability of particular data for particular analyses. This group will work with the CEAP researchers to link written methods protocols to data fields. A metadata template will be adapted or created and distributed to watershed sites.
  c) Group members: Sadler, Chen, Ross, D. James, Hardegree (RL), Hatfield (MSEA), Carlson (NRCS), Coshocton member, SWAT member.

3) System Design and Development
    a) Charge: Design the data system to meet system requirements and provide or obtain programming to develop the database.
    b) Approach: The group will evaluate system design documents from other data management systems, (e.g. http://www.fsl.orst.edu/hydrodb/index.htm). Based on the system requirements, the group will define the technical scope; inputs, processes, and outputs of modules; testing plan; and resource requirements. The system framework, such as the database management system (e.g., MS SQL Server, MySQL, Oracle) data harvesting/populating/updating methods, security, and web interfaces will be established. The programming tools (e.g., XML, Perl, JAVA, PHP, MS-Visual Basic, MS.net) and the skills (e.g., designer, programmers, user interface specialist, database manager/administrator) to implement, operate and maintain the data system will be identified. The operational platform (architecture/hardware, operation system, database management system, the service tools, etc, staffing requirements) will be determined. Different operational platforms may be used for the alpha system (El Reno) and subsequent systems (OCIO-supported), but the system configurations and functionality would be similar. A written Design Plan will provide direction to the Data Team Leaders (Steiner and Sadler), who will identify and help obtain required resources and collaborations, and to Task Groups 4 through 7 to guide their work.
    c) Group members: Sadler, Chen, Lombardo, J. Ross, D James, Anson, Oster, O. David (OMS), SWAT member.

4) Create Alpha database system (prototype):
    a) Charge: Develop and evaluate a prototype data system working iteratively with the System Design group.
    b) Approach: Incorporating system and design requirements as they become available from Groups 1 to 3, a prototype data system will be developed at El Reno, OK using data from the Little Washita River Experimental Watershed (LWREW) and other data. Steps will include:
        i) Perform data quality check and create a template metadata file for the LWREW data.
        ii) Develop the database structure. That is, identify the data entities (e.g. watershed unit, climate station, stream flow gauges, etc.), the associated attributes of data entity, the relationship between the data entities, and the required data tables.
        iii) Create an empty database using the SQL-based database management system (e.g. MySQL). The LWREW data will be utilized for quality testing in the system design document.
        iv) Develop utilities to facilitate data harvesting, populating and archiving LWREW data as well as for system maintenance/security. For example, a filter to restructure Little Washita data into a standardized exchange format will be developed. The LWREW data will be populated into the database.
        v) Develop web-based interfaces to provide interactions between the end users of LWREW data and the data system. For example, web-based forms will be used to query the user regarding requirements for data analysis, visualization, and compilation of input and test files for SWAT and other models. Web-based tools such as HTML, XML with embedded Java, PHP, or Perl scripts may be needed.
        vi) Implement online help, tutorials, and FAQs.
        vii) Establish a Focus Group representative of end-user groups to evaluate

        performance of the system and verify conformance to System and Design Requirements.
    c) Group members: Chen, Ross, Lombardo, James

5) Establish Beta Database system
    a) Charge: Move the prototype data system to an operational platform and establish a pilot watershed data system.
        i) Walnut Creek, IA; Godwin Creek, MS; Goodwater Creek, MO; Little River, GA; and Town Brook, NY; are priority watersheds identified by the Watershed Design and Risk Assessment Teams (See Objectives 2 and 3 below)
        ii) Priority fields will be data required for SWAT and other model input and validation files, as identified by the model validation team (see Objective 3 below).
    b) Approach: The pilot data system will be scaled up by sequentially populating data from the priority watersheds. The tasks include:
        i) Develop import filters and an Input Wizard (with Task Group 2) and provide training/support to sites in use of Metadata templates
        ii) Perform quality check on data and metadata files from the priority watersheds.
        iii) Work sequentially with the watershed teams to apply data filters and import a representative subset of data into the database.
        iv) Conduct load testing and scalability assessment according to Design Requirements.
        v) Provide online help, tutorials, FAQs as well as training and support.
        vi) Sites will need to develop required management and conservation practice layers, working with NRCS, other agencies, and through analysis of imagery.
        vii) Sites will work with Team 5 and local partners to develop required management and economic information.
    c) Group members: Chen, Lombardo, Ross, James, Pilot-site scientists and data managers, model validation team, and programmers.

6) Rollout the Pilot Database System
    a) Charge: Develop an operational platform, which will deliver a set of integrated data services and administration tools for the expanded database system.
    b) Approach: The pilot sites will apply the data filters to upload complete data sets into the database. The URL will be publicized to the CEAP team.
    c) Group members: See Task 5.

7) Release Version 1 data system
    a) Charge: Import data from additional sites and fields, including data from the Hydrology Laboratory Database http://hydrolab.arsusda.gov/wdc/arswater.html, and publicize the URL to the public.
    b) Approach: The pilot database system will be expanded to a fully implemented data system by populating additional site data into the pilot data system. A similar approach taken for building the pilot data system from the prototype data system will be followed, working sequentially with individual watershed teams to import data from local databases to the ARS Watershed Database. When data have been evaluated to the satisfaction of the local watershed research team and the CEAP Data Team, make the data for that location available to other users of STEWARDS (initially other CEAP researchers and later public access).
        i) Publish (on-line) the user's manual and technical documents that describe the information technologies, database structure, metadata standards, data policies, and web-based tools/utilities.

   - ii) Develop training materials and provide training program to the user groups.
   - iii) Promote the usage of the data system via presenting papers at conferences, in journals and establishing links to related database sites.
- c) Group Members: All.

Expected Products and Timelines, Objective 1: This objective will result in the delivery of a data system that documents the effects of conservation practices on the 12 Benchmark Watersheds. Specific tasks to be accomplished, schedules, and responsible scientists for Team 1 are shown in the **Milestones and Expected Outcomes** section. Some of the products and milestones required to meet the primary deliverable are given below.

Milestones	**Timeline – Months from start**
System requirement document completed	2 mo
System design document completed	January, 2005
Alpha DB established	January, 2005
Import wizard: Template/training for metadata delivered to pilot sites	
Beta DB completed for validation team	
Training to CEAP collaborators on pilot	
Release (web-based) available to public	

Table 2. Organization Structure for the CEAP Data Management Team.

Team Composition	Individuals	Roles, Responsibilities
Chairs	Steiner, Sadler	Lead development and implementation of plan. Monitor timelines. Communicate to CEAP and other ARS watershed sites. Coordinate with other CEAP teams and other related research/data management activities within the scientific community.
Site Research Leaders and Scientists	Various	Provide technical input to requirements of the database. Provide resources (human, fiscal, physical) for site activities. Coauthor papers, reports.
Site Data Managers	Ross, Oster, James, Batten, Hester, Anson.	Support design of database system. Work with sites on transporting data from individual sites to central systems. Support development of user interface system, documentation, and training materials.
Research Associate	Chen	Provide technical support in design of database and development of user interface. Provide technical support, programming support, and coordination to watershed sites during database population phase. Maintain communication and coordination with OCIO, model validation and development teams, and NRCS.
OCIO	Lombardo	Provide technical support to the project, particularly in areas of communication, System Requirements, Design and Development, through release. Provide access to expertise in database design, programming, database management, user interface development, GIS, IT security, and data and IT policy.
NRCS	Carlson, Anderson	Support development of System Requirements, including user interface and training plan to meet the needs of NRCS. Work with NRCS watershed liaisons in developing conservation data layers.
NPS	Weltz, Bucks, Shafer	Coordinate Program-level communication with OCIO, NRCS, and others. Work with Chairs and Research Leaders to develop data policies.

Contingencies Objective 1: It is anticipated that each watershed location will provide human and fiscal resources required to prepare metadata files, data files, and work with data team on import of data. If a location has inadequate resources, the minimal data required for CEAP analyses will be identified and the data team will provide additional support to that location. This may result in a location's data coming into the system later than scheduled.

Team leaders anticipate availability of the operational platform at the OCIO level. If this is not possible, then the pilot and/or operational data system will be maintained at El Reno or another research location.

It is anticipated that funding from NRCS will partially support this activity through FY07. If that funding were not available in future years, base funds at the locations and/or discretionary funds from the Area and Headquarters funds would support the activity but the timelines would be adjusted.

Objective 2. Measure and quantify water quality, water quantity, soil quality, and ecosystem effects of conservation practices at the watershed scale in a variety of hydrologic and agronomic settings.

A structured study of various conservation practices and their attributes affecting transfers of water, sediment, and nutrients is to be undertaken in this project. Objective 2 focuses on several issues for which knowledge has been developed concerning agricultural systems and conservation practices for improved water quality. An important element in the approach to meeting this objective is an extensive literature review of the effects of CPs on water quality and ecosystems. This review is being conducted in collaboration with a panel of experts selected by and working with the Soil and Water Conservation Society. Examples of research on the effectiveness of general programs (Gale, et al, 1993) and specific classes of CPs (USGS, 1998) will be incorporated.

Objective 2 will be divided into four sub-objectives.

Sub-objective 2a Quantify the variability of hydrologic, geomorphic and biogeochemical processes that influence the effectiveness of conservation practices (CPs) in fields, riparian zones and channels within and among selected watersheds.

This sub-objective will develop the basic understanding of the processes specific to each watershed that influence the effectiveness of CPs and the spatial and temporal distribution of key variables controlling these processes. Hydrologic, water quality, geomorphic and land use analysis and modeling will be conducted to characterize watershed conditions under which CPs can be effective. These analyses and the data acquired to support them will provide the basis for modifying, conditioning and calibrating models to simulate conditions similar to the experimental watersheds.

Scientific questions that frame the approach include:

1. What are the measurable effects of agricultural conservation and management practices on ground and surface water quality at the watershed scale?

2. What are the physical, chemical, and biological processes that affect the water-quality resulting from implementation of conservation practices in each watershed?
3. Are the water-quality effects of CPs additive, multiplicative, or independent?

Approach: The variability of characteristics and processes that control the movement and fate of water, agrochemicals, sediment and pathogens will be identified and quantified. The approach to this sub-objective will concentrate on identification and analysis of local hydrologic conditions that affect or are affected by conservation practices specifically implemented in each watershed. Interaction with local researchers and agencies implementing CPs will be included in plans. Where appropriate, comparisons between and among the selected watersheds will be accomplished on a coherent basis, requiring consistent data sets by which experiments at various scales and numerical simulations of upland, riparian, and channel processes can be undertaken. Analyses and comparisons of hydrologic and biogeochemical processes active in a variety of hydrologic settings and land-use combinations will be used to evaluate the effectiveness of a broad range of conservation programs aimed at mitigating water quality problems across the country.

1. Identify, inventory and map natural resource problems, vulnerable hydrologic conditions and potential sources of contaminants in each watershed including fields and uplands, riparian zones and channel networks. This step will result in identification of areas particularly prone to generating or delivering contaminants to water resources. Sensitive areas or conditions may include large sources of nitrogen, phosphorus, sediment, pesticides and pathogens; areas with large permeability or groundwater recharge, highly erodible areas in uplands, riparian, areas and stream channels; or areas lacking biochemical conditions to transform or store contaminants. These areas or conditions can occur individually or in combination. Mapping and analysis of critical natural resource and land-use variables that control contaminant sources, transport, and transformation processes will be conducted through a variety of activities that include combinations of the following in each watershed:
    a. Land-use inventory using information from NASS annual surveys, landowners, local NRCS offices, and FSA.
    b. Identification of CPs on fields, in riparian zones and channels in collaboration with NRCS, FSA, and state and local organizations supported by examination of aerial photography and other sources of remotely sensed data.
    c. Aerial reconnaissance of watershed and channel network to facilitate intermediate-scale analysis of landscape and channel conditions that contribute to vulnerability to water quality impairment.
    d. Ground reconnaissance of selected areas identified from analysis of indirect or remote observations
    e. Analysis of field, riparian, and channel processes in areas representing a range of hypothesized vulnerability.

2. Identify similar watershed(s) or sub-watersheds for comparative purposes and for addressing national benefits of CPs. Tasks include:

   a. Prepare summary matrix of critical variables (Table 1) and produce regional maps of those variables or surrogates showing where results may be applied based on coordination of results from all watersheds.
   b. Identify potential paired watershed study opportunities where observational research can be conducted to support comparative analysis.

3. Inventory and acquire topographic (DEM), hydrologic, general land use and soils data in digital format. This task will be coordinated with the data base development and management conducted under Objective 1.
   a. Prepare base maps with watershed boundaries, land use, hydrography, soils, geomorphic features, and landscape modifications affecting hydrology such as terraces and artificial drainage.

   b. Develop common reporting scales, frequencies, and data systems to be used for all watershed studies in collaboration with scientists pursuing Objective 1.

4. Quantify historical and existing hydrologic and geomorphic conditions and processes that control the movement of water, sediment and contaminants through the watershed and channel network. A minimum set of variables will be collected in all 12 watersheds to accommodate the modification and calibration of watershed models (see 5 below) and facilitate regional and national analysis and evaluations. These data will be collected and managed using protocols established in the data collection and standardization and database development and management sections of this plan. Included in the minimum data set are:
   a. Precipitation and evapotranspiration characteristics,
   b. Stream flow (continuous record, peaks, flow-durations, recurrence intervals, base flow),
   c. Suspended sediment, nutrient (N and P) transport (concentrations with associated instantaneous discharge to develop transport ratings, loads at given discharges, annual loads at a range of spatial scales),
   d. Specific land use identifying location of crops and livestock systems,
   e. CPs being evaluated.

   In addition to this minimum data set, other data will be collected to address issues common only to one region or a limited number of watersheds (Table 1).

   Other measures and analysis will be conducted where water quality issues and CPs warrant including:
   a. Measure channel geomorphology in watersheds where bank erosion contributes substantially to sediment loads. This will involve reconnaissance through rapid geomorphic assessments (RGAs) followed by, at minimum, determination of the channel evolution stage and channel-stability index for main-stem channels. Also included will be cross-section and thalweg surveys of main channel, particle-size distribution of bed and bank materials, and geotechnical testing of stream banks.
   b. *E. coli* concentrations and stream loads in areas with substantial sources of pathogens. This will be followed by routine measurements where local

infrastructure can be established to document temporal and spatial distribution.

- c. Sediment and water-column concentrations of pesticides in surface waters and their temporal and spatial distribution. This will be done in watersheds where significant pesticide use is coupled with historical evidence of common rainfall runoff events during application periods. This must be tied to crop, land, and chemical use surveys and/or remotely-sensed data.
- d. Soil physical, chemical, and biological properties and temporal and spatial patterns of vegetative cover and condition. This will be done in watersheds where conservation practices are anticipated to substantially impact the soil and vegetation condition in ways that may have watershed scale impacts (e.g., significant areas converted from reduced to intensive tillage, conversion of cropland to perennial vegetation, of other).

5. Relate principal source areas of contaminants to transport paths and processes using spatial analytical tools and models such as AnnAGNPS, SWAT, and CONCEPTS.
    - a. Use analysis of contaminant sources and transport paths and processes on individual watersheds over a range of spatial scales (fields, riparian areas, to target research on specific paths and processes characteristic within the channels, sub-watersheds, whole watershed).
    - b. Modify and calibrate models, where necessary, to accommodate conditions in experimental watersheds not adequately simulated in original models.
    - c. Develop or utilize existing terrain models and indices to identify areas where contaminant transport can be intercepted or modified by CPs.
    - d. Characterize contaminant transport for conditions with various levels of CP implementation to determine existing and potential effectiveness of conservation measures on concentrations and loads in streams and ground water.

6. Validate models using water quantity and water quality data from the ARS Benchmark Watersheds and make recommendation for further model enhancement and development.

Expected Products and Timelines, Sub-objective 2a:

1. Descriptions of natural resource problems, vulnerable hydrologic conditions, and sources of contaminants (Manuscripts years 1-5).
2. Research designs for paired watershed analysis of CPs (years 3-5).
3. Databases to support research within and among watersheds (initiate in year 2).
4. Improved watershed and water-quality models that accommodate the range of conditions found in all 12 watersheds (year 5).
5. Statistical summaries describing correlations between land use and trends of nutrient, sediment, pesticide, and pathogen concentrations in surface and ground water over decades and at multiple spatial scales.

Specific tasks and timelines are given in Appendix D for sub-objective 2a.

<u>Sub-objective 2b</u> Identify and quantify the effects of specific CPs and systems on contaminant and water transport processes at different scales within selected watersheds.

This sub-objective will establish a basic understanding of the effects of individual and combinations of CPs on water quality at multiple scales. Resulting information will be used to improve models to adequately simulate hydrologic and water-quality responses. Models that have been modified and calibrated to the range of hydrologic conditions represented by these watersheds will provide the basis for analyzing water-quality responses in regions with similar conditions and contribute to the national analysis.

Scientific questions that frame the approach include:

1. How does the timing and location of a suite of conservation practices affect water quality within the hydrologic and agronomic system of each watershed?
2. What is the appropriate time scale in which to expect changes in surface and/or ground water conditions?
3. What are the optimal placement patterns of CPs in a watershed that will meet water-quality goals?
4. What are the effects of CPs (individual and systems) on water and contaminant transport processes?

Approach: The specific CPs and systems of practices to be evaluated in each watershed are summarized in Table 1. The scales at which each practice may be evaluated are listed in Table 3. These practices vary among watersheds to reflect hydrologic setting, priority resource concerns, implementation priorities of local technical committees and cooperation by producers. Design criteria for any given practice may vary among watersheds, because criteria are set at the state level.

Table 3. Research watershed areas, duration of records, and experimental approaches used in the CEAP watersheds.

Watershed	Smallest area monitored (ha)	Largest area monitored (ha)	Years pre-treatment data	Years post-treatment data	Probable experimental design
S. Fork Iowa River	6	58,050	3	0	PW, PP
Walnut Creek	9	5,130	9	4	PW
Salt River, Mark Twain Lake	88	119,286	11	0	PW, PP
U. Washita River	50	13,468	NA	NA	PP, PW, UD
Goodwin Creek	11	2,130	0	22	PP, UD
Yalobusha River	2	4,000	2	3	PP, PW, UD
Beasley Lake	3	850	0-6	0-4	PP
U. Leon River	0.5	607,600	0	0	PW, UD
Little River	47	33,400	6	0	PP, UD
Town Brook	3700	91,300	0 (TBW), 6(CANN)	6	PW, PP, UD
St. Joseph River	3	2,000-4,450	3	0	PW, PP, UD
U. Big Walnut Creek	10-20	2,000-4,000	NA	0	PW, PP, UD

PW - Paired watersheds
PP - Pre and post studies and analysis of effects since initiation of CPs
UD – Upstream/downstream studies

In general, each watershed will include five components in its experimental design:

1. *Evaluate the placement of practices within a watershed.* For each practice to be evaluated in each watershed, results from subobjective 2a will be used to identify sensitive sites where it is hypothesized that a practice would be most effective in addressing a specific water quality impairment. Literature reviews and simple modeling approaches will be used to estimate how contaminant loads are reduced by given practices. Priority areas where CPs would have optimum effect, as mapped under subobjective 2a, will provide the basis to evaluate the effects of CP implementation on agricultural management systems and ownership patterns. Watershed analysis will provide policy-relevant information about pollutant trading within a watershed. The potential effect of implementing CPs under a variety of strategies (e.g., optimum placement vs. placement under random or existing entitlement criteria) will be

evaluated. Placement strategies may also be pursued at the field-scale using precision agriculture technologies.

2. *Evaluate the benefits and costs of juxtaposing two or more practices (eg. an in-field and an edge-of-field practice) within a watershed.* The body of literature on the effectiveness of individual practices for specific pollutants is growing. However, there are tradeoffs between runoff-delivered and leached pollutants. These tradeoffs are recognized but have not been quantified. An edge-of-field practice might be able to capture contaminants that an in-field practice does not effectively contain on site. We need to understand how complementary (edge-of–field) practices might compensate for off-site effects of in-field practices.

3. *Quantify specific hydrologic effects of a practice in priority settings.* Paired watershed studies are a traditional approach to quantify conservation benefits, but may be not be viable at the scale of all CEAP watersheds. Consequently, conservation benefits will also be quantified by conducting upstream/downstream comparisons (Franklin et al., 2002a), and pre/post implementation comparisons where appropriate. Thorough site investigations and hydrologic data will be conducted to define a mechanistic understanding of CP function. Under any of the experimental designs, long-term research will be conducted to obtain an understanding of water-quality responses through implementation development and maturity of CPs, as well as inter-annual hydrologic variations.

4. *Monitor hydrologic response to CP implementation at more than one scale.* A minimum three-scale nested approach will be pursued in each watershed. These include field or hillslope, small watershed, and large watershed scales (Franklin et al., 2002b). Water quality responses and discharge will be monitored at all three scales in all 12 watersheds. Direct groundwater monitoring (piezometers, lysimeters, or wells) or indirect monitoring (tile flow or base flow) will be conducted with the method to be determined in each watershed based on the groundwater resource and research needs. Research will identify how water quality responses may lag CP implementation at each scale, and effect of scale, such as stream order, on the optimal type and placement of practices.

5. *Improve, calibrate, and validate models to help quantify conservation benefits in experimental watersheds and extend assessments to similar, unstudied watersheds and regions.* Existing models will be adapted to simulate the effects of individual and combinations of CPs on specific water-quality constituents. These adaptations will be accomplished through collaboration among scientists working in each watershed and the model development and validation team. The nationwide assessment of CPs will depend on estimation techniques that include modeling with the ARS models SWAT, AnnAGNPS and CONCEPTS. Data from several of the CEAP watersheds will be used to help improve the national-scale EPIC and APEX modeling effort.

Expected Products and Timelines, Sub-objective 2b: Computer simulations have been conducted on several of the watersheds using one or more of the CEAP models available. Provided that producer incentive payments are available in each watershed, the experimental design specific to each watershed will be implemented within two years. After four years, initial results will be analyzed to determine potentials for publication and technology transfer. Techniques for mapping sensitive areas are also to be defined within two years. Modeling scenarios will be developed and compared, with the intent of publication/technology transfer within five years. Specific products include the following:

1. Mapping techniques to evaluate or plan the placement of CPs (4 years).
2. Mapping techniques and simple and complex model / assessment tools to estimate the effectiveness of placement strategies (10 years).
3. Model validation studies to assist with national assessment (5 years).
4. Design criteria to assist conservation planners to combine CPs in a whole-farm planning context (10-15 years).
5. Techniques to use watershed analyses to evaluate pollutant-trading scenarios (10-20 years).

See Appendix D for specific tasks and responsible scientists.

Watersheds contributing to sub-objective 2b: Each of the 12 benchmark watersheds will contribute to this objective. However the timing and magnitude of these contributions will vary depending on the scope and extent of water quality impairment, type and pathway of pollutants that are the target of research, scale and timing of research implementation, and nature of the practice(s) being evaluated (Tables 1).

Cross-watershed collaborations: Collaborations will be established among watersheds in which similar practices or suites of practices are being evaluated, as well as similar pathways and types of contaminants. Collaborations will also be established where experimental approaches are similar, to ensure that statistical methods and other evaluation criteria are common among watersheds. Results of model validation studies will be shared among locations to identify consistencies in modeling strengths and weaknesses that have implications for national assessments. Results of scaling studies will also be compared to determine if we can identify consistent scaling effects of water quality response to CP implementation.

Sub-objective 2c **Determine the effects of specific conservation practices and systems on terrestrial and aquatic ecosystems.**

This sub-objective will provide initial experiments to evaluate ecosystem effects in a limited number of watersheds. Efforts to meet this objective will be expanded if capacity and collaboration expands at other watersheds. The goal is to assess effects of selected conservation practices on ecological parameters at a range of scales and continuums, from uplands, edges of fields, wetlands, riparian areas, to water bodies. Scales may be defined using management zones, soil boundaries, or vegetative land cover patterns. Upland areas may include row crops, forest or grazing lands. Edge of field areas may consist of fence rows, vegetative buffers, vegetated drainage ditches, constructed or naturally occurring wetlands and small impoundments. Stream and riparian areas may be evaluated in conjunction with fencing, use-exclusion, or riparian vegetation conservation practices. Activities under this objective will supplement ongoing studies by documenting how conservation practices help create more functional ecological communities through improved habitat conditions.

Scientific questions that frame the approach include:

1. How does the timing and location of a system of conservation practices affect terrestrial and aquatic ecosystems within the watersheds studied?
2. What is the appropriate time scale in which to expect changes in terrestrial and aquatic ecosystems?
3. What are the optimal placement patterns of CPs in a watershed that will meet goals of terrestrial and aquatic ecosystems?
4. What are the effects of CPs (individual and systems) on terrestrial and aquatic ecosystems?

Anticipated outcomes of this research objective are concepts that link land and water stewardship and ecosystem improvement on our nation's agricultural landscape. It will provide quantitative documentation of habitat improvements associated with individual conservation practices and suites of practices.

Approach:

1. *Identify CEAP watersheds and other areas with similar terrestrial and/or aquatic ecosystems in which comparative studies can be conducted to assess national benefits of conservation practices (Table 3).*

2. *Define an appropriate experimental design and scales that will permit quantification of a given ecological attribute associated with a management practice or combination of practices.* A range of time spans for continuous management or a range in the amounts of management inputs to the watershed systems will be determined to estimate long-term changes in ecosystem characteristics. If suitable sites within CEAP watersheds are not available for the evaluation of conservation practices, experimental sites (proximate to, but not necessarily within the watershed) will be established to evaluate the effects of specific practices. Both sampling frequency and experimental study design will support modeling by evaluating ecological components proposed for inclusion in the watershed models currently designated for CEAP. The field sites will provide calibration or validation data sets that will greatly enhance the value of subsequent modeling on a wider scale. Under the constraints of CEAP schedules, the broadest possible time scale for the field studies will be valuable in evaluating the model applications.

3. *Define the ecological assessment process*. Assessment of improvements in watershed ecology will be measured by a balanced approach that considers both classical community and landscape ecology and a process-based approach. Classical ecology will focus on changes in species diversity, populations of organisms, and community structure within habitats. Process based approaches will focus on resource pools, abiotic driving forces, and fluxes. The assessment of effects may be achieved by either of two methods: 1)measure before and after implementation of the conservation practices or 2)contrast study sites with and without implementation of

conservation practices. Where feasible, reference sites will augment basic study design to provide fully functional ecosystem comparisons.

Specific ecological parameters or surrogates that may be affected by tillage, buffer and drainage net management (e.g., species diversity, species richness, biological community structure and integrity, habitat quality, and soil quality) will be selected from existing protocols or by protocol modification. These parameters will then be later narrowed and refined to best fit models used in CEAP assessments.

4. *Ecosystem assessment requires consideration of the entire landscape, from upland positions to within water bodies.* Over the landscape, however, are natural divisions into sub-ecosystems that may provide an opportunity to compartmentalize the way in which assessments are implemented. In the discussion below, the landscape ecosystem has been separated into terrestrial, riparian and wetland, and aquatic components. While the ecosystem components are outlined separately, it is recognized that there is overlap and interdependence among subsystems, and that the ultimate goal of this research is to demonstrate benefit to whole ecosystem health, i.e., if one link in the system is out of balance, the entire system is affected.

   a. *Terrestrial.* Terrestrial ecosystem components associated with cropping areas, buffers, field edges (specifically ecotones) and contrasting improved mesocosm-scaled habitat provided by conservation practices will be characterized and expanded to a more holistic watershed or landscape scale (Shields, et. al., 2002).

      One emphasis will be to measure changes in the ecology of soils (Coleman and Crossley, 1996) as gauged by improvements in habitat, biodiversity, and stability. Changes in soils of terrestrial ecosystems in uplands and field edges will be assessed with a multi-tiered approach that uses a minimum data set in the first tier and a second tier of tests that would be used when indicated by specific outcomes from the minimal data set (soil or water data). Such a multi-tiered approach has been used with a minimum data set to evaluate soils in four Major Land Resource Areas using 449 NRCS Natural Resource Inventory (NRI) sites (Brejda et al., 2000a). This sampling facilitated contrasting different cropping systems effects (including CRP) and group measurements into principal components that described variability (Brejda et al., 2000b; Brejda et al., 2000c). Evaluating effects of conservation practices on soil ecology will involve variables using site-specific sampling, experimentation, and modeling. Soil micro-, meso-, and macro-flora and fauna along with chemical and physical soil characteristics will be used to identify ways that management can influence soil ecology. Parameters of interest may vary by location, but will include population assessments for soil flora (e.g., Fatty Acid Methyl Ester analysis) and fauna and plants complemented by measurements of soil organic carbon content, microbial biomass carbon, aggregate stability, available water holding capacity, bulk density, electrical conductivity, and soil-test phosphorus.

      A second approach will be to use the soil management assessment framework (SMAF) as described by Andrews et al. (2004) to evaluate the effects of alternate management practices at selected locations within various CEAP watersheds. Several sampling strategies will be explored but in general they will involve either nested or landscape-based approaches. After selecting appropriate sampling sites where current conservation practices (i.e. tillage, manure management, crop sequence) are hypothesized to have a strong potential impact on water quality soil cores will be collected and analyzed for indicators such as bulk density, pH, EC, total organic C and N, aggregate stability, NO3-N, and soil-test P. The indicators will be evaluated using the SMAF framework. This will provide individual scores (0 to 1) for the various indicators that are adjusted for taxonomic class, parent material, slope, sampling time, cropping system and other factors (Andrews et al., 2004). If desired an overall additive index value for the various management practices can be computed using the framework. The indicator scores and the index value (if desired and meaningful) will then be correlated to available endpoints (e.g. leaching loss, runoff, erosion, and yield) for the soil resource areas that were sampled.

A third focus will be on habitat use with much needed new documentation on improvements in restricted habitats like those that support amphibians and Neotropical birds (global concern) (Smiley, et. al., 1997). In watersheds where row crop systems are predominant, the areas adjacent to fields provide the best opportunity for assessing habitats. Terrestrial life will be evaluated by measuring changes in species diversity, population dynamics, community structure, trophic relationships, and habitat use as affected by conservation practices (Cooper et al., 1997a,b). Wildlife (vertebrate) sample sites (Smiley et al., 1998b) will be selected in a manner to evaluate all major land use and edge categories. These may include fallow fields, CRP forest, and drainage pathways. Baited and non-baited camera traps and scent stations can be used to assess populations of large fauna, while live traps along with drift fences and pitfall traps will be used for smaller organisms, and visual observations may be used to assess avian fauna. Seining and hoop netting will be use to capture organisms in wetland areas. Mark and recapture methods will be used in the event population size estimates become necessary for management practice evaluation.

b. *Riparian and wetland.* Riparian and wetland characterization will be similar to that described for terrestrial ecosystems. Some of these assessments will include: (a) percent area with native vegetation cover (Cooper and Davis, 2000); (b) percent perennial flow channels with wooded buffer; (c) ecosystem complexity (e.g., soil conditions, vegetative diversity, and species composition); (d) species habitation numbers; and (e) indices of patchiness and connectedness for both populations and habitat (Smiley et al., 1998a).

Considerable work has been done to characterize upland soil responses to some conservation practices (e.g., various tillage) while wetland soils under other conservation practices (e.g., riparian buffers) have received less attention. Habitat associated with large wetlands is well-documented, however, biotic use of small "islands" of riparian or wetland habitat (i.e., localized conditions) such as that found on many farms has yet to be properly addressed.

c. *Aquatic.* Aquatic habitat assessment with focus on benthic macroinvertebrates (Cooper et al., 2001) and fish and their habitats (Knight et al., 2001; Knight et al., 2004) which will be sampled in perennial stream reaches or pools/ponds using a protocol based on EPA's Rapid Bioassessment Protocols for wadeable streams and rivers or ARS derived sampling techniques (Testa and Cooper, 2002). Methods will be modified as needed to suit local conditions.

The effects of conservation practices on aquatic ecosystems (Cooper et al., 2003) will be evaluated by developing a few robust, simple metrics of habitat quality that can be applied at the watershed scale. Research will be required to select the most efficient metrics suitable for wide application, but a candidate list includes: (a) stream flow expressed as one or more indices that quantify the departure from a reference condition (Richter et al. 1998); (b) water quality parameters; (c) in-channel large wood (LW) density; (d) recruitment and transport processes are considered for developing realistic estimates of in-channel debris density (Shields et al., 2000); (e) bed material type; (f) the spatial distribution of water width, depth and mean velocity at base flow; (g) degradation and depositional patterns (Cooper et al., 2000); (h) habitat quality as measured by biotic index; (i) biotic diversity.

5. *Adapt CEAP watershed models to output values of ecosystem metrics.* The utility of the ecosystem metrics will be tested by computing them for conditions within selected CEAP watersheds with a range of conservation practices. Adapting CEAP watershed models to output values of ecosystem metrics will allow measurement of the effects of conservation practices on ecological resources at the watershed scale.

Expected Products and Timelines, Sub-objective 2c:

1. Identify watersheds and supplementary sites (years 2 to 4).
2. Synopsis of historical data (year 2 to 3).
3. Establishment of parameters, designs, and scale, ensuring linkages between ecosystem improvements to the total landscape (years 2 to 4).
4. Refinement of parameters and designs (years 3 to 6).
5. Assessments documenting ecosystem improvements associated with conservation practices (years 2 to 10).
6. Model validation data sets (years 5 to 10).

Specific tasks and timelines are given in **Milestones and Expected Outcomes.**

Contingencies for Objective 2: Evaluation of conservation practices requires timely delivery from NRCS and/or FSA of digital, georeferenced data on critical variables that define the specific designs and expenses associated with each practice implemented. In the absence of these data by the end of fiscal year 2005, ARS and local collaborators will be required to use indirect methods to estimate the location and scale of CP implementation or reallocate resources and delay analysis until such time that adequate information on the location of CPs is acquired.

A collaborative system will be needed by which NRCS, FSA, and other agencies responsible for conservation programs will implement practices in areas determined critical as sources of contaminants or particularly sensitive to contaminant transport as determined by preliminary analysis during the first two years of the project. In the absence of such a system, substantial delays will result in providing data critical to validate models. However, ARS has selected watersheds that have or will have infrastructure to measure long-term changes in environmental effects as CPs are implemented under less favorable systems. Under any system of CP implementation, measurements will be available to define the effects, including defining effects that are not detectable.

It is possible that areas of a watershed where measurement infrastructure has been established will not have a sufficient number of conservation practices implemented to facilitate measurement of the environmental effects at minimum observable thresholds. Under these circumstances, only estimated effects can be reported until such time as CP implementation policies can be modified to permit confirmation of estimates and validation of models. Efforts will be made to acquire long-term USDA funds to implement practices in locations likely to produce maximum environmental effects.

The effects of CPs on soil characteristics and ecosystems will be studied in some of the watersheds. Before and after design or paired fields will be used to evaluate soil physical, chemical, and biological properties and edge-of-field runoff, sediment, and nutrient losses from baseline and conservation cropping systems. Runoff, sediment, and nutrient losses will be determined using rainfall simulator studies. In addition, selected paired-field sites will be instrumented to measure natural runoff using small in-field runoff collectors (Franklin et al., 2002c) for use in model (EPIC/APEX) validation.

Concepts and equations from the CENTURY model have been adapted to develop a sub-model of C and N transformations in soil as an addition to APEX (Izaurralde et al., 2001). In preliminary evaluation using data from Texas, Kansas, Nebraska and Canada simulation of soil organic C changes explained about 91% of variation in those data (J. Williams and W. Dugas, personal communication, 2002). Following further validation of APEX using data collected in this project, we will simulate soil carbon (including total carbon, metabolic litter, structural litter, microbial biomass, slow humus, and passive humus) associated with baseline and conservation scenarios. The Soil Quality Index Tool (Andrews et al., 2004) will be evaluated using research data and used for communications and outreach within the watersheds.

Data from these field-scale soil studies will be used develop contrasting soil parameters for analyses of “conservation” vs. “conventional” scenarios at a watershed scale, with the scenarios customized to be relevant to each particular watershed.

Objective 3. Validate models and quantify uncertainties of model predictions at multiple scales by comparing predictions of water quality to measured water, soil and land management effects of conservation practices.

Approach: This analysis will validate output and quantify uncertainty effects on output caused by spatial variability/resolution, temporal variability and measurement errors from selected models using stream flow and water quality data collected from the 12 Benchmark Watersheds. This analysis will also present comparisons between scenarios of various conservation practice implementation patterns within ARS watersheds that have extensive data histories. The analysis will estimate changes in key environmental components indicative of water quality resulting from USDA's conservation programs. This analysis will consider the NRCS Core 4 practice categories: 1) nutrient management; 2) tillage management; 3) conservation buffers; and 4) pest management. Each of these conservation management categories contains numerous individual conservation practices. Over 250 individual conservation practices are described in the NRCS Conservation Programs Manual and are available for implementation.

The model evaluation and uncertainty analysis objective will utilize the data collected in Objective 2 (Measure and quantify effects of conservation practices) as archived in Objective 1 (Develop and implement a data system). This will include model input data such as weather, soils, land use and management and also soil and water quality data used for model validation and uncertainty analysis. Validated model output will be used in Objective 4 (Develop and apply policy planning tools) as input to economic models. The model validation and uncertainty analysis team will work closely with scientists working on Objective 5 (Develop and verify regional watershed models) to improve the existing models and incorporate the models into OMS.

Model Validation and Uncertainty Analysis. This analysis will serve as a broadly qualitative benchmark against which the accuracy of the National Assessment will be evaluated. The watersheds that are suitable for this analysis are limited. This limitation is primarily due to the availability of detailed information on the watersheds' physical characteristics, management history, and the existence of a long-term database documenting changes in measurement endpoints for both stressors and assessment endpoints. The 12 ARS Benchmark Watersheds (see Appendix A) will be used for the analysis.

The CEAP National Assessment will perform a large-scale validation of APEX and SWAT model output for each 8-digit watershed defined by the USGS. Using data from over 15,000 gauging stations and spatial interpolation using regression analysis, the USGS has determined stream flow, sediment and nutrient loadings for each 8-digit watershed (approximately 2,100 in the coterminous U.S.). Although the National Assessment validation provides confidence in model output at the national scale, it does not ensure that the models are accurately simulating specific management practices or that upland and channel processes are realistically simulated at multiple scales. The Watershed Assessment validation and uncertainty effort described here will provide a more detailed validation and uncertainty analysis of scale processes and NRCS conservation practices than the National Assessment. This will add considerable confidence to the National Assessment and also provide a basis for future model improvements.

Model Selection. Models are accumulations of mathematical algorithms that provide output based on a pre-defined set of relationships between endpoints of concern and the environmental processes controlling their cycling, leaching and runoff to receiving waters. These algorithms reflect our best understanding of these processes but incorporate differing process assumptions, have different structures, and, as a consequence, may yield somewhat different results. To evaluate the quality of assessments, and how they may translate to cost criteria that will affect risk management policy decisions, there are three questions that must be addressed in order to evaluate the potential implications of basing policy decisions on model predictions: 1) Are the differences between our "best science" model projections statistically and environmentally significant; 2) What are the magnitudes of variation within and between locations evaluated; and 3) What are the model components that contribute the most sensitivity to variation in precision of output?

The water quality analysis will compare measurable environmental indicators of water quality with and without implementation of the conservation programs. The National Assessment (like most national environmental policy) relies heavily upon the codification of our best environmental research into models that simulate the response of environmental assessment endpoints (water quality) to stressors (agriculture). The National Assessment has selected the Soil Water Assessment Tool (SWAT) for its simulation of an average national water quality response to conservation practice implementation. The ARS WAS will also use the SWAT model to provide a direct point of comparison to the National Assessment. In addition, the ARS WAS will compare SWAT model output with results from other models that incorporate different process representations in their simulations. A comparison of these models will provide information on the variation in response predictions that may be provided by our best current understanding of the relationships between stressor (land management) and assessment endpoint (water quality). The additional models that will be evaluated in this analysis include: 1)the Annualized Agricultural Non-Point Pollution Simulator (AnnAGNPS) model (Bingner and Theurer, 2001), 2) the Riparian Ecosystem Management Model (REMM) (Lowrance et al., 2000), and 3) the Conservational Channel Evolution and Pollutant Transport System (CONCEPTS) model (Langendoen, 2000).

Conservation Practice Scenario Development. For each watershed, the relative frequencies of adoption will be determined for the conservation practices most frequently implemented for water quality improvement. Model comparisons will be made simulating water quality impacts that result from adoption of the top practices (up to three) in each watershed. Simulations will consider each of the dominant practices being adopted individually and mixed combinations of individual practice adoptions (Table 4). For each combination of practices simulated, comparisons will be made assuming adoption rates on 0, 10, 30, 50 and 100 percent of the agricultural acreage in the watershed. Model runs will also be conducted simulating water quality impacts for current practice adoption rates and for adoption rates in 1985 (or earliest available) to estimate actual current condition and potential improvements since conservation program implementation. Acreage not enrolled in conservation programs will be considered unmitigated production agriculture typical of the watershed.

Table 4. Percent Practice Implementation Test Matrix.

	Practice A	Practice B	Practice C
Scenario 1	0	50	50
Scenario 2	50	0	50
Scenario 3	50	50	0
Scenario 4	33	33	33
Scenario 5	100	0	0
Scenario 6	0	100	0
Scenario 7	0	0	100

Measurement Endpoint Identification. The endpoints considered indicative of water quality for this first phase of ARS WAS will include components that are already encoded as outputs from the SWAT and AnnAGNPS models (stream flow -- continuous record, peaks, flow-durations, recurrence intervals, base flow; suspended sediment; nutrient -- N and P species; and most heavily used pesticides). The probability that the measurement endpoint would be reduced by a particular amount in comparison to several benchmark criteria will be reported. Benchmarks for evaluation of the likelihood that each target stressor will have an adverse effect will be the appropriate state-established TMDL and state criteria for peak concentrations. The output from simulations will be a family of response curves for each response unit-scenario-benchmark combination that indicate:
1) the practices or practice combinations resulting in the greatest absolute magnitude of risk reduction potential (reduction level at 100% acreage adopting practice); 2) the practices or practice combinations resulting in the greatest incremental returns on investment (largest slope in response to increased acreage); and 3) whether effective thresholds of reduction exist (linear versus logarithmic responses to acreage increases).

Sub-objective 3a Develop a model validation standard for systematic quantification of accuracy in CEAP-WAS simulations.

Approach: The American Society of Civil Engineers (1993) recommends comparing model-generated estimates to observed data, both visually and statistically, as a method of evaluating model performance. Visual comparisons in the form of graphical plots (hydrographs) provide a general overview of the data while statistical goodness-of-fit comparisons provide a quantitative evaluation of model performance. Visually comparing simulated flows to observed flows will be a necessary first-step. Particular attention should be given to the timing and magnitude of peak flows and the shape of recession curves. Comparing measured versus simulated flow duration curves will aid in determining how well the model predicted the range in magnitude of daily flows throughout the validation period.

Three criteria for quantifying the agreement between simulated and observed values of continuous stream flows are recommended including deviation of stream flow volumes (D_v), Nash-Sutcliffe model efficiency coefficient (E), and prediction efficiency (P_e). These tests will complement the visual inspection of the hydrographs. The deviation of stream flow volume is a measure of the accumulation of differences in the observed and simulated values for the particular period of analysis. Lower D_v values indicate better model results and D_v equal to zero indicates a perfect model.

The second evaluation criterion is the model coefficient of efficiency (Nash and Sutcliffe, 1970), which Sevat and Dezetter (1991) found to be the best objective function for reflecting the overall fit of a hydrograph. Model efficiency expresses the fraction of the measured stream flow variance that is reproduced by the model. The coefficient of efficiency (E) for any continuous time series output can be computed. In cases where E equals zero the model estimate is no better as a predictor than is the observed average, while E equal to one indicates a perfect fit of the model solution. In Motovilov et al (1999), simulation results were considered to be good for values of $E \geq 0.75$, while for values of E between 0.75 and 0.36, the simulation results were considered to be satisfactory. Values less than 0.36 were considered to be unsatisfactory.

The third evaluation criterion is the prediction efficiency (P_e) which is the coefficient of determination (r^2), computed by regressing the ranking of descending values of observed versus simulated daily stream flow. To a large degree the prediction efficiency is a quantitative measure of the flow duration curve, since it measures the closeness of fit over the range in values of observed and simulated runoff. The range of r^2 is 0 to 1 and typically values greater than 0.5 are considered acceptable.

Sub-objective 3b Validate models using water quantity and water quality databases from the 12 ARS Benchmark watersheds and make recommendations for further model enhancement and development.

Approach: The ARS Benchmark watersheds will serve as a standard for comparison to develop calibrations and also to quantify the exact range of error in model outputs. The CEAP National Assessment will validate the APEX and SWAT models at the large watershed scale using available data from the U.S. Geological Survey. However, the ARS Benchmark watersheds, with long and comprehensive data histories, provide the only source of information detailed enough to answer the question of how well these models reflect reality. In addition to the long data histories, the advantage offered by the nested small watershed assessment studies is the increased spatial and temporal resolution needed for error and uncertainty analysis.

The CEAP-WAS program, in response to the 2002 Farm Bill, requires examining watershed management scenarios needed to meet the wide diversity of conservation objectives, including protection and enhancement of soil, water, and air quality, carbon storage, wildlife habitat, and other environmental benefits. The set of ARS modeling tools implemented to meet this demand will have to address on-farm effects like soil quality as well as off-farm effects such as reductions in the potential for contamination of water and air from farm fields and impairment of downstream aquatic habitat. Equally needed is the identification of sources of pollutant loading within a watershed. We will validate the CONCEPTS and REMM models on watersheds where processes such as stream/riparian water quality and channel erosion are important. The existing ARS models are not able to address, individually or collectively, all resource concerns. This is in part because of the lack of a complete understanding of the interacting processes over the full range of spatial and temporal scales of operation, and in part because the magnitude of interaction between individual processes varies substantially among regions and even among watersheds within regions, resulting in the yet unresolved model-transferability problem. Therefore, a significant portion of the validation effort will be devoted to identifying needs and making recommendations for further model enhancement, development and regionalization that would address benefits of conservation practices and other environmental issues in the major agricultural regions of the nation and for use in future watershed and national assessments.

Sub-objective 3c Estimate uncertainty in model predictions resulting from calibration parameter identification and ranges of input data resolution and quality.

Approach: Two causes of model uncertainty will be evaluated. The first is model input uncertainty caused by spatial variability, temporal variability and measurement errors. There have been several techniques developed to automate model calibration and to estimate the impact of input uncertainty on model output. These techniques include the Monte Carlo method, Latin-Hypercube simulations, and global population evolution-based search methods. These techniques will be reviewed and as appropriate linked with the models to estimate model input uncertainty impacts on selected ARS benchmark watersheds using measured inputs and results from gaging stations for analysis.

The second form of uncertainty arises in using data from different spatial resolutions. Different levels of uncertainty could be defined for various levels of spatial resolutions. For selected ARS benchmark watershed, all model scenario runs will be completed using three levels of input data resolution:

1. Uncalibrated model default parameter sets (as in the National Assessment);
2. Model parameter sets that have been calibrated to match watershed observations as closely as possible; and
3. Detailed site-specific parameterizations where input data are collected at resolutions exceeding those of nationally-available data bases.

The value of predicted water quality measurement endpoint(s) resulting from multiple proportions of the sub-watershed cropped acres in conservation practices will be plotted for each level of input data resolution (Figure 3). Deviations in the acreage required to achieve target concentration reductions will be developed. Acceptable levels of uncertainty at various resolutions with varied conservation practices will be developed. In the example presented in the idealized Figure 3, the national default parameterization predicts that a reduction of the target measurement endpoint from 12 mg/L to 8 mg/L would require between 58 and 75% of a watershed to be in conservation practice, while the site-specific parameterization of the model predicts a requirement of between 20 and 35%. Comparisons will also be made to historical water quality monitoring databases from the ARS WAS benchmark watersheds and relative levels of model output deviation from observed data will be reported. The magnitudes of these deviations will be reported as estimates of potential uncertainty in values reported by the National Assessment.

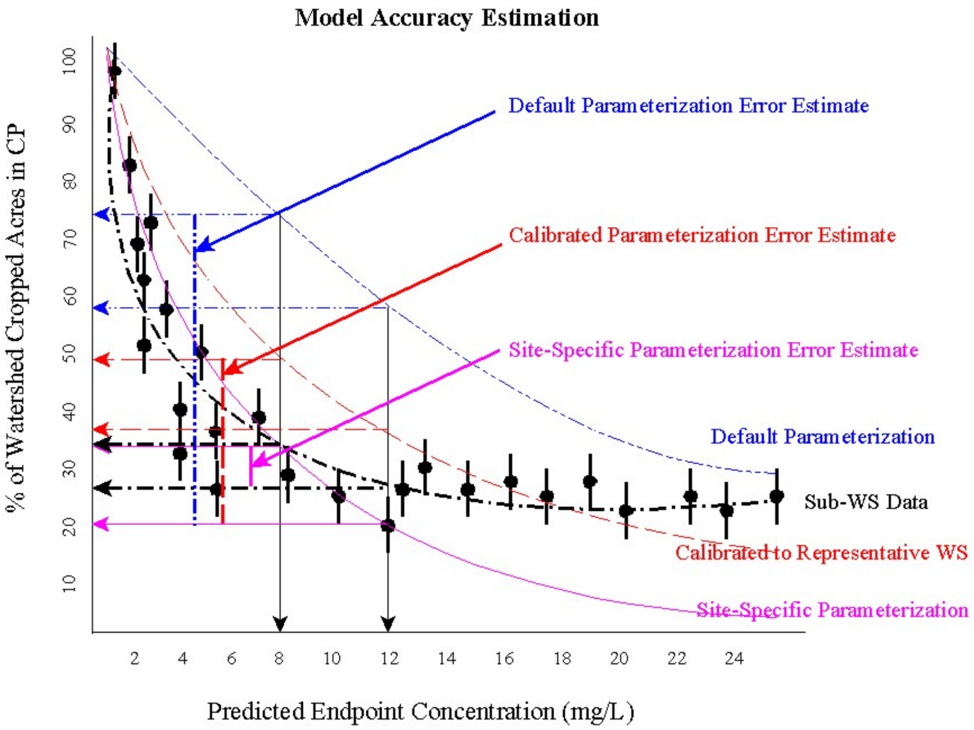

Figure 3. Effect of input data resolution on comparison of model output to actual watershed data.

<u>Sub-objective 3d</u> Estimate the sensitivity of water quality responses to targeted placement of conservation practices within individual watersheds.

Approach: Model input data will be sub-divided to the individual farm-field scale within ARS WAS benchmark watersheds in order to delineate minimum sizes for distinct polygons (HRUs or sub-watershed or field…depending on model terminology). It is proposed that the repeated parsing of polygon area will result in a population of simulation units that sufficiently represent the full range of response potentials that exist within the benchmark watersheds. SWAT and AnnAGNPS simulations will be run and the predicted measurement endpoint concentration for each polygon will be plotted as a cumulative distribution (Figure 4). If the shape of the resulting cumulative frequency curve is linear, all polygons are predicted to respond equally to conservation practice implementation. However, a non-linear curve suggests that some simulation units are predicted to respond more strongly to practice implementation. Such a result will be taken as indication that policy-makers may have the option of targeting implementation within larger watersheds to increase program effectiveness. Such results will also be used to target research efforts into responsive watersheds to help select landscape characteristics indicative of “hot spots” or highly sensitive areas.

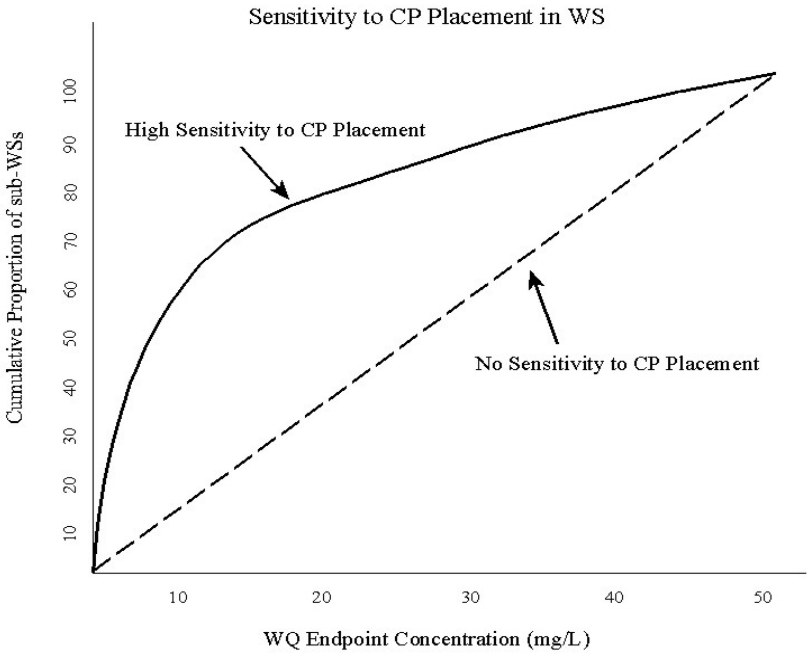

Figure 4. Shape of curves depicting sub-watershed responses as cumulative distributions estimate sensitivity to practice placement.

<u>Sub-objective 3e</u> Develop tools to identify watersheds and/or sub-watersheds most likely to respond to conservation practice implementation.

Approach: Model input data will be sub-divided to represent each first-order stream reach as a sub-watershed within each of the ARS WAS benchmark watersheds. SWAT and AnnAGNPS simulations will be run assuming that 0, 10, 30, 50, and 100% of the cropped acres in the watershed have conservation practices implemented. The value of predicted water quality measurement endpoint(s) predicted for each sub-watershed will be plotted as a cumulative frequency distribution (CDF) for each level of practice implementation (Figure 5). The magnitude of deviation between the CFD curves at different levels of implementation is proposed as an estimate of the magnitude of response that can be expected to result from an individual practice (or suite of practices) implemented in the target watershed (or region represented by the benchmark watershed). For example, in the idealized example presented, the “responsive” watershed is predicted to see a reduction of ~ 40 mg/L in the measurement endpoint on at least 50% of its sub-watersheds when the test practice is implemented on 30% of the cropped acres in the watershed. The less responsive watershed is predicted to see a reduction of only ~15 mg/L under the same conditions.

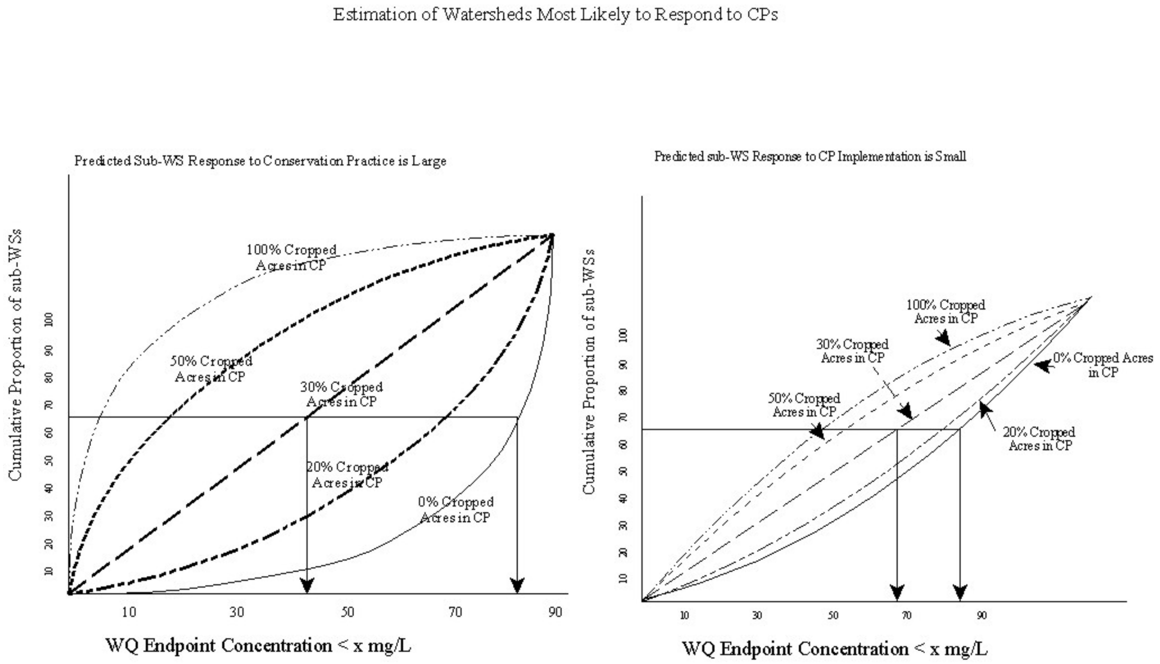

Figure 5. Use of sub-watershed cumulative response distributions to identify watersheds most likely to benefit from practice implementation.

<u>Sub-objective 3f</u> Develop tools to estimate the temporal resolution (timing and magnitude) of conservation practice effects within watersheds.

Approach: SWAT and AnnAGNPS simulations will be run assuming that 0, 10, 30, 50, and 100% of the cropped acres in the watershed have conservation practices implemented. The value of predicted water quality measurement endpoint(s) predicted for each level of practice implementation will be plotted with monthly resolution (Figure 6). Results will be examined to determine whether there are specific times during the year when practice implementation(s) are predicted to manifest the greatest reduction in measurement endpoints of concern. Model predictions will be compared to historical monitoring data from the benchmark watersheds: 1) to estimate the potential magnitude or uncertainty associated with model output; 2) to evaluate whether some regions are more susceptible to acute reductions in water quality; and 3) to estimate the magnitude of improvement that might accrue from conservation practice implementation. At selected benchmark watersheds, the potential magnitudes of reductions will be compared to sensitive life stages of aquatic biota to evaluate the potential for adverse impact.

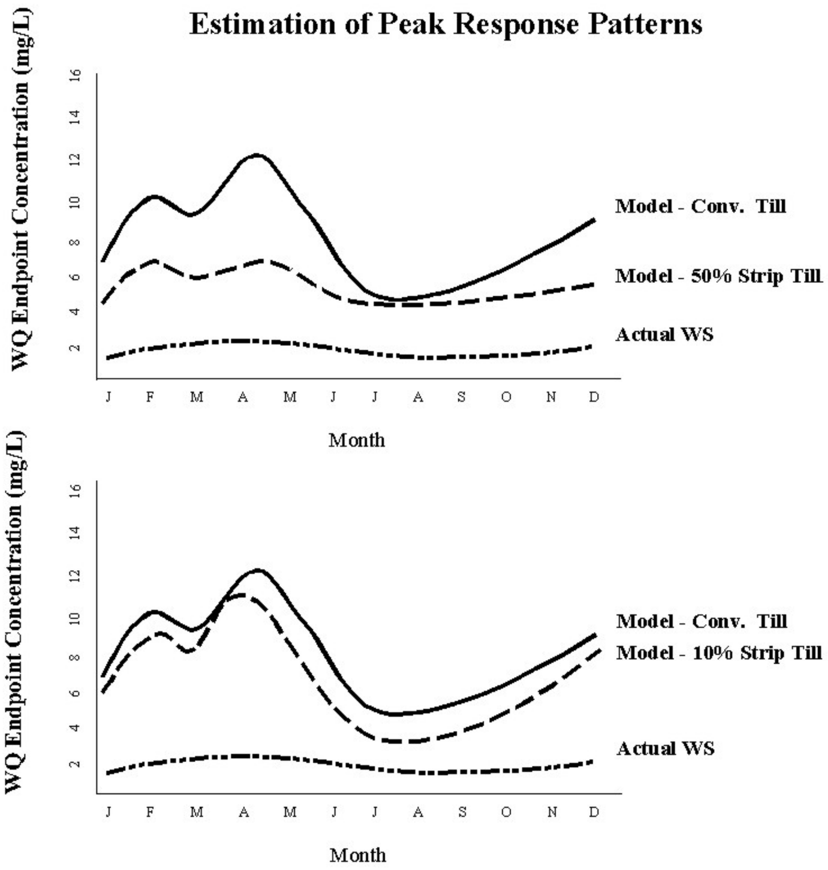

Figure 6. Increased resolution of model output time steps to estimate effect of practice implementation on peak response improvements.

Expected Products and Timelines, Objective 3:

1. A comparison of the magnitude of model prediction differences (relative model error) for selected measurement endpoints estimated at the national, regional and small watershed scales (FY 2006).
2. A comparison of predicted water quality improvements with actual water quality trends for selected measurement endpoints (model accuracy) (FY 2006).
3. An analysis of variations in regional sensitivities to model input data (e.g., land use) resolution (FY 2006).
4. A comparison of the shape variations in Cumulative Distribution Functions of predicted population responses to changes in acreage adopting conservation practices to indicate whether distinctly responding sub-populations of watersheds can be identified (FY 2007).
5. An analysis of the relative regional efficacy for suites of conservation practices (FY 2007).
6. Standard calibration data scenarios tailored to regional conditions...thus improving confidence in subsequent assessments (FY 2008).
7. An analysis presenting minimum adoption thresholds for major homogeneous regions of the U.S. (FY 2008).
8. Develop a validation standard for quantification of model accuracy (2004).
9. Develop data sets for evaluation and validation of five benchmark watersheds (2004).
10. Simulate impact of current and proposed conservation practices on five benchmark watersheds (2005).

11. Develop data sets for evaluation and validation on remaining seven benchmark watersheds (2005).
12. Simulate impact of current and proposed conservation practices on remaining seven benchmark watersheds (2006).

Additional details of products and timelines for Team 3 are given in the **Milestones and Expected Outcomes** section.

Contingencies for Objective 3: Estimations of uncertainty in model projections will require detailed input information specific to the benchmark watersheds and sub-watersheds being evaluated. Specific information required includes: delineation of land use change over time; location, type, timing, and degree of practice implementations; availability of soil maps at multiple resolutions; detailed records of farm management histories within watersheds; detailed information on farm management plans and associated costs; and the availability of detailed aerial photographs and/or satellite imagery covering a 20-30 year history. Much of this information exists in NRCS and FSA files but may not be available in digital format or may be restricted from anything more than on-site access. The timely provision of all such input data sets is required at least 24 months prior to product delivery. In the absence of actual data, watershed teams will develop surrogate estimates for the required higher-resolution data sets. Examples include: 1) using topographic information to estimate variation and location of different soil types in the watersheds; 2) substitution of "typical" crop rotations and associated management inputs for actual land management histories; and 3) use of nearest NOAA weather station data for estimates of watershed climatology.

The greatest value for comparison to model estimates of watershed responses to practice implantation will come from benchmark watersheds where targeted implementation percentages can be established within select sub-watersheds. In the absence of the ability to target resources, we will use aerial photographs and satellite imagery to estimate the extent of conservation practices being applied within benchmark watersheds (e.g., winter covers, residue removal, grassed waterways) as a surrogate for actual farm management information.

Comparison to actual watershed data and to National Assessment regional populations of watersheds will require the timely delivery of such information to the Risk Analysis Team. Comparison to these data sets will be made only for those watersheds providing complete information.

Objective 4. Develop and apply policy-planning tools to aid selection and placement of conservation practices to optimize profits, environmental quality, and conservation program efficiency.

Economic and social issues associated with conservation practices will be addressed in this project two ways. First, basic economic and social studies, such as the impacts of alternative conservation practices, will be conducted on three selected Benchmark Watersheds through extramural agreements with university cooperators. Second, Team 4 will develop policy planning tools that can be used by NRCS to assist in selection and placement of conservation practices to optimize profits, environmental quality and other issues. The data obtained through the extramural agreements will be used to validate and test the policy planning tools. The tools that are developed will be tested on the Benchmark Watersheds and supplied to NRCS for use in policy planning.

The three watersheds where socio-economic assessment will be conducted are: Town Brook, NY; Upper Big Walnut Creek, OH; and St. Joseph River, IN. All these watersheds are source waters to major metropolitan areas. The water quality concern at Town Brook is excessive P from animal production systems. At the St. Joseph River and Upper Big Walnut Creek watersheds, agricultural chemicals and sediment from row cropped corn and bean productions are the focus of conservation effect assessment.

The socio-economic assessments will be expanded to other of the Benchmark Watersheds as funds are available during the course of the project.

Three goals for conservation practices and programs will be assessed under this objective: (1) environmental outcome at the watershed level; (2) profit maximization at the farm level; and (3) program efficiency. These goals may be either complimentary or conflicting. In mathematical programming, this is accomplished by expressing each sub-objective as an objective function subject to constraints. The results of the multiple-objective optimization will be a set of pareto-optimal solutions (Pedersen and Goldberg, 2004) that represent different preferences of the decision-maker. Approaches to achieve these goals including data collection, optimization objective functions, computational environment and methods are detailed below.

Data Collection. In an experimental study of a conservation practice, it is useful to gather information on the costs of implementing the practice, and any resulting change in revenue. This information is necessary, but not sufficient for the calculation of an optimum solution. The farmer has other production activities where the money could be used, and the revenue foregone in those alternative activities. The opportunity cost, must be used to evaluate the true cost of a conservation practice to the farmer. The calculation of the economic costs of a conservation practice therefore requires information on the prices and quantities of all inputs and outputs of all production on a farm. The economic analysis is dependent on farm-level data, and a model that optimizes over all production activities at the farm level.

Physical data and the SWAT model setup for each study watershed will be provided by Teams 2 and 3. Economic data for three selected watersheds will be provided by the extramural agreements.

Analytical Framework - **GOAL 1**. The environmental outcomes at the watershed level are obtained from the models produced in Objective 3 of this study. These outcomes consist of levels of production of unwanted (bad) outputs, including sediment and agricultural chemicals released into the environment, or any other measures derived from the model. Environmental performance indexes will be constructed that include all relevant variables for a study watershed following the approach of Färe and Grosskopf (2004). These indexes are based on production relationships, that in effect, endogenize the weights assigned to each bad outcome.

GOAL 2. Maximization of farm profit subject to the production model and conservation constraints will yield values for the optimal use of traditional inputs, conservation activities and optimal output levels. Data envelopment analysis (DEA) provides the best methodology for the economic analysis of agricultural technology and practices required by USDA-ARS-CEAP. DEA was introduced by Charnes, Cooper and Rhodes (1978), and avoids the assumption of efficiency, functional form and error distribution common to other methods of production analysis (Färe and Primont, 1995). **GOAL 3.** Program efficiency is calculated from the cost minimization solution that achieves a change in environmental quality (calculated above).

Each sub-objective is specified as an objective function in an optimization. Recent methods of multi-objective optimization allow the calculation of the pareto-optimal set in a single optimization. The results of the optimization will allow a stake-holder to chose (or compare) a pareto-optimal solution based on their own preferences.

Computational Environment. At the National Forage Seed Production Research Center (NFSPRC), USDA, Whittaker has constructed a Beowulf cluster (Sterling, et al., 1995) consisting of a server and 12 computation nodes. The server node has 2 Pentium 4 processors (3.2 GHz.), 1 Gigabyte of RAM, a 10/100 Mbps (megabits/second) NIC (network interface card) for contact with the outside world and an integrated INTEL 10/100/1000 Mbps NIC for the private network. The computation nodes each have a Pentium 4 (2.4 GHz.) processor, 1 Gigabyte of RAM, and an integrated INTEL 10/100/1000 Mbps NIC. All the machines have hard drives. The nodes are connected through a 1 Gigabyte/second ethernet switch. A single keyboard, monitor and mouse serve all the machines through a 16 port KVM switch. The operating system on the cluster is Linux, Redhat 9.0, kernel version 2.4.20-20.9 SMP. The OSCAR cluster software package (Open Cluster Group, 2003) was selected for installation, primarily because it supports Redhat 9.0 (Whittaker, 2004).

Computational Methods. A genetic algorithm (GA) offers two major advantages for the large computational problem posed by this study. First, a GA provides an effective method for multi-objective optimization (Deb, 2001), and second, the theoretical speed increase offered by parallel computation can be approached by calculating the evaluation of the GA at each mutation on a different computational node. The GA will be implemented using PGAPack (Levine, 1996), a general-purpose GA algorithm library that uses the MPI interface for parallel computing. In this computational set-up, the main program reads in the data, calls PGAPack functions, and sets the objective functions and constraints. In the evaluation of each mutation, SWAT is called as a subroutine. There is a working prototype of this software at the NFSPRC that is currently being used for auto-calibration of SWAT and for estimation of risk and uncertainty using SWAT (Whittaker, 2004). The software is compiled into a single LINUX executable file that can run on any LINUX system. The software is much faster on a parallel computer, but will run on a single processor without alteration.

The use of a genetic algorithm provides a method for a direct linkage of the physical model with the economic model. In the evaluation step of the GA, a calibrated physical model is called as a subroutine with arguments from solutions from the last generation, and the objective functions are specified as constraints. The output from the physical model is therefore endogenous in the optimization to calculate the pareto-optimal set of solutions.

Objective 4 will be accomplished through the following sub-objectives with Sub-objectives 4a-4c focusing the assessment on the three selected watersheds and Sub-objectives 4d-4f for all Benchmark watersheds.

Sub-objective 4a Determine the farm firm financial impacts of and the decision making values for utilizing alternative production practices and systems given the unique natural capital, environmental characteristics and cultural norms in the three selected watersheds.

Approach: Develop farm firm production decision models including input, output, and practice choices that characterize farm decisions consistent with unique physical and cultural environment for each of the selected watersheds.

Sub-objective 4b Determine which acres, which production systems, which inducements and the level of costs involved to induce land management changes to meet alternative WQ standards (TSS, DO, chemicals, fecal coliform, etc.).

Approach: Develop models for selection of BMP and other approaches to achieve particular pollution reduction goals. These models will consider overall program cost, as well as farm-level response based on farm firm production and financial models, and incorporate hydrologic transport models for the watershed.

Sub-objective 4c Estimate and place a value on some of the benefits resulting from reductions in concentration of contaminants and the corresponding changes in ecological system health.

Approach: Using state-of-the-art economic methods (e.g. experimental economics, contingent valuation and hedonic modeling), estimate the value of a portion of the benefits resulting from the pollution reduction and the concomitant increase in environmental quality.

Sub-objective 4d Develop planning tools to assess environmental outcome at the watershed level.

Approach: Acquire data on environmental outcome at each benchmark watershed from the watershed team representative. Optimize placement of conservation practices using environmental criteria. Team 3 will provide calibrated models with all associated data and code, the uncertainty of model predictions, estimates of response and cost for conservation practices, and tools for estimation of timing, magnitude and response of watershed to conservation practices.

<u>Sub-objective 4e</u> Develop planning tools to assess the profit maximization at the farm level.

<u>Approach:</u> Acquire data on input/outputs at the farm and field scale from the watershed representatives, and from publicly available sources. Acquire, from Team 3, data on the cost of a conservation practice and the response at the farm level. Specify farm level model of production based on profit maximization. Specify farm level model of production based on profit maximization, subject to constraints of conservation practices and environmental effects.

<u>Sub-objective 4f</u> Develop planning tools to assess the conservation plan's efficiency and pareto-optimal solutions based on the results of the multiple-objective optimizations in 4d and 4e.

<u>Approach:</u> Specify basin level model of production based on profit maximization, subject to constraints of conservation practices and environmental effects and perform multiple-objective optimization.

Expected Products and Timelines, Objective 4: This research will result in socio-economic data and methodologies for assessing the impacts of USDA conservation programs. The tasks and timelines for Team 4 development of the policy planning tools are given in the **Milestones and Expected Outcomes** section.

Contingencies for Objective 4: Data acquisition is the major contingency that must be considered for objective 4. Economic data at the farm level is difficult and expensive to obtain. There are no national surveys that offer enough observations at the study watershed level. The alternative strategy to a watershed census would be a combination of extension budgets and budget generators to obtain field level data. Representative farm data could be inferred from the budgets using Census of Agriculture data to estimate distributions. Farm management and input data collected during the MESA study at benchmark watersheds in Missouri, Iowa and Mississippi can be used in a postmortem fashion in conjunction with the physical data collected at these watersheds. Maximization of the profit function will be most affected by this data, optimization of environmental quality and program efficiency much less so.

Objective 5. Develop and verify regional watershed models that quantify environmental outcomes of conservation practices in major agricultural regions.

Different physiographic and agro-climatic regions of the country typically have different dominant hydrologic processes, agricultural systems and management, and environmental problems. They, in turn, influence the nature of conservation practices and their effects. Theoretically, it may be possible to expand a watershed model to include options for all different processes, practices, and problems. However, such a model will soon become too big, complex, and unwieldy for users. It will also become difficult for current but especially future developers to update and maintain. Therefore, it is prudent to customize or tailor watershed models by regions. At the same time it is also prudent to use object-oriented, stand-alone, modular components in building such a model, so that each component is easier to understand, test, and modify or replace in the future. In the process of building these new models of the future, we will also attempt to assure that the models go from field scale to a sub-watershed and on to the watershed scale in a sound and consistent manner in representing the effects of conservation practices.

New assessment tools are needed for the CEAP National Assessment to provide scientifically sound results across regions. The current modeling tools SWAT, AnnAGNPS, REMM and CONCEPTS, while very functional for their originally intended use, can be difficult to expand to include dominant processes and practices in each region because of their monolithic nature. A flexible modeling structure is needed to efficiently build models that are customized to regional processes, concerns, and issues. The goal of this objective is to develop a modular computer model structure with interchangeable components that can address differences in regional soil and water conservation and water quality needs. The modular model will be developed using components or modules from the existing models that represent the best available science for assessing the effects of conservation practices as much as possible, supplemented by new or improved components as needed. However, the development of all stand-alone, independent, reuseable, and interchangeable components or modules for different regions is a long-term goal (10+ years). The complex and interwoven nature of the existing watershed models and different programming languages often used will require a lot of manual effort and time to allow ideal modularization of all components during the 4-5 years of this project. Our major focus during this period will be to develop the computer framework to build regionalized modular watershed models, with necessary auxiliary functionalities such as visualization, parameter estimation, and uncertainty analysis. As an interim step, we will break up the large models into coarse, non-independent, multi-module components and adopt them for different regions, either outside or inside the Object Modeling System (OMS) described below. All the needed new or improved components will be independent OMS-compatible modules.

In the long-term, this project will use a new framework of modular model development that integrates modular scientific components of existing models and future models into a common, collaborative, and flexible system. Such a system will maintain modularity, reusability, and interoperabililty or compatibility of both science and auxiliary components. The system will also recognize the fact that different categories of applications may require different levels of scientific detail and comprehensiveness, as driven by problem objectives, scale of application, and data constraints. These functionalities of the system will be obtained by establishing standard libraries of inter-operable science and auxiliary components or modules that provide the building blocks for a number of similar applications.

The Object Modeling System (OMS), currently under development by ARS, USGS, and NRCS, will provide a new model development environment. The performance of the scientific modules will be verified, and the completed regionalized watershed models will be tested against data from the ARS Benchmark Watersheds and other sources. Development will be carried out to upscale results of field and watershed analysis to areas as large as 8-digit hydrologic unit watersheds. A prototypic working regional model will be produced for a region that will demonstrate how OMS can be used to develop a regionally tailored model. User documentation and training materials will be developed for technology transfer.

This objective will be accomplished through the following sub-objectives:

Sub-objective 5a Identify regions and define process and sub-process modules for each regional area of the national assessment of effects of conservation practices and systems.

Approach: The accomplishment of this sub-objective will involve the following steps:

1. Identify preliminary modeling regions based on practical experience with the functions and characteristics of current models in dealing with the problems, local conditions (topography, soils, water, climate, management/conservation practices, etc.), situations, scenarios, system boundaries, that exist in the various regions.
2. Define the process and sub-process modules and sources that will be needed in each region. The modules should simulate the processes consistently from fields or management units to watershed scale.

Sub-objective 5b Obtain needed scientific components from existing relevant legacy software tools for use in CEAP regional assessment. Depending on the complexity of the code, the components may be coarse multi-modules at this stage.

Approach: The accomplishment of this sub-objective will involve the following steps:

1. Extract relevant scientific components from legacy software such as SWAT, AnnAGNPS, REMM, and CONCEPTS, or other models as appropriate, and integrate them into OMS.
2. Identify and develop necessary auxiliary function modules (e.g. GIS and common database access, parameter estimation, uncertainty analysis)

Sub-objective 5c Identify and develop additional modules to address improved simulation of conservation practices/systems, BMPs and other processes.

Approach: The accomplishment of this sub-objective will involve the following steps:

1. Evaluate the existing technology to simulate the effects of BMPs and identify the best available methods.
2. Develop modules from identified methods.
3. Verify the new modules against the origin.
4. Evaluate modules against measured data

Sub-objective 5d Develop modular spatial modeling, scaling, parameterization methodologies to accurately transmit the effects of various conservation practices/systems on different farm fields and site-specific management units to watershed scale. This modeling has two components: first from fields or management units with a single management practice to fields with different management practices, and second from fields to channels. Different processes come into play in these two phases.

Approach: The accomplishment of this sub-objective will involve the following steps:

1. Identify the appropriate spatial modeling methodology, scaling techniques and the input parameters to be scaled.
2. Evaluate the existing land-to-land, land-to-streams, and in-stream transport methodologies to scale the field effects to watershed level.
3. Develop and implement the improved spatial modeling and up-scaling procedure in OMS.

Sub-0bjective 5e Develop prototype regional fields-to-watershed model integrating appropriate modules and data linkages.

Approach: The accomplishment of this sub-objective will involve the following steps:

1. Provide tools for verification and validation of assembled model packages.
2. Assemble prototype and evaluate with test data.

Sub-objective 5f Transfer modular system to regional modeling and assessment teams.

Approach: The accomplishment of this sub-objective will involve the following steps:

1. Develop user documentation.
2. Train regional model development teams.

3. Provide ongoing support.

Expected Products and Timelines, Objective 5: This research will result in the development and testing of new modular models for specific regions that can be used by NRCS to quantify environmental effects of conservation practices. The models will be delivered to NRCS at the end of the project. Tasks, goals, and responsible scientists for Team 5 are given in the **Milestones and Expected Outcomes** section.

Contingencies for Objective 5: The successful development of the OMS system and the creation of the OMS library of reuseable scientific and auxiliary modules are heavily dependent on extracting modules from existing models. The level of difficulty in extracting the modules depends on the complexity and degree of interwoven structure of the code of the parent model. During the 5 years of this project, we may have to extract coarse, multi-module components that will later be decomposed further into stand-alone modules. In cases where modules are not available or cannot be extracted from existing models, new modules will be developed. Each new module will need to be individually tested and verified. The long-term objectives are the development, testing, and verification of stand-alone reusable modules.

The OMS team is keeping abreast of similar system developments in other countries, particularly Europe and Australia. The team will initially analyze the OMS system to determine which parts of the system need to be replaced, modified, or extended to achieve the objectives and requirements of the project. Timely sources of filling these needs will be identified based on the European and Australian experiences.

Collaborators

ARS will work in close partnership with NRCS on this project. NRCS will provide information on implementation of conservation practices on the Benchmark Watersheds and technical assistance to land owners in applying conservation practices on the land. NRCS will also provide soils and land use data needed to conduct water quantity and quality analysis, soil quality analysis, and economic analysis. ARS and NRCS have entered into Interagency Agreement number 67-3A75-4-63 (NRCS)/60-0500-4-1000 (ARS) to define the role for each agency in conducting the Conservation Effects Assessment Project. The two agencies will be assisted by a diverse group of collaborators in each watershed. The collaborators include state environmental agencies, conservation districts, educational institutions, state Agricultural Experiment Stations, businesses, municipalities, watershed alliances, land owners, and others.

Integration and Project Management

The primary purpose of this project is to support the CEAP National Assessment by delivering the five anticipated products listed on page 4 to NRCS and other stakeholders. The project involves more that 50 scientists spread across 12 ARS research locations with field data being collected on 12 Benchmark Watersheds. Successful accomplishment of the purpose of this complex project can be achieved only through careful coordination and management.

Integration. The five project objectives are tightly linked. Figure 7 is a graphical description of the relationship among the five teams that are charged with achieving their respective objectives and delivering the products to NRCS for use in the National Assessment. Team 1 is charged with developing a data system for storing and managing the basic data and delivering the data system to NRCS. The data system will be populated by data collected by Team 2 on the 12 watersheds. Team 6 will provide guidelines for methods and procedures to be used for data collection and analysis. Close coordination among Teams 1, 2, and 6 is required to ensure that meaningful data are obtained from the watersheds and entered into the data system. Team 2 is also responsible for delivering to the Nation Assessment team a quantification of the effects of various conservation practices as determined on the watersheds.

Team 3 is responsible for evaluating the performance of the models that will be used in the National Assessment and delivering estimates of uncertainty in model outputs. The model evaluations will be done using data collected on the watersheds. To accomplish this objective, scientists in Team 3 will work closely with field researchers in Team 2 to evaluate the models on specific watersheds and with Team 1 to access data in the data system for model evaluation.

Team 4 will be involved with developing economic planning tools for delivery to the National Assessment team. The work involves coupling physical models from Team 3 with economic models to form a tool for determining optimal multi-objective decisions regarding selection and placement of conservation practices; therefore, co-ordination between Team 3 and Team 4 is required. Economics data will be collected jointly by Teams 2 and 4 on selected watersheds that will become part of the data system, thus requiring cooperation among Teams 1, 2, and 4. The economic planning tools developed by Team 4 will be provided to the National Assessment team.

Team 5's primary responsibility is the development of region-specific models in modular form. The team will use models developed by Team 3 as legacy models for development of regional modular models. Coordination with Team 3 will be required to determine which features are needed for specific regions and to ensure that modular versions of models give correct results. Teams 3 and 5 will work together to test the new models. Team 5 will also work closely with Team 1 to obtain data for testing the new regional modular models. The regional modular models developed by Team 5 are expected to be available at the end of this project. The new modular models will be provided to the National Assessment team for future assessments.

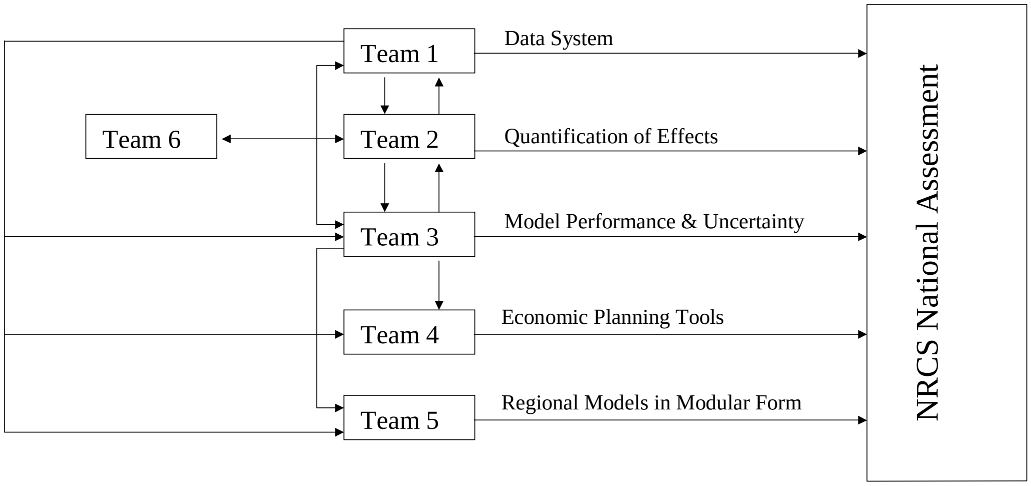

Figure 7. Relationship among six CEAP research teams.

Task Management. The completion of the objectives of this project requires the timely execution of numerous inter-dependant tasks. The specific tasks to be accomplished are shown in the **Milestones and Expected Outcomes** section. Timelines and responsible scientists are shown for each task. A quarterly progress reporting system will be implemented to ensure that the project stays on track. The quarterly reports will involve a simple green light, yellow light, red light system. A green light for a specific task will indicate that the task is on schedule with no problems. A yellow light will indicate that a problem exists but that the responsible parties can correct the problem. A red light will indicate that a major problem exists that will require intervention by a higher level of management. Team Leaders will request these stop light reports from each responsible scientist on their respective teams in October, January, April, and July each year. The Team Leaders will compile the reports for all tasks within their teams and forward to the CEAP Coordinator. When significant problems exist, the Coordinator will work with the ARS National Program Staff, Research Leaders, and Area Directors as appropriate address the problem.

Annual Meetings. Regularly scheduled annual meetings will be held involving the ARS CEAP leadership, all participating scientists, selected representatives from NRCS, and invited guests as appropriate. The purpose of the annual meetings will be for investigators to report significant results and achievements and to promote communication among all participants. Opportunities will be provided for individual Team planning sessions as well as inter-team coordination.

External Reviews. A standing external CEAP Review Panel will be appointed. The Panel will be composed of a representative from NRCS with CEAP leadership responsibilities and others from organizations that have an interest in conservation programs. The Panel will be asked to attend the CEAP Annual Meetings to hear progress reports and future plans. After each meeting, the Panel will provide an assessment of progress and a critique and/or recommendations for future direction. The CEAP Coordinator and the National Program Staff will use the Panel's annual recommendations as a basis for project re-alignment.

Physical and Human Resources

This project is unique in terms of the number of locations and scientists, and overall resources dedicated to this 5-year effort. An extensive network of collaborations is required to meet the project's goals, and the failure of one scientist or team to deliver specified products endangers the success of the whole. Given the unique design and urgency for completion of this project in a timely manner, both Line Managers and National Program Staff must exercise their normal duties and responsibilities meticulously if the CEAP plan is to be successfully implemented and the milestones and goals achieved as outlined in the project plan.

To implement the entire CEAP plan, specific roles and responsibilities are required in addition to the normal oversight and coordination by the CEAP Coordinator and Team Leaders, as follows:

CEAP Coordinator

- Oversee the implementation of the project.
- Coordinate and co-direct the overall effort of the ARS CEAP watershed assessment studies and coordinate the development and execution of the National Assessment modeling activity.
- Organize and coordinate ARS CEAP Team meetings and conference calls to ensure that the specific CEAP objectives, goals, and deliverables are met in a timely manner.
- Coordinate the preparation of quarterly Team Management Reports summarizing the Teams progress/concerns towards completing its goals. Disseminate the quarterly reports (October, January, April, and July) to Area Directors (AD), National Program Leaders (NPL), Research Leaders (RL) and Team Leaders.
- Organize and conduct annual meetings of all CEAP scientists to provide communication and coordination.

Team Leaders

- Ensure all Team Members (as described in the Project Plan) understand their responsibilities to meet the objectives, goals, and deliverables of the project plan.
- Implement the CEAP Project Plan by working with the Coordinator, Research Leaders, Team Members, NPLs, and ADs.
- Prepare quarterly Team Management Reports summarizing the Teams progress/concerns towards completing its goals. Distribute the reports to the Coordinator on the fifteenth day of September, December, March, and June of each year.
- Assist the Coordinator in organizing and conducting annual meetings of all CEAP scientists.

Scientists and Support Personnel

The 57 scientists involved in the project are listed in Appendix A. Each scientist will be responsible for:

- Conducting each assigned research task (see **Milestones and Expected Outcomes** below).
- Providing quarterly progress reports to the appropriate Team Leader.
- Participating in annual CEAP scientist meetings.

The scientists are supported by a large number of well-trained field and laboratory technicians, computer specialists, and other technical support personnel.

Physical Resources

The ARS locations involved in the project have a wealth of physical resources available for the research. The 12 Benchmark Watersheds have state-of-the-art water measurement and water sampling equipment in place with other equipment to be added during the course of the project. Many of the research locations have well equipped laboratories for analysis of soil, plant, and water samples.

Milestones and Expected Outcomes

Project goals, tasks, and, milestones assigned to each team are given below:

ARS Data Management - Team1

Team Leaders: Jean Steiner, El Reno, OK and John Sadler, Columbia, MO

Overall Responsibilities:

1. Determine data management procedures/protocols to be used.
2. Develop metadata requirements.
3. Design, develop, and implement a web-based data system.
4. Monitor progress made in implementing the data management system for the watersheds.
5. Document and archive information on the number and kind of conservation practices implemented on watersheds and water and soil quality parameters in cooperation with other agencies and watershed partners.

Overall Deliverable to NRCS:

1. Provide a water, soil, management, and socio-economic data system to document effect of conservation practices.

Objective 1. Develop and implement a data system to organize, document, manipulate and compile water, soil, management, and socio-economic data for assessment of conservation practices.

Goal	Task	Start Date	Target Date	Responsible Scientist
1.1 Refine and implement the operational and communication plan for Objective 1.	**1.1.1** Develop and implement a communication and monitoring process to coordinate the multiple aspects of the project.		done	Steiner
	1.1.2 Develop a data policy that meets the needs of the CEAP-WAS research team and is consistent with Agency, Department, and Government data policy.	Jan 05	Oct 2005	Steiner, Lombardo
1.2 Define the system requirements and prepare a written document that will provide the basis for System Design.	**1.2.1** Review system requirements documents from other data management systems (e.g., MSEA, U.S. Forest Service Hydrological Data Access Project http://www.fsl.orst.edu/hydrodb/.	Jan 04	Oct 04	Sadler
	1.2.2 Acquire inventory of data sets compiled from ARS watershed sites and model input, and output requirements from the models required by the research teams.		done	Ross
	1.2.3 Incorporate information from the inventory of data sets compiled from ARS watershed sites, the inventory of methodologies used to measure particular fields, model input and output requirements for the models to be used by the research team to identify the capacity/functionality of the data system (e.g. data fields, data access, analysis, visualization).	July 04	Aug 04	Sadler,

Goal	Task	Start Date	Target Date	Responsible Scientist
	1.2.4 Utilize the consensus-based approach to develop the system requirements for the watershed database.	underway	Sep 04	Sadler
	1.2.5 Deliver a written system requirements plan to the database design group and the CEAP Team Leaders. See goal 1.5	underway	Oct 04	Sadler
1.3 Develop the metadata requirements for the project and provide a written requirements report. Deliver report to systems requirement group.	**1.3.1** Incorporate information from the inventory of data sets compiled from ARS watershed sites, the inventory of methodologies used to measure particular fields, model input and output requirements for the models to be used by the research team to identify data fields and metadata requirements.	July 04	Aug 04	Sadler, Chen
	1.3.2 Utilize the consensus-based approach to develop the metadata standards for the watershed database.	Aug 04	Sep 04	Sadler
	1.3.3 Deliver a written metadata requirements to the system requirement group.		Sep 04	Sadler
1.4 Develop a metadata wizard to support watershed locations in preparing the metadata files. This goal is linked with goal 6.1	**1.4.1** Adapt or create a metadata template.	June 05	Dec 05	Chen, Lombardo
	1.4.2 Develop methods to capture data from methods report from Team 6.	Jan 06	Jan 07	Chen
	1.4.3 Develop training schedule	Sep 05	Dec 05	Chen and watershed RLs
	1.4.4 Train and offer technical support to locations in compilation of metadata files.	Dec 05	June 06	Chen
1.5 Design a data system that will meet system requirements. Obtain the needed programming.	**1.5.1** Based on system requirements define the technical scope, inputs, processes, and outputs of modules, testing plan, and resource requirements.	Nov 04	Mar 05	Sadler Lombardo, Chen
	1.5.2 Establish the system framework, such as the database management system (e.g., MS SQL Server, MySQL, MS-ACCESS, Oracle) data harvesting/populating/updating methods, security, and web interfaces.	Nov 04	Mar 05	Sadler Lombardo, Chen
	1.5.3 Identify the programming tools (e.g., XML, Perl, JAVA, MS-Visual Basic, MS.net) and the skills (e.g., designer, programmers, user interface specialist, database manager/administrator) to implement, operate and maintain the data system.	Nov 04	Mar 05	Sadler, Lombardo, Chen
	1.5.4 Determine the operational platform (architecture/hardware, operation system, database management system, the service tools, etc, staffing requirements)	Nov 04	Mar 05	Sadler Lombardo, Chen
	1.5.5 Provide a written Design Plan to the Data Team Leaders (Steiner and Sadler), who will identify and help obtain required resources and collaborations, and to Task Groups 4 through 7 to guide their work.	Nov 04	Mar 05	Sadler Lombardo, Chen

Goal	Task	Start Date	Target Date	Responsible Scientist
1.6 Develop a prototype data system according to the specifications of the System Design.	**1.6.1** Perform data quality check and create template metadata files for the LWREW data.	Jan 05	Aug 05	Chen, Ross
	1.6.2 Develop the database structure. Identify the data entities (e.g. watershed unit, climate station, streamflow gauges, etc.), the associated attributes of data entity, the relationship between the data entities, and the required data tables.	Jan 05	Aug 05	Chen, Lombardo, Ross
	1.6.3 Create an empty database using the SQL-based database management system (e.g. Microsoft Access). The LWREW data will be utilized to perform QA/QC procedures identified in the system design document.	Jan 05	Aug 05	Chen, Lombardo, Ross
	1.6.4 Develop utilities to facilitate data harvesting, populating and archiving LWREW data as well as for system maintenance/security. For example, a filter to restructure Little Washita data into a standardized exchange format will be developed. The LWREW data will be populated into the database.	Jan 05	Aug 05	Chen, Ross
	1.6.5 Develop web-based interfaces to provide interactions between the end users of LWREW data and the data system. For example, the web-based forms to query data for data analysis, visualization, and compilation of input and test files for SWAT and other models. The web-based tools such as HTML, XML with embedded Java or Perl scripts may be needed.	Mar 05	Aug 05	Chen Lombardo
	1.6.6 Implement the online help, tutorials, and FAQs to help the users utilizing the data system.	Mar 05	Aug 05	Chen Lombardo
1.7 Extend the prototype data system to a pilot watershed data system by including the data from five priority watersheds. The watershed data system will support the goals of the CEAP-WAS model validation team and provide web-based access pilot locations and the modeling team.	**1.7.1**Perform quality check on the data and metadata files from the priority watersheds.	Aug 05		Chen and watershed RLs
	1.7.2 Work sequentially with individual watershed teams to apply the data filters and import a representative subset of data into the database.	Aug 05		Chen and watershed RLs
	1.7.3 Conduct load testing and scalability assessments according to design requirements.	Aug 05		Chen, Lombardo
	1.7.4 Work with NRCS, other agencies, and Sites to document required management and conservation practice layers.	Aug 05		Steiner

Goal	Task	Start Date	Target Date	Responsible Scientist
	1.7.5 Sites will work with Gerald Whitaker and local partners to document required management and economic information.			Steiner
	1.7.6 Adapt the web-based utilities/tools, developed in the prototype data system, for the pilot data system. The web-based utilities/tools will provide interactions between the modeling team members and the pilot data system.			Chen
	1.7.7 Provide online help, tutorials, FAQs as well as training/support to the end-users.			Chen, Lombardo
1.8 Develop an operational platform, which will deliver a set of integrated data services and administration tools for the expanded database system.	**1.8.1** Apply the data filters to upload complete data sets into the database and publicize the URL to the CEAP team.			Chen, Lombardo
1.9 Import data from additional sites and fields, including data from Hydrology Laboratory Database http://hydrolab.arsusda.gov/wdc/arswater.html.	**1.9.1** Work sequentially with individual watershed teams to develop programs to import data from local databases to the ARS Watershed Database.			Chen, watershed RLs
	1.9.2 Develop map that identifies all CEAP-WAS Benchmark Watersheds and other ARS Watersheds and provides background information			Chen, Lombardo
1.10 Develop and implement documentation, training, and long-term operation of the data system. Provide web-based access to the public.	**1.10.1** Develop the user's manual to access the ARS watershed data system, the technical documents that describe the information technologies, database structure, metadata standards, data policies, and web-based tools/utilities.	Aug 05	Aug 06 At pilot scale	Steiner, Chen
	1.10.2 Develop the training materials and provide training program to the public.	Aug 05	Aug 06 At pilot scale	Steiner, Chen
	1.10.3 Promote the usage of the data system to the public via presenting the papers on the conferences, in the journals and contacting the related database sites for providing the links from their web sites to the ARS watershed data system.	Oct 07	Oct 09	Steiner, Sadler

ARS Watershed Design for Determining Environmental Effects - Team 2

Team Leaders: Mike Burkart, Ames, IA; and Martin Locke, Oxford, MS

Overall Responsibilities:

1. Design methods to assess effects of conservation practices on water quality, water conservation, soil quality, and aquatic and terrestrial ecosystems at the watershed scale.
2. Identify dominant conservation practices to be assessed in various settings through collaboration with local NRCS representatives and local watershed committees.
3. Select methodologies that can be used to quantify environmental effects/benefits from single and multiple conservation practices.

Emphasis will be placed on coordinating existing watershed activities, defining modifications in existing project plans, and determining methods for collecting data relative to single and multiple conservation practices.

Overall Deliverable to NRCS:

2. Quantification, at multiple scales, of the effects of conservation practices on water quality, water quantity, soil quality, and ecosystems.

Models to be Studied: SWAT (S), AnnAGNPS (A), CONCEPTS (C), REMM (R), PRZM (P)

<table>
<tr><th colspan="5">Objective 2. Measure and quantify water quality, water quantity, soil quality, and ecosystem effects of conservation practices at the watershed scale in a variety of hydrologic and agronomic settings.</th></tr>
<tr><th colspan="5">Sub-objective 2a. Quantify the variability of hydrologic, geomorphic and biogeochemical processes that influence the effectiveness of conservation practices (CPs) in fields, riparian zones and channels within and among selected watersheds.</th></tr>
<tr><th>Goal</th><th>Task</th><th>Start Date</th><th>Target Date</th><th>Responsible Scientist</th></tr>
<tr><td rowspan="2">2.1 Identify, inventory, and map natural resource problems, vulnerable hydrologic conditions and potential sources of contaminants in each watershed including fields and uplands, riparian zones and channel networks. Sensitive areas or conditions may include large sources of nitrogen, phosphorus, sediment, pesticides and pathogens; areas with large permeability or groundwater recharge, highly erodible areas in uplands, riparian, areas and stream channels; or areas lacking biochemical conditions to transform or store contaminants.</td><td>2.1.1 Collect Land-use inventory using information from NASS annual surveys, landowners, local NRCS offices, and FSA.</td><td>BL TBD
GC 10/04
SFIR 10/04
LitR 10/04
MTR 09/04
StJ TBD
TB 10/04
WC TBD
UBWC 10/04
UWR 10/05</td><td>BL TBD
GC 9/05
SFIR 10/09
LitR 9/09
MTR 4/05
StJ TBD
TB 12/07
WC TBD
UBWC TBD
UWR 10/09+</td><td>Locke
Bingner
Tomer
Bosch +
Lerch
Heathman
Gburek
Jaynes
King
Starks</td></tr>
<tr><td>2.1.2 Identification of CPs on fields, in riparian zones and channels through collaboration with NRCS, FSA, and examination of aerial photography and other sources of remotely sensed data.</td><td>BL TBD
GC 10/04
SFIR 10/04
LR TBD
LitR 10/04
MTR 10/03
StJ TBD
TB 10/04
WC TBD
UBWC 10/04
UWR 5/04
YR 10/04</td><td>BL TBD
GC 9/05
SFIR 10/09
LR TBD
LitR 12/09
MTR 9/07
StJ TBD
TB 12/07
WC TBD
UBWC TBD
UWR 10/06
YR 9/07</td><td>Locke
Bingner +
Tomer
K.Potter
Sullivan
Lerch
Heathman
Gburek
Jaynes
King
Starks
Romkens</td></tr>
</table>

Goal	Task	Start Date	Target Date	Responsible Scientist
	2.1.3 Collect aerial reconnaissance of watershed and channel network to facilitate intermediate-scale analysis of landscape and channel conditions that contribute to vulnerability to water quality impairment.			
	2.1.4 Collect ground reconnaissance of areas identified from all indirect or remote observations			
	2.1.5 Evaluate the need for including detailed analysis of field, riparian, and channel processes in areas representing a range of hypothesized vulnerability.			
2.2 Identify similar watershed(s) or sub-watersheds for comparative purposes and for addressing national benefits of CPs.	**2.2.1** Prepare summary matrix of critical variables identified under A.1 and produce regional maps of those variables or surrogates showing where results may be applied based on coordination of results from all watersheds.	SFIR TBD MTR 10/06 StJ TBD UWR TBD	SFIR TBD MTR 9/07 StJ TBD UWR TBD	Tomer Lerch Warnemuende Starks
	2.2.2 Identify potential paired watershed study opportunities where observational research can be conducted to support analysis under Objective 2.	SFIR 10/04 LR 10/04 LitR 10/04 StJ TBD TB 10/04 WC TBD UBWC 10/04 UWR TBD YR 10/04	SFIR 10/05 LR 10/05 LitR 9/05 StJ TBD TB 12/07 WC TBD UBWC TBD UWR TBD YR 9/07	Tomer Harmel Bosch Warnemuende Gburek Jaynes King Starks Wilson
2.3 Inventory and acquire topographic (DEM), hydrologic, general land use and soils data in digital format. This goal will be coordinated with the data base development and management activities in CEAP.	**2.3.1** Prepare base maps with watershed boundaries, land use, hydrography, soils, geomorphic features, and landscape modifications affecting hydrology such as terraces and artificial drainage.	BL TBD GC 10/04 SFIR 10/04 LitR 10/04 MTR 1/06 StJ TBD TB 10/04 WC TBD UBWC 10/04 UWR 2/04 YR 10/04	BL TBD GC 9/05 SFIR 10/09 LitR 9/09 MTR 9/07 StJ TBD TB 12/07 WC TBD UBWC TBD UWR 10/05 YR 9/07	Locke Bingner + James Sullivan Lerch Heathman Gburek Jaynes King Van Liew Wilson+
	2.3.2 Develop common reporting scales and data systems to be used for all watershed studies. This is a joint task with Team 1 and Team 3. Team 3 will provide guidance for data sets. Team 1 will provide database structure.	GC 10/04 SFIR TBD LitR 10/04 MTR TBD StJ TBD TB 10/04 WC TBD UBWC 10/04 UWR 4/05	GC 9/05 SFIR TBD LitR 9/09 MTR TBD StJ TBD TB 12/07 WC TBD UBWC TBD UWR 12/05	Bingner Tomer Lowrance Lerch Heathman Gburek Jaynes King Steiner

Goal	Task	Start Date	Target Date	Responsible Scientist
2.4 Quantify historical and existing hydrologic and geomorphic conditions and processes that control the movement of water, sediment and contaminants through the watershed and channel network.	**2.4.1** Collect the minimum data set including: a. precipitation and evapotranspiration characteristics b. streamflow (continuous record, peaks, flow-durations, recurrence intervals, baseflow) c. suspended-sediment, nutrient (N and P species) and pesticide transport (concentrations with associated instantaneous discharge to develop transport ratings, loads at given discharges, annual loads at a range of spatial scales) d. specific land use identifying location of crops and livestock systems e. CPs either in place or planned	BL TBD GC 10/04 SFIR 10/04 LitR 10/04 MTR 1/03 StJ TBD TB 10/04 WC TBD UBWC 10/04 UWR 1/04 YR 10/04	BL TBD GC 9/05 SFIR 10/09 LitR 9/09 MTR 9/07 StJ TBD TB 12/07 WC TBD UBWC TBD UWR 10/09+ YR 9/09	Cullum Alonso + Tomer Bosch+ Lerch, Vories Heathman Gburek Jaynes King Starks Wilson
	2.4.2 Collect other data to address issues common only to one region or a limited number of watersheds. This includes: a. Channel geomorphology in watersheds where bank erosion contributes substantially to sediment loads. This will involve reconnaissance through rapid geomorphic assessments (RGAs) followed by, at minimum, determination of the channel evolution stage and channel-stability index for main-stem channels. Also included will be cross-section and thalweg surveys of main channel, particle-size distribution of bed and bank materials, and geotechnical testing of streambanks. b. Conduct reconnaissance measurements of *E. coli* concentrations and stream loads in areas with substantial sources of pathogens. This will be followed by routine measurements where local infrastructure can be established to document temporal and spatial distribution. c. Conduct reconnaissance surveys of sediment and water-column concentrations of pesticides in surface waters and their temporal and spatial distribution. This will be done in watersheds where significant pesticide use is coupled with historical evidence of common rainfall runoff events during application periods. This must be tied to crop, land, and chemical use surveys and/or remotely-sensed data.	Channel GC 10/04 UWR 10/06 Pathogen BL TBD SFIR 10/04 LR 10/05 Pesticides BL TBD LitR 10/04 MTR 3/05 StJ TBD UBWC TBD	Channel GC 9/05 UWR 10/09 Pathogen BL TBD SFIR 10/07 LR 10/09 Pesticides BL TBD LitR 9/09 MTR 9/07 StJ TBD UBWC TBD	Channel Simon Van Liew Knight Moorman Harmel Smith T.Potter Lerch Warnemuende King

Goal	Task	Start Date	Target Date	Responsible Scientist
2.5 Relate principal source areas of contaminants to transport paths and processes using spatial analytical tools and models such as AnnAGNPS, SWAT, CONCEPTS.	**2.5.1** Use analysis of contaminant sources and transport paths and processes to target research on specific paths and processes characteristic within the individual watersheds over a range of spatial scales (fields, riparian areas, channels, sub-watersheds, whole watershed).			
	2.5.2 Develop or utilize existing terrain models and indices to identify areas where contaminant transport can be intercepted or modified by CPs.	SFIR 10/04 MTR 11/04 StJ TBD TB 4/04 UBWC 10/04	SFIR 10/09 MTR 9/07 StJ TBD TB 12/07 UBWC TBD	Tomer Lerch Heathman Veith King
2.6 Evaluate the placement of practices within a watershed.	**2.6.1** Evaluate each watershed, using the results from sub-objective 2a to identify sensitive sites where it is hypothesized that a practice would be most effective in addressing a specific water quality impairment.			
	2.6.2 Use Literature reviews and simple modeling approaches to estimate how contaminant loads are reduced by given practices. Priority areas where CPs would have optimum effect, as mapped under sub-objective 2a, will provide the basis to evaluate the effects of CP implementation on agricultural management systems and ownership patterns.			
2.7 Evaluate the juxtaposing of two or more practices (eg. an in-field and an edge-of-field practice).				
2.8 Quantify the specific water-quality effects of a practice in priority settings.	**2.8.1** Quantify conservation benefits by conducting upstream/downstream comparisons, and pre/post implementation comparisons where appropriate.			
	2.8.2 Conduct thorough site investigations and collect hydrologic to define a mechanistic understanding of CP function.			
2.9 Monitor water quality and quantity response to CP implementation at more than one scale. A minimum three-scale nested approach will be pursued in each watershed. These include field or hillslope, small watershed, and large watershed scales.	**2.9.1** Monitor water quality responses and discharge at all three scales in all 12 watersheds.			
	2.9.2 Conduct direct groundwater monitoring. (piezometers and lysimeters or indirect tile flow or baseflow).	SFIR 10/05 MTR 10/04 UWR 5/05 StJ TBD YR 10/04	SFIR 10/09 MTR 9/07 UWR 10/09+ StJ TBD YR 9/09	Tomer Lerch Daniel Warnemuende Wilson

Goal	Task	Start Date	Target Date	Responsible Scientist
2.10 Improve, calibrate, and validate models to help quantify conservation benefits in experimental watersheds and extend assessments to similar, unstudied watersheds and regions.	**2.10.1** Adapt existing models to simulate the effects of individual and combinations of CPs on specific water-quality constituents. These adaptations will be accomplished through collaboration among scientists working in each watershed and Team 3 and Team 5.	Watershed-Model	Watershed-Model	
		SFIR-S-10/06	SFIR-S-10/09	Tomer
		LitR-R-10/04	LitR-R-9/09	Lowrance
		LitR-S&A-10/04	LitR-S&A-9/09	Bosch
		MTR-S-10/03	MTR-S-9/07	Lerch
		StJ-S&A-TBD	StJ-S&A-TBD	Heathman
		TB-S-4/04	TB-S-12/07	Veith
		WC-S-TBD	WC-S-TBD	Jaynes
		UBWC-S-TBD	UBWC-S-TBD	King
		UWR-S-6/04	UWR-S-12/07	Starks
		UWR-A-12/05	UWR-A-12/07	Starks
		UWR-C-6/07	UWR-C-10/09	Starks
		YR-A-10/04	YR-A-9/09	Bingner
2.11 Deliver mapping techniques used to evaluate or plan the placement of CPs.		GC 10/04	GC 9/05	Bingner
		SFIR 10/05	SFIR 10/09	Tomer
		StJ 10/06	StJ 9/09+	Heathman
		Channel	Channel	
		GC 10/04	GC 9/05	Simon+
		BL TBD	BL TBD	Locke
		YR TBD	YR TBD	Wilson
2.12 Deliver mapping techniques and simple and complex model/assessment tools to estimate the effectiveness of placement strategies.		GC 10/04	GC 9/05	Bingner
		SFIR 10/07	SFIR 10/09	Tomer
		StJ 10/06	StJ 9/09+	Heathman
		MTR 10/04	MTR 9/07	Lerch
		TB 4/04	TB 10/07	Veith
		Channel	Channel	
		GC 10/05	GC 9/06	Langendoen
2.13 Conduct model validation studies to assist with national assessment.		UWR 12/05	UWR 12/06	Van Liew
2.14 Design criteria which assists conservation planners in combining CPs in a whole-farm context.		MTR 5/04	MTR 9/06	Lerch
		StJ 10/04	StJ 9/09+	Huang
		TB 10/04	TB 10/07	Veith
2.15 Deliver techniques to use watershed analyses to evaluate pollutant-trading scenarios.		LitR 10/04	LitR 9/09	Bosch
		StJ 10/06	StJ 9/09+	Heathman
Sub-objective 2c. Determine the effects of specific CPs and systems on terrestrial and aquatic ecosystems.				
2.16 Determine combinations of soil, climate and CPs that may yield information on the active biogeochemical and hydrologic processes.	**2.16.1** Acquire soils data from a number of watersheds assessing similar CPs. Parameters of interest may vary by location, but will include soil organic carbon content, microbial biomass carbon, aggregate stability, available water holding capacity, bulk density, electrical conductivity, and soil-test phosphorus.	SFIR 10/04	SFIR 10/09	Cambardella
		UBWC TBD	UBWC TBD	Fausey
		UWR 5/05	UWR 10/09+	Steiner
		YR 10/04	YR 9/09	Wilson
		MTR 5/05	MTR 9/09	Kremer

Goal	Task	Start Date	Target Date	Responsible Scientist
2.17 Identify watersheds with similar terrestrial and/or aquatic ecosystems in which comparative studies can be conducted to assess national benefits of CPs.		UBWC TBD UWR TBD	UBWC TBD UWR TBD	Fausey Starks
2.18 Assess terrestrial ecosystems in uplands and field edges using a muti-tiered approach.	**2.18.1** Identify the CPs of interest and cross referenced with the specific soil responses that are known or can be anticipated, which would, in turn, suggest measurements with the potential to yield the information needed to document those responses.	SFIR 10/04 UBWC TBD	SFIR 10/09 UBWC TBD	Cambardella Fausey
	2.18.2 Conduct measurements suggested by 2.20.1	SFIR 10/04 UBWC TBD	SFIR 10/09 UBWC TBD	Cambardella Fausey
	2.18.3 Assess effects by**:** a. measuring before and after implementation of the CPs; b. contrasting areas where the CPs have been implemented to areas where CPs have not been implemented.	UBWC TBD	UBWC TBD	Fausey
	2.18.4 Use soil management assessment framework (SMAF) to evaluate effects of management practices.	SFIR 10/05 MTR 10/03 StJ TBD UWR 4/06	SFIR 10/09 MTR 9/07 StJ TBD UWR 10/09	Karlen Lerch Stott Starks
	2.18.5 Collect soil-quality-indicator data in areas where conservation practices are hypothesized to have substantial impact on water quality and evaluate using SMAF.	SFIR 10/04 LitR TBD MTR 10/03 Stj TBD	SFIR 10/08 LitR TBD MTR 9/07 Stj TBD	Karlen TBD Lerch, Kremer Stott
	2.18.6 Correlate indicator scores from SMAF to endpoints (leaching loss, runoff, erosion).	SFIR 10/05 MTR 10/03 Stj TBD	SFIR 10/09 MTR 9/07 Stj TBD	Karlen Lerch Stott
2.19 Evaluate the effects of CPs on wetlands and riparian ecosystems by developing a few robust, simple metrics of habitat quality that can be applied at the watershed scale.	**2.19.1** Conduct population assessments for soil flora and fauna.	UBWC TBD	UBWC TBD	Fausey
	2.19.2 Select wildlife sample sites which allow evaluation of all major land use categories including: a. row crop; b. CRP forest; c. natural riparian forest; d. constructed wetland	UBWC TBD	UBWC TBD	Fausey
2.20 Sample and analyze fish and benthic macroinvertebrates based on EPA's Rapid Bioassessment Protocols for wadeable streams and rivers.	**2.20.1** Measure captured fish for length and estimate weight. Preserve smaller fish for future identification and measurement in the lab.	BL TBD GC 10/04	BL TBD GC 9/05	Knight Shields
	2.20.2 Collect data to evaluate habitat features. Data will include: a. catch by weight; b. catch by number; c. effort, catch per unit effort (CPUE); d. species composition	GC 10/04	GC 9/05	Shields
2.21 Deliver model validation data sets for models.		GC 10/04 SFIR 10/04 LR 10/05 LitR 10/04 MTR 09/04 StJ TBD TB 10/04 WC TBD UBWC TBD UWR 10/05	GC 9/05 SFIR 10/09 LR 10/09 LitR 9/09 MTR 09/07 StJ TBD TB 12/07 WC TBD UBWC TBD UWR 10/09+	Bingner + Tomer K.Potter, Harmel Bosch + Lerch Heathman Veith Jaynes King Starks

ARS Model Validation, Evaluation and Uncertainty Analysis – Team 3

Leaders: Ronald Bingner, Oxford, MS, Jeffrey Arnold, Temple, TX, and Tim Strickland, Tifton, GA.

Responsibilities:

1. Develop ARS model validation standards for systematic quantification of uncertainty in model predictions resulting from calibration parameter identification and ranges of input data resolution and quality.
2. Use the standard to validate SWAT/APEX and AnnAGNPS and the regionalized models developed by the Model Development and Regionalization Team.
3. Evaluate the watershed models SWAT/APEX and AnnAGNPS with the purpose of making recommendations for refinements and upgrades by the Model Development and Regionalization Team.
4. Link REMM and CONCEPTS to the SWAT/APEX and AnnAGNPS models.

Overall Deliverable to NRCS: Validation of model performance through quantifying uncertainties of model predictions at multiple scales.

Models to be Studied: SWAT (S), AnnAGNPS (A), CONCEPTS (C), REMM (R), PRZM (P)

Objective 3. Validate models and quantify uncertainties of model predictions at multiple scales by comparing predictions of water quality to measure water, soil, and land management effects of conservation practices.

Goal	Task	Start Date	Target Date	Responsible Scientist
3.1 Develop a model validation standard	**3.1.1** Develop a model validation standard for systematic quantification of accuracy in the ARS benchmark watershed simulations		6/05	Van Liew Bingner Arnold
3.2 Validate and evaluate models through comparison to historical field data	**3.2.1** Calibrate the SWAT and AnnAGNPS predictions and then validate for statistical and environmental significance using the standards developed in Objective 3.1. Identify model components that contribute to variation in precision to guide future model development.		<u>Watershed-Model</u>	
			GC-S&A-12/06	Bingner
			Leon-S&APEX-12/07	Arnold, C. Green
			LitR-S&P-12/05	Bosch, Wauchope
			LitR-S&A-12/06	Bosch, Wauchope
			LitR-S&A-12/07	Bosch, Wauchope
			MTR-S-12/07	Alberts, Sadler
			TB-S-12/07	Veith
			WC-S-12/05	Jaynes
			WC-A-12/06	Jaynes
			UWR-S&A-12/05	Van Liew

Goal	Task	Start Date	Target Date	Responsible Scientist
	3.2.2 Evaluate the CONCEPTS and REMM models on watersheds where processes such as stream/riparian water quality and channel erosion are important.		Watershed-Model GC-C-12/07 LitR-R-12/07 UWR-S&A-12/07	 Langendoen Lowrance Van Liew
.	**3.2.3 R**un SWAT and AnnAGNPS (and others as appropriate) model simulations for each sub-watershed within the ARS benchmark watersheds to predict the percentage of each sub-watershed required to implement individual or suites of conservation practices in order to achieve the maximum legal standards. This will be used to set a policy relevant comparison standard for each model.		Watershed-Model GC-S&A-12/06 Leon-S&APEX-12/07 LitR-S&P-12/05 LitR-S&A-12/06 LitR-S&A-12/07 MTR-S-12/07 TB-S-12/07 WC-S-12/05 WC-A-12/06 UWR-S&A-12/05	 Bingner Arnold, C. Green Bosch, Wauchope Bosch, Wauchope Bosch, Wauchope Alberts, Sadler Veith Jaynes Jaynes Van Liew
	3.2.4 Compare SWAT and AnnAGNPS models to identify the range of implementation sub-watersheds over which the models provide comparable results. This analysis will serve to help target areas for model improvement by identifying specific sub-watersheds where process representations may not be representative.		Watershed-Model GC-S&A-12/07 Leon-S&APEX-12/07 LitR-S&A-12/07 WC-A-12/06 UWR-S&A-12/07	 Bingner Arnold, C. Green Bosch, Sullivan, Strickland Jaynes Van Liew
3.3 Estimate uncertainty in model predictions resulting from calibration parameter identification and ranges of input data resolution and quality	**3.3.1** Evaluate and develop techniques to estimate the impact of input uncertainty on model output.		12/06	Van Liew Veith Arnold

Goal	Task	Start Date	Target Date	Responsible Scientist
.	**3.3.2** Complete model scenario runs using the three levels of input data resolution: a. Uncalibrated model default parameter sets. b. Model parameter sets that have been calibrated to match watershed observations as closely as possible. c. Detailed site-specific parameterizations where input data are collected at resolutions exceeding those of nationally-available data bases.		<u>Watershed-Model</u> GC-S&A-12/07 Leon-S&APEX-12/07 SFIR-S-12/07(ab) LitR-S&P-12/06 LitR-S&A-12/07 MTR-S-12/05 (a) MTR-S-12/05 (bc) WC-S-12/05 (b) UWR-S&A-12/05(a) UWR-S&A-12/06(bc) UWR-S&A-12/07(c)	 Bingner Arnold, C. Green Tomer, C. Green Bosch, Wauchope Bosch, Wauchope Alberts, Sadler Alberts, Sadler Jaynes Van Liew Van Liew Van Liew
	3.3.3 Develop deviations in the acreage required to achieve target concentration reductions.		<u>Watershed-Model</u> GC-S&A-12/07 Leon-S&APEX-12/07 MTR-S-12/07 UWR-S&A-12/07	 Bingner Arnold, C. Green Alberts, Sadler Van Liew
	3.3.4 Conduct and report comparisons to historical water quality monitoring databases from the ARS benchmark watersheds and relative levels of model output deviation from observed data.		<u>Watershed-Model</u> GC-S&A-12/07 Leon-S&APEX-12/07 LitR-S&P-12/06 LitR-S&A-12/07 WC-S-12/05	 Bingner Arnold, C. Green Bosch, Lowrance, T. Potter Bosch, Lowrance, T. Potter Jaynes
3.4 Estimate the sensitivity of water quality responses to targeted placement of conservation practices within individual watersheds.	**3.4.1** Sub-divide model input data to the individual farm-field scale within ARS benchmark watersheds and delineate minimum sizes for distinct polygons.		<u>Watershed-Model</u> GC-S&A-12/07 Leon-S&APEX-12/07 MTR-S-12/05 UWR-S&A-12/05	 Bingner Arnold Alberts, Sadler Van Liew

Goal	Task	Start Date	Target Date	Responsible Scientist
	3.4.2 Report results such that policy-makers can use targeted research efforts in responsive watersheds to help select landscape characteristics indicative of “hot spots” or highly sensitive areas.		Watershed-Model GC-S&A-12/07 Leon-S&APEX-12/07 SFIR-S-12/06 MTR-S-12/07 TB-S-12/07 UWR-S&A-12/07	Bingner Arnold, C. Green Tomer, C. Green Alberts, Sadler Veith Van Liew
	3.4.3 Report results such that policy-makers can target implementation within larger watersheds to increase program effectiveness.		Watershed-Model GC-S&A-12/07 Leon-S&APEX-12/07 MTR-S-12/07 TB-S-12/07 UWR-S&A-12/07	Bingner Arnold, C. Green Alberts, Sadler Veith Van Liew
3.5 Develop tools to identify watersheds and/or sub-watersheds most likely to respond to conservation practice implementation.	**3.5.1** Sub-divide model input data to represent each first-order stream reach as a sub-watershed within each of the ARS WAS benchmark watersheds.		Watershed-Model Leon-S&APEX-12/07 LitR-S&P-12/06 LitR-S&A-12/07 UWR-S&A-12/05	Arnold, C. Green Bosch, Wauchope Bosch, Wauchope Van Liew
	3.5.2 Run SWAT and AnnAGNPS simulations assuming that 0, 10, 30, 50, and 100% of the cropped acres in the watershed have conservation practices implemented. The value of predicted water quality measurement endpoint(s) predicted for each sub-watershed will be plotted as a cumulative frequency distribution for each level of practice implementation. The magnitude of deviation between the CFD curves at different levels of implementation is proposed as an estimate of the magnitude of response that can be expected to result from an individual practice (or suite of practices) implemented in the target watershed (or region represented by the benchmark watershed).		Watershed-Model GC-S&A-12/07 Leon-S&APEX-12/07 LitR-S&P-12/06 LitR-S&A-12/07 MTR-S-12/07 WC-S-12/05 UWR-S&A-12/07	Bingner Arnold, C. Green Bosch, Wauchope Bosch, Wauchope Alberts, Sadler Jaynes Van Liew

Goal	Task	Start Date	Target Date	Responsible Scientist
3.6 Develop tools to estimate the temporal resolution (timing and magnitude) of conservation practice effects within watersheds.	**3.6.1** Run SWAT and AnnAGNPS simulations assuming that 0, 10, 30, 50, and 100% of the cropped acres in the watershed have conservation practices implemented.		Watershed-Model GC-S&A-12/07	Bingner
	3.6.2 Plot the value of predicted water quality measurement endpoint(s) predicted for each level of practice implementation with monthly resolution.		Watershed-Model GC-S&A-12/07	Bingner
	3.6.3 Examined results to determine whether there are specific times during the year when practice implementation(s) are predicted to manifest the greatest reduction in measurement endpoints of concern. Model predictions will be compared to historical monitoring data from the benchmark watersheds to estimate the potential magnitude or uncertainty associated with model output; to evaluate whether some regions are more susceptible to acute reductions in water quality; and to estimate the magnitude of improvement that might accrue from conservation practice implementation.		Watershed-Model GC-S&A-12/07	Bingner
	3.6.4 Compare the potential magnitudes of reductions at selected benchmark watersheds to sensitive life stages of aquatic biota to evaluate the potential for adverse impact.		TBD	TBD

ARS Economic Analysis - Team 4

Leaders: Gerald Whittaker, Corvallis, OR; and Chi-hua Huang, West Lafayette, IN

Responsibilities:

1. Make assessments and determine the threshold values and cost-effectiveness at which implementation of conservation practices can achieve targeted improvements in water quality, water conservation, and soil quality.
2. Determine how the methodologies and procedures can be compared and improved for conducting the assessments.
3. Determine how procedures can be developed for estimating uncertainty bounds in terms of the different environmental effects/benefits.

Overall Deliverable to NRCS:

4. Deliver planning tools to evaluate environmental and cost effectiveness of selection and placement of conservation practices at multiple scales.

Objective 4. Develop and apply policy-planning tools to aid selection and placement of conservation practices to optimize profits, environmental quality, and conservation program efficiency.

Goal	Task	Start Date	Target Date	Responsible Scientist
4.1 Determine the farm firm financial impacts of and the decision making values for utilizing alternative production practices and systems given the unique natural capital, environmental characteristics and cultural norms in the three selected watersheds.	**4.1.1** Develop farm firm production decision models including input, output, and practice choices that characterize farm decisions consistent with unique physical and cultural environment for each of the selected watersheds.	Jan 05		University cooperators*
4.2 Determine which acres, which production systems, which inducements and the level of cots involved to induce land management changes to meet alternative WQ standards (TSS, DO, chemicals, fecal coliform, etc.)	**4.2.1** Develop models for selection of BMP and other approaches to achieve particular pollution reduction goals. These models will consider overall program cost, as well as farm-level response based on farm firm production and financial models, and incorporate hydrologic transport models for the watershed.	July 05		University cooperators*
4.3 Estimate and place a value on some of the benefits resulting from reductions in concentration of contaminants and the corresponding changes in ecological system health.	**4.3.1** Using state-of-the-art economic methods (e.g. experimental economics, contingent valuation and hedonic modeling), estimate the value of a portion of the benefits resulting from the pollution reduction and the concomitant increase in environmental quality.	Sept 05		University cooperators*
4.4 Develop planning tools to assess environmental outcome at the watershed level.	**4.4.1** Acquire data on environmental outcome at each watershed from the watershed team representative.	Jan 05		Whittaker and watershed RLs
	4.4.2 Optimize placement of conservation practices using environmental criteria. Team 3 will provide calibrated models with all associated data and code, the uncertainty of model predictions, estimates of response and cost for conservation practices, and tools for estimation of timing, magnitude and response of watershed to conservation practices.	Jan. 05		Whittaker

4.5 Develop planning tools to assess the profit maximization at the farm level**.**	**4.5.1** Acquire data on input/outputs at the farm and field scale from the watershed representatives, and from publicly available sources.	Nov. 04		Whittaker
	4.5.2 Acquire, from Team 3, data on the cost of a conservation practice and the response at the farm level.			Whittaker
	4.5.3 Specify farm level model of production based on profit maximization.	Nov. 04		Whittaker
	4.5.4 Specify farm level model of production based on profit maximization, subject to constraints of conservation practices and environmental effects.	Jan. 05		Whittaker
4.6 Develop planning tools to assess the conservation plan's efficiency and pareto-optimal solutions based on the results of the multiple-objective optimizations in 4.4, and 4.5.	**4.6.1** Specify basin level model of production based on profit maximization, subject to constraints of conservation practices and environmental effects and perform multiple-objective optimization.	Jan. 06		Whittaker

* University Cooperators are Profs. Steve Lovejoy of Purdue University (St Joseph River watershed), Robert Weaver of Pennsylvania State University (Town Brook watershed) and Brent Sohngen of Ohio State University (Upper Big Walnut Creek watershed)

ARS Model Development and Regionalization - Team 5

Leaders: Lajpat Ahuja, Fort Collins, CO, and Mathias Romkens, Oxford, MS.

Responsibilities:

1. Develop watershed models to provide state-of-the-art modeling capabilities for estimating conservation effects on a regional basis.
2. Use the Object Modular System (OMS) to assist with the development of the regionalized models for future national assessments.
3. Design regional models to address the essential processes for a particular region of the United States. Models, including SWAT, AnnAGNPS, REMM, CONCEPTS, and other models as appropriate, will be considered.

Overall Deliverable to NRCS:

5. Develop, verify, and deliver new regional software tools that quantify environmental outcomes of conservation practices in major agricultural regions.

Objective 5. Develop and verify regional watershed models that quantify environmental outcomes of conservation practices in major agricultural regions.

Goal	Task	Start Date	Completion Date	Responsible Scientist
5.1 Identify regions and define process and sub-process modules for each regional area of the national assessment of effects of conservation practices and systems.	**5.1.1** Acquire the latest versions of SWAT, AnnAGNPS, REMM, CONCEPTS including all documentation		Feb 05	Ahuja, Rojas (NRCS)
	5.1.2 Identify preliminary modeling regions based on practical experience with the functions and characteristics of current models-the problems, local conditions (topography, soils, water, climate, management/conservation practices, etc.), situations, scenarios, system boundaries, that exist in the various regions.	Aug 04	Mar 05	Werner (NRCS), Romkens, Arnold, Geter (NRCS), Theurer (NRCS)’ Ascough, Flanagan
	5.1.3 Define the process and sub-process modules and sources that well be needed in each region. The modules should simulate the processes consistently from fields or management units to watershed scale.	Aug 04	Dec 07	Werner, Romkens, Theurer, Arnold, Geter, Ascough, Flanagan
5.2 Obtain needed scientific components from existing relevant legacy software tools for use in CEAP regional assessment. Depending on the complexity of the code, the components may be coarse multi-modules at this stage.	**5.2.1** Extract relevant scientific components from legacy software such as SWAT, AnnAGNPS, REMM, and CONCEPTS or other models as appropriate, and integrate them into OMS. (Dedicated time from Arnold Bingner, Theurer, Lowrance, and Langendoen	Aug 04	Dec 07	Rojas, Bingner, Arnold, Lowrance, Langendoen, Theurer, Flanagan
	5.2.2 Identify and develop necessary auxiliary function modules (e.g. GIS and common database access, parameter estimation, uncertainty analysis).	Aug 04	Dec 07	David, Bingner

Goal	Task	Start Date	Target Date	Responsible Scientist
5.3 Identify and develop additional modules to address improved simulation of conservation practices/systems, BMPs and other processes.	**5.3.1** Evaluate the existing technology to simulate the effects of BMPs and identify the best available methods.	Aug 04	Dec 08	Heilman, Malone, Ma, Romkens, Dabney, McMaster
	5.3.2 Identify the best available experimental data sets as standard data to test modules and the whole model, as much as possible for Team 1	Aug 04	Dec 07	Wauchope, Romkens, Malone, McMaster, CEAP Database Team
	5.3.3 Develop modules from identified methods.	Dec 05	Dec 08	Geter, Rojas, Ascough, Ma, McMaster, Flanagan
	5.3.4 Evaluate modules against measured data.	Dec 06	June 09	Ma, Malone, Ascough, Ahuja, McMaster, Flanagan
5.4 Develop modular spatial modeling, scaling, and parameterization methodologies to accurately transmit the effects of various conservation practices/systems on different farm fields and site specific management units to watershed scale.	**5.4.1** Identify the appropriate spatial modeling methodology, scaling techniques and the input parameters to be scaled.	Sep 04	Sep 08	T. Green, Garbrecht, Ahuja, Ascough, McMaster
	5.4.2 Evaluate the existing land-to-land, land-to-streams, and in-stream transport methodologies to scale the field effects to watershed level.	Sep 05	Sep 08	Ascough, Flanagan, T. Green
	5.4.3 Develop and implement the improved spatial modeling and up-scaling procedure in OMS	Sep 06	Sep 09	Ahuja, Ascough, T. Green, McMaster
5.5 Develop prototype regional field-to-watershed model integrating appropriate modules and data linkages.	**5.5.1** Provide tools for verification and validation of assembled model packages.	Aug 04	June 08	David
	5.5.2 Assemble prototype and evaluate with test data.	Jan 08	Dec 09+	Geter, David, Ascough
5.6 Transfer modular system to regional modeling and assessment teams.	**5.6.1** Develop user documentation.	June 08	Dec 09+	Rojas
	5.6.2 Train regional model development teams.	Jan 09	Dec 09+	David, Geter, Rojas
	5.6.3 Provide ongoing support.	Jan 09	Aug 11	Geter, David, Rojas

NRCS Collaborators
Jon Werner, Washington, DC; Fred Theurer, Washington, DC; Ken Rojas, Ft. Collins, CO; and Frank Geter, Ft. Collins, CO

ARS Data Quality Assurance – Team 6

Leaders: Ray Bryant, University Park, PA, and Norman Fausey, Columbus, OH.

Team Members: The team includes representatives from each of the 12 Benchmark Watersheds. The watershed representatives are: South Fork, Iowa River – Amy Morrow; Walnut Creek – Amy Morrow; Salt River, Mark Twain Lake – TBD; Upper Washita River – John Daniel; Goodwin Creek – Daniel Wren; Yalobusha – TBD; Beasley Lake – Matt Moore; Upper Leon River – Daren Harmel and Richard Haney; Little River – Joe Sheridan and Richard Lowrance; Town Brook – Bil Gburek; St. Joseph River – Douglas Smith; Upper Big Walnut Creek – Norman Fausey

Responsibilities:

1. Identify the methods/procedures used for data collection in support of CEAP related research and modeling efforts to assess water quality, water conservation, soil quality, and aquatic and terrestrial ecosystems.
2. Assure soil and water data quality through implementation of an inter-laboratory data comparison program.

Overall Deliverable to NRCS:
None (All deliverables are internal to CEAP watershed research projects)

Objective: Determine precision and accuracy of analytical data among watersheds in support of the five overall objectives.

Goal	Task	Start Date	Target Date	Responsible Scientist
6.1 Inventory and document sample collection and processing procedures, analytical methods, and data formats currently being used to measure or monitor hydrology, climate, land characteristics, water quality, water conservation, soil quality, aquatic and terrestrial ecosystems, and economics in the 12 ARS benchmark watersheds.	**6.1.1** Identify methods of sample collection and processing procedures, analytical methods, and data formats currently in use under existing CRIS project plans.	Jan 05	July 05	Fausey and Bryant
	6.1.2 Deliver compilation of CEAP methodology to CEAP watershed representatives and Team 1.	July 05	Aug 05	Fausey and Bryant
	6.1.3 Identify methods of sample collection and processing procedures, analytical methods, and data formats for use in new CRIS project plans that include CEAP research activities.	July 05	Dec 06	ARS CEAP watershed representatives
	6.1.4 Deliver compilation of new CEAP methodology to CEAP watershed representatives.	July 06	Jan 07	Fausey and Bryant
6.2 Develop an inter-laboratory data comparison program.	**6.2.1** Organize a QA/QC committee having membership from each watershed	Jan 05	Mar 05	Fausey and Bryant
	6.2.2 Develop a plan for sample sharing and data comparison	Mar 05	June 05	Fausey and Bryant QA/QC committee
	6.2.3 Implement inter-laboratory data comparison program		Oct 05	Fausey and Bryant QA/QC committee

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Past Accomplishments of Investigators

Fifty-six scientists will be directly involved in the project. The scientists represent a variety of disciplines related to the conservation of natural resources, modeling, hydrologic processes, data management, economic analysis, and other fields. A list of participating scientists is given in Appendix A. Individual accomplishment statements for all scientists are not feasible due to the large number. The following are accomplishment statements for the Project Coordinator and Team Leaders.

Past Accomplishments of Lajpat R. Ahuja, Soil Scientist/Research Leader

Education:

B.Sc. (Hons), Agronomy/Chemistry, University of Delhi, India, 1954.
M.Sc., Soil/Water Management, Indian Agricultural Research Institute, New Delhi, India, 1961.
Ph.D., Soil Physics, University of California, Davis, 1968.

Research Experience:

1968-71:	Postdoctoral Research Associate, Purdue University, West Lafayette, IN
1972-76:	Assistant Soil Scientist, University of Hawaii. Honolulu, HI.
1976-78:	Associate Soil Scientist, University of Hawaii. Honolulu, HI. Associate Professor of Soil Science, Univ. of Hawaii, Hilo, HI.
1979-91:	GS-13-GM-15, Soil Scientist, USDA-ARS. Durant, OK.
1991-Present:	GM-15 Research Leader/Supervisory Soil Scientist, USDA-ARS, Ft. Collins, CO.

Accomplishments:

Authored or coauthored 250+ publications and 100+ major presentations.
Discovered a mathematical similarity for infiltration into crusted soils that led to new models of infiltration. Recently, established relations between infiltration and percent surface residue cover.

Developed several new simpler methods to determine soil water retention and hydraulic conductivity curves in the field and soil cores. Recently developed methods to estimate water retention curve and Ksat from soil bulk density and 1/3-bar water content
Developed a method of scaling both the soil water retention and unsaturated conductivity curves of dissimilar soils—of different textural classes—as contrasted with the restrictive similar-media scaling.

Established the nature of rainfall-soil interaction in the transfer of soil chemicals to runoff as an accelerated diffusion process and developed a detailed and a simple model for estimating chemicals in runoff.

Developed new concepts of subsurface lateral flow of water in sloping layered soils and new ways to estimate subsurface flow of chemicals in runoff.

Developed a simple new model for preferential movement of surface-applied agricultural chemicals to groundwater through macropores, and established an important role of surface soil aggregation to the transport, and differences in chemical leaching between crop rows vs. inter rows.

Developed new models of how tillage and reconsolidation change the soil water retention curves.
Led a team effort to develop, validate, and publish the ARS Root Zone Water Quality Model: Modeling Management Effects on Water Quality and Crop Production. Water Resources Publications, Highland Ranch, CO.

Contributed components to and guided team efforts to develop GPFARM, a farm/ranch level decision support system for strategic planning—to evaluate economic and environmental impacts of agricultural systems.

Senior Editor on a CRC book "Agricultural System Models in Field research and Technology Transfer", 2002.

Guest Editor, Special Issue of Geoderma journal on "Quantifying Agricultural Management Effects on Soil Properties and processes", 2003.

Awards: Consulted for International Atomic Energy Agency, UN-FAO, Japan, India, and Switzerland; Associate Editor (1987-92) and Technical Editor (1994-96) Soil Sci. Soc. Am.; Member, ARS-NRCS-CSREES Partnership Management Team; ARS Technical Expert in infiltration and related soil water movement; Elected Fellow, Soil Science Society of America, 1994; Elected Fellow, American Society of Agronomy, 1996; Honorary Advisor, Chinese Academy of sciences, Yucheng Experiment station.

Selected Publications:
Ahuja, L.R. Modeling soluble chemical transfer to runoff with rainfall impact as a diffusion process. Soil Sci. Soc. Am. J. 54:312-321. 1990.

Ahuja, L.R. and Williams, R.D. Scaling soil water characteristic and hydraulic conductivity based on Gregson-Hector-McGowan approach. Soil Sci. Am. J. 55:308-319. 1991.

Heathman, G.C., Ahuja, L.R., Timlin, D.J. and Johnsen, K.E**.** Surface aggregates and macropore effects on chemical transport in soil under rainfall. *SSSAJ. 59:990-997.* 1995.

Ahuja, L.R., Johnsen, K.E. and Heathman, G.C**.** Macropore transport of a surface-applied bromide tracer: model evaluation and refinement. *SSSAJ. 59:1234-1241.* 1995.

Ahuja, L.R., Fiedler, F., Dunn, G.H., Benjamin, J.G. and Garrison, A**.** Changes in soil water retention curve due to tillage and natural consolidation. *SSSAJ. 62:1228-1233.* 1998.

Ahuja, L. R., Rojas, K. W., Hanson, J. D., Shaffer, M. J. and Ma, L. (Eds.). Root Zone Water Quality Model. Water Resources Publications LLC. Highlands Ranch, CO. 358pp. 2000.

Cameira, M.R., Ahuja, L., Fernando, R.M., and Perreira, L.S**.** Evaluating field measured soil hydraulic properties in water transport simulations using RZWQM. *J. Hydrol*. 236:78-90. 2000.

Ma, L**.,** Ahuja, L.R., Ascough II, J.C., Shaffer, M.J., Rojas, K.W., Malone, R.W., and Cameira, M.R**.** Integrating system modeling with field research in agriculture: Applications of the Root Zone Water Quality Model (RZWQM) *Advances in Agronomy*. 71:233-292. 2000.

Ruan, H., Ahuja, L.R., Benjamin, J.G., and G, 2003.reen T.R**.** Residue cover and crusting effects on infiltration: Simulations for field applications*. SSSAJ*. 65:853-861. 2001.

Ahuja, L.R., Guest Editor, Special Issue of Geoderma on Agricultural Management Effects on Soil Properties and Processes. *Geoderma (J).* 116: 1-248. 2003.

Past Accomplishments of Jeffrey G. Arnold, Agricultural Engineer

Education:
1981 Univ. of Illinois; major, Agricultural Engineering; B.S. 1981
1983 Univ. of Illinois; major, Agricultural Engineering; M.S. 1983
1992 Purdue Univ.; Agricultural Engineering; Ph.D. 1992

Experience:
1983-1986, GS-9, Hydraulic Engineer, USDA, ARS, Temple, TX
1986-1989, GS-11, Hydraulic Engineer, USDA, ARS, Temple, TX
1989-1992, GS-12, Agricultural Engineer, USDA, ARS, West Lafayette, IN
1992-present, GS-13, Agricultural Engineer, USDA, ARS, Temple, TX
1996-present, GS-14, Agricultural Engineer, USDA, ARS, Temple, TX

Accomplishments:
Development of a river basin scale model called SWAT (Soil and Water Assessment Tool). The model is composed of physically based components for hydrology, erosion, plant growth, and related processes for multiple subbasins, and components for routing the sediment, nutrients, and pesticides through streams and impoundments. Inputs are readily available through a Geographic Information System (GIS) interface. The model is generally applicable, and capable of computing the off-site impacts of land and water management.

Development of a linked surface-groundwater flow model by developing a groundwater model and coupling it to a surface water model. The model provides the capability for determining basin-wide management impacts on the comprehensive basin water budget. This allows simulation of management scenarios such as climate and vegetation changes, pond and reservoir management, groundwater withdrawals, and stream and reservoir withdrawals, which were not previously possible at the river basin scale.

Development of an automated base flow (ground water) separation technique. The procedure enables estimates of the amount of base flow derived from stream flow records. Such estimates are critical in the assessment of low flow characteristics of streams for use in water supply and pollution assessment. A second automated technique was developed to calculate the slope of the base flow recession curve from the stream flow record. This slope can be used to estimate recharge to the shallow aquifer and as an input to water budget models.

At the request of US EPA, SWAT was modified to meet EPA requirements using a GIS (Geographic Information System) interface to transfer the technology. Development of SWAT routines for urban runoff, bacteria, and pond/reservoir water quality. Development of a GIS interface for SWAT, which automates inputs from maps and spatially displays model outputs. SWAT has been accepted by US EPA Office of Science and Technology and is being used across the U.S. in developing TMDL’s.

The NRCS used the SWAT model developed in the 1997 Resource Conservation Appraisal. The model was validated against measured USGS stream flow and sediment data across the entire U.S. The model was linked to national economic models and used for national planning addressing scenarios that include: 1) agricultural and municipal water use; 2) tillage trends; 3) fertilizer and animal waste scenarios; 4) flood prevention structures; and 4) cropping systems.

Selected Publications:

DiLuzio, M. and Arnold, J.G. 2004. Formulation of a hybrid calibration approach for a physically based distributed model with NEXRAD input data. J. of Hydrology 298(1-4):136-154.

Jayakrishnan, R., Srinivasan, R. and Arnold, J.G. 2004. Comparison of rain gage and WSR-88D stage III precipitation data for the Texas-gulf river basin. J. of Hydrology 292(1-4):135-152

Arnold, J.G., Allen, P.M., and Morgan, D. 2001. Hydrologic model for design of constructed wetlands. Wetlands 21(2):167-178.

Arnold, J.G., Srinivasan, R., Muttiah, R.S., Allen, P.M., and Walker, C. 1999. Continental scale simulation of the hydrologic balance. J. American Water Resources Association 35(5):1037-1052.

Arnold, J.G. and Allen, P.M. 1999. Automated methods for estimating baseflow and groundwater recharge from stream flow records. J. American Water Resources Association 35(2):411-424 .

Arnold, J.G., Srinivasan, R., Muttiah, R.S., and Williams, J.R. 1998. Large area hydrologic modeling and assessment part I: model development. J. American Water Resources Association 34(1):73-89.

Srinivasan, R., Ramanarayanan, T.S., Arnold, J.G., and Bednarz, S.T. 1998. Large area hydrologic modeling and assessment part II: model application. J. American Water Resources Association 34(1):91-101.

Arnold, J.G., Allen, P.M., Muttiah, R.S., and Bernhardt, G. 1995. Automated base flow separation and recession analysis techniques. Groundwater 33(6): 1010-1018.

Arnold, J.G., Williams, J.R., and Maidment, D.A. 1995. A continuous time water and sediment routing model for large basins. J. Hydraulics Div., ASCE 121(2): 171-183.

Arnold, J.G. and Allen, P.M. 1993. A comprehensive surface-ground water flow model. J. of Hydrology 142(1993):47-69.

Past Accomplishments of Ronald L. Bingner, Agricultural Engineer

Education:

1998	University of Illinois, Agricultural Engineering; PhD
1988	University of Kentucky, Agricultural Engineering; MS
1979	University of Illinois, Agricultural Engineering; BS

Experience:

1986-present	Agricultural Engineer (GS11-13), USDA-ARS, National Sedimentation Laboratory, Oxford, MS
1983-1986	Agricultural Engineer, USDI, Bureau of Indian Affairs, Northern Pueblos Agency, Santa Fe, NM
1979-1982	Agricultural Engineer, University of Kentucky, Lexington, KY

Accomplishments:

<u>Appropriate Application of Erosion Models on Watersheds:</u>

The selection of an appropriate erosion model for aid in the identification of best management practices is dependent on the practices and the magnitude of scale involving the field or watershed studied. The results demonstrated the appropriateness of each model for each conservation practice studied. This information can be applied by NRCS engineers in their conservation management planning throughout the United States and specifically on the DEC watersheds in northern Mississippi.

<u>BMPs and In-stream Structures Within Watersheds Analyzed With Modeling Technology:</u>

Large-scale modeling technology capable of simulating total sediment load from watersheds was developed, which is critical to the evaluation phase of the DEC project. The resulting model is the first simulation tool capable of providing information on the long term impact management practices have on fields and consequently, on channels. Results have shown that the model can be used to evaluate the long term consequences of management practices to control erosion on a watershed. The total load from all watershed sources along with the long term impact of in-stream structures can now be determined using an integrated watershed system analysis. This strategy can be directly applied to evaluate erosion control measures installed by NRCS and USACOE in DEC project watersheds and other watersheds throughout the United States. This technology has been incorporated into the watershed pollutant-loading model, AGNPS, as the stream water quality component CONCEPTS.

<u>Watershed Modeling Technology Developed for Conservation Planning:</u>

The effect of watershed management practices on pollutant loading can be evaluated using the watershed model, AGNPS, developed as a partnership project between ARS and NRCS. The development of the AGNPS project is the culmination of several years of partnership efforts between ARS and NRCS to produce a continuous watershed model that addresses the needs of NRCS. Application of AGNPS can provide technology needed to determine the impact of management practices on pollutant loading from a watershed and the downstream effects on water quality.

Selected Publications:

Simon, A., Langendoen, E.J., Bingner, R.L., Wells, R.R., Heins, A., Jokay, N., and Jaramillo, I. Lake Tahoe basin framework implementation study: Sediment loadings and channel erosion. Research Report No. 39. US Department of Agriculture, Agricultural Research Service, National Sedimentation Laboratory, Oxford, MS. 2004.

Simon, A., Langendoen, E.J., Bingner, R.L., Wells, R.R., Yuan, Y., and Alonso, C.V. Suspended-sediment transport and bed-material characteristics of Shades Creek, Alabama and ecoregion 67: Developing water-quality criteria for suspended and bed-material sediment. Research Report No. 43. US Department of Agriculture, Agricultural Research Service, National Sedimentation Laboratory, Oxford, MS. 2004.

Yuan, Y., Bingner, R. L., Williams, R. G., Lowrance, R. R., Bosch, D. D., Sheridan, J. M. Integration of AnnAGNPS and REMM for watershed riparian buffer system assessment. Riparian Ecosystems and Buffers: Multi-scale Structure, Function, and Management. American Water Resources Association Summer Specialty Conference, June 28-30, Olympic Valley, CA. 2004.

Wauchope, R. D., Ahuja, L. R., Arnold, J. G., Bingner, R. L., Lowrance, R. R., Van Genuchten, M., and Adams, L. D. Software for pest-management science: Computer models and databases from the United States Department of Agriculture – Agricultural Research Service. Pest Management Science 59 (6/7): 691-698. 2003.

Yuan, Y., Dabney, S., and Bingner, R. L. Cost/benefit analysis of agricultural BMPs for sediment reduction in the Mississippi Delta. Journal of Soil and Water Conservation 57(5): 259-267. 2002.

Yuan, Y., and Bingner, R. L. Determination of topographic parameters for application of hydrologic and water quality models on flatland watersheds. ASAE Paper No. 02-2161, St. Joseph, Michigan, 19 pp. 2002.

Simon, A., Bingner, R. L., Langendoen, E. J., and Alonso, C. V. Actual and reference sediment yields for the James Creek Watershed - Mississippi. NSL Technical Report #31. 185 pp. 2002.

Bingner, R. L., Theurer, F. D. Physics of suspended sediment transport in AnnAGNPS. Proceedings of the 2002 Second Federal Interagency Hydrologic Modeling Conference, Las Vegas, NV, July 28 – August 1, 2002. No page numbers, published as CD-ROM. 12 pp. 2002.

Bingner, R. L. and F. D. Theurer. AnnAGNPS: estimating sediment yield by particle size for sheet & rill erosion. In Proceedings of the Sediment: Monitoring, Modeling, and Managing, 7th Federal Interagency Sedimentation Conference, Reno, NV, 25-29 March 2001. p. I-1 - I-7. 2001.

Bingner, R. L. and F. D. Theurer. AGNPS 98: A Suite of water quality models for watershed use. In Proceedings of the Sediment: Monitoring, Modeling, and Managing, 7th Federal Interagency Sedimentation Conference, Reno, NV, 25-29 March 2001. p. VII-1 - VII-8. 2001.

Past Accomplishments of Ray B. Bryant, Research Leader

Education:

1973	Texas Tech University, Soil Science; B.S.
1977	Texas Tech University, Soil Science; M.S.
1981	Purdue University, Pedology; PhD.

Experience:

2001-present	Research Leader, USDA-ARS, University Park, PA
1997-2001	Professor, Cornell University, Ithaca, NY
1987-1997	Associate Professor, Cornell University, Ithaca, NY
1981-1987	Assistant Professor, Cornell University, Ithaca, NY
1978-1981	Graduate Instructor, Purdue University, West Lafayette, IN

Accomplishments:

As a Cornell faculty member and Soil Survey Leader for the Cornell University Agricultural Experiment Station, Dr. Bryant provided leadership for cooperative soil survey in New York State for 20 years. In 2001, he joined ARS as Research Leader for the USDA-ARS Pasture Systems and Watershed Management Research Unit in University Park, PA. Dr. Bryant developed the leading conceptual model for predicting fragipan distribution in landscapes, an accomplishment that has had a significant impact on the making of soil surveys in the Northeast, North-central, Mississippi Valley and other areas of the world where fragipan soils occur. He collaborated in developing a simulation model to represent the dynamics of podzolization. The model was calibrated and used to predict aluminum and dissolved organic carbon movement in an Orthod. He supervised and collaborated on studies that laid a philosophical foundation for an expert system for Soil Taxonomy and resulted in a prototype. He has provided leadership of an international committee charged with developing taxa for soils formed by anthropogenic processes, and in this role is developing the basic philosophy for classifying these soils. Dr. Bryant supervised and collaborated on several studies that have important implications for global change and include recommendations for management to enhance carbon sequestration in soils. Other studies resulted in the identification of relationships in soil and environmental chemistry that affect the risk of phosphorus (P) loss from agricultural soils. Basic research on identifying environmental thresholds of soil phosphorus and developing pedotransfer functions to relate soil test data to environmental levels of soil phosphorus were used in the development of a P Index for New York State. He supervised and collaborated on studies of manure management strategies to reduce P Index scores and to assess the impacts of P Index implementation.

Selected Publications:

Kogelmann, W. J., Lin, H.S., Bryant, R.B., Beegle, D. B., Wolfe, A. M. and G. W. Petersen. 2003. A Statewide Assessment of the Impacts of P-Index Implementation in Pennsylvania. Journal of Soil and Water Conservation

Giasson, E., Bryant, R.B. and Bills, N.L. 2003. Optimization of Phosphorus Index and Costs of Manure Management on a New York Dairy Farm. Agron. J. 95:987-993.

Galbraith, J.M., Kleinman, P.J. and Bryant, R.B. 2003. Sources of uncertainty affecting soil organic carbon estimates in northern New York. Soil Sci. Soc. Am. J. 67:1206-1212.

Sharpley, A.N., Kleinman, P.J., McDowell, R.W., Gitau, M. and Bryant, R.B. 2002. Modeling phosphorus transport in agricultural watersheds; Processes and possibilities. J. Soil and Water Cons. 57: 425-439.

Giasson, E., Bryant, R.B. and DeGloria, S.D. 2002. GIS-based spatial indices for identification of potential nutrient export at watershed scale. J. Soil and Water Cons. 57: 373-380.

Bryant, R., Mikhilova, E.A., Vassenev, I.I., Scherbakov, A.P. 2000. Chernozem Transformations in Russia Steppe and USA Prairies: Implications for Global Change - In: Anthropogeneous Evolution of Chernozems (A.P. Scherbakov and I.I. Vassenev edit.). Voronezh, Voronezh State University. P. 276-300.

Kleinman, P.J.A., Bryant, R.B., Reid, W.S., Sharpley, A.N. and Pimentel, D. 2000. Using soil phosphorus behavior to identify environmental thresholds. Soil Science 165:943B950.

Giasson, E., Van Es, C., Van Wambeke, A. and Bryant, R.B. 2000. Assessing the economic value of soil information using decision analysis techniques. Soil Science 165:971B978.

Kleinman, P. J. A., Bryant, R. B., and Reid, W. S. 1999. Development of pedotransfer functions to quantify phosphorus saturation of agricultural soils. J. Environ. Qual. 28:2026-2030.

Galbraith, J. M. and Bryant, R.B. 1998. A functional analysis of Soil Taxonomy in relation to expert system techniques. Soil Sci. 163:739-747.

Galbraith, J. M., Bryant, R.B. and Ahrens, R.J. 1998. An expert system for Soil Taxonomy. Soil Sci. 163:748-758.

Bryant, R. B. and Arnold, R. 1994. Quantitative modeling of soil forming processes. SSSA Spec. Pub. No. 39. ASA, CSSA, and SSSA, Madison, WI. 185 p.

Hoosbeek, M. R. and Bryant, R. B. 1993. Towards more quantitative modeling of pedogenesis - a review. Geoderma 55:183-210.

Bryant, R. B. and Macedo, J. 1990. Differential chemoreductive dissolution of iron oxides in a Brazilian Oxisol. SSSAJ 54:819-821.

Bryant, R. B. 1989. Physical processes of fragipan formation. p. 141-150. *In* N.E. Smeck and E. J. Ciolkosz (ed.) Fragipans: Their occurrence, classification and genesis. SSSA Spec. Pub. 24, ASA, CSSA, and SSSA, Madison, WI.

Past Accomplishments of Michael R. Burkart, Hydrologist/Research Leader

Education:

1964	University of Wisconsin, Mathematics and Physics; B.S.
1969	Northern Illinois University, Geology; M.S.
1976	University of Iowa, Geology; Ph.D.

Experience:

1995-2004	Research Leader, USDA-ARS, Agricultural Land and Watershed Management Research Unit, National Soil Tilth Laboratory, Ames, Iowa
1992-1995	Hydrologist, USDA-ARS, National Soil Tilth Laboratory, Ames, Iowa
1979-1992	Hydrologic Studies Chief, U.S. Geological Survey, Iowa City, Iowa
1976-1979	Hydrologist, U.S. Geological Survey Bismarck North Dakota
1974-1976	Hydrologist, U.S. Geological Survey, Iowa City, Iowa
1969-1972	Geophysicist, Texaco, Bellaire, Texas

Accomplishments:

Developed method to use digital elevation models to calculate hydrologic and terrain variables that can be used to strategically place riparian buffers and wetlands over large watersheds.

Developed a mass-balance model to estimate surplus nitrogen in agricultural systems to be used as an indicator of potential leaching of nitrate to ground water initially used as input to the Committee on Environment and Natural Resources, Hypoxia Task Force Report.

Designed and implemented regional research that defined the occurrence of herbicides and nitrate in shallow aquifers of the Midwest and related hydrologic, land-use, and, soil characteristics to contaminant occurrence.

Developed a method using remotely acquired data to define the potential for both ground and surface water contamination from manure storage lagoons and basins as well as the risks of manure application on surrounding soils.

Instrumental in planning the integration of water quality research interests with other federal agencies, particularly USDA and EPA, that became their MSEA/MASSTER.

Determined that exchange of water and dissolved agrichemicals between surface and groundwater is an important process to explain the enigmatic distribution of herbicides in shallow aquifers in the Midwest.

Designed and conducted research to delineate aquifers, interpret their geologic origin and materials, quantify their hydraulic properties, and define chemical quality of water at various scales. This included detailed definition of the geometry of individual water-table aquifers, county-scale Quaternary sand and gravel aquifers in North Dakota, and aquifers of regional importance such as the Dakota and St.Peter-Jordan aquifers in Iowa.

Selected Publications:

Burkart, M.R., D.E. James, M.D. Tomer. 2004. Hydrologic and Terrain Variables to Aid Strategic Location of Riparian Buffers. Jour. Soil and Water Conservation 59:5:216-223.

Burkart, M.R., W. W. Simpkins, A. J. Morrow, and J. M. Gannon. 2004. Occurrence of Total Dissolved Phosphorus in Unconsolidated Aquifers and Aquitards in Iowa. Jour. Amer. Water Resour. Assoc. 40:3:827-834.

Tomer, M.D. and M.R. Burkart. 2003. Long-term effects of nitrogen fertilizer use on ground water nitrate in two small watersheds. Jour. Environ. Qual. 32:2158-2171.

Burkart, M.R., Stoner, J.D. 2001. Nitrogen in groundwater associated with agricultural systems. *in* R. Follett and J. Hatfield (eds.) Nitrogen in the Environment: Sources, Problems, and Management. Pp. 123-145. Elsevier , New York.

Burkart, M. , D.W. Kolpin, R. Jaquis, and K. Cole. 2001. Soil Characteristics and agrichemicals in groundwater of the Midwestern United States. Water Science and Technology. 43:5:251-260.

Burkart, Michael R. and David E. James. 1999. Agricultural-nitrogen contributions to hypoxia in the Gulf of Mexico Hypoxia. Jour. Environ. Qual. 28:3:850-859.

Kramer, L.A., M.R. Burkart, D.W. Meek, R.J. Jaquis, and D.E. James. 1999. Field-scale watershed evaluations on deep loess soils II: Hydrologic responses to different agricultural land management systems. Journ. Soil and Water Conserv. 1999.

Simpkins, W.W., M.R. Burkart, M.F. Helmke, T.N. Twedt, D.E. James, R.J. Jaquis, K.J. Cole. 1999. Hydrogeologic settings of selected earthen waste storage structures associated with confined animal feeding operations in Iowa. *In* Earthen Waste Storage Structures in Iowa, A Study for the Iowa Legislature. EDC-186. Iowa State University. pp. 1-25.

Burkart, M. R., P.W. Gassman, T.B. Moorman, and P. Singh. 1999. Estimating atrazine leaching in the Midwest. Jour. Amer. Water Resour. Assoc. 35:5:1089-1100

Burkart, M. R., W. W. Simpkins, P. J. Squillace, and M. Helmke. 1999. Tributary stream infiltration as a source of herbicides in an alluvial aquifer. Jour. Environ. Qual. 28:1: 69-74.

Burkart, M. R., Dana W. Kolpin, and David E. James. 1999. Assessing groundwater vulnerability to agrichemical contamination in the Midwest U.S. Water Sci. And Tech. 39:3: 103-112. 1999.

Past Accomplishments of Norman R. Fausey, Soil Scientist/Research Leader

Education:

1962	The Ohio State University, Agronomy, B.S.
1966	The Ohio State University, Soil Physics, M. S.
1975	The Ohio State University, Soil Physics, Ph.D.

Research Experience:

1976-Present	Soil Scientist/Research Leader, USDA-ARS, Columbus, OH
1967-1976	Soil Scientist, USDA-ARS, Columbus, OH

Areas of Expertise:

Effects of soil physical properties on water movement in soil.

Water table management by drainage, controlled drainage, and subirrigation for crop productivity and environmental protection.

Effects of water table management on soil physical, chemical, and biological processes and properties.

Selected Publications:

Fausey, N.R., L.C. Brown, H. W. Belcher, R.S. Kanwar. Drainage and Water Quality in Great Lakes and Cornbelt States. J. Irrigation and Drainage Eng. 121(4):283-288. 1995.

Evans, Robert O. and Fausey, Norman R. Effects of Inadequate Drainage on Crop Growth and Yield. IN *Agricultural Drainage.* Agron. Monograph No. 38, pp. 13-54. 1999.

Fisher, M.J., Fausey, N.R., Subler, S.E., Brown, L.C., and Bierman, P.M. Water Table Management, Nitrogen Dynamics, and Yields of Corn and Soybean. Soil Sci. Soc. Am. J. 63:1786-1795. 1999.

Richards, S.T., Batte, M.T., Brown, L.C., Czartoski, B.J., Fausey, N.R., and Belcher, H.W. Farm Level Economic Analysis of a Wetland-Reservoir Subirrigation System in Northwestern Ohio. J. Prod. Agric., Vol. 12, No. 4, pp. 509-510 and 588-596. 1999.

Fausey, N.R., Hall, G, Bigham, J., Allred, B., Christy, A. Properties of the fractured glacial till at the Madison County, Ohio, field workshop pit site. *The Ohio Journal of Science*. 2000. Vol. 100(3/4). Pp. 107-112.

Senay, G.B., Ward, A., Lyon, J., Fausey, N., Nokes, S., Brown, L. The relations between spectral data and water in a crop production environment. *International Journal of Remote Sensing*. 2000. Vol. 21(9). pp. 1897-1910.

Luckeydoo, L.M., N.R. Fausey, L.C. Brown, C.B. Davis. Early Development of Vascular Vegetation of Constructed Wetlands in Northwest Ohio Receiving Agricultural Waters. *Agriculture Ecosystems & Environment*. 1741. 89-94. 2001.

Fausey, N.R. Drainage, Aeration and Trafficability. Lal, L., editor. Marcel Dekker, New York, NY. *Encyclopedia of Soil Science*. 2002. pp. 361-363.

Fausey, N.R. Subirrigation. Lal, R., editor. Marcel Dekker, New York, NY. *Encyclopedia of Soil Science*. 2002. pp. 1276-1278.

Hatfield, J.L., Bucks, D.A., Alberts, E.E., Dowdy, R.H., Fausey, N.R. and Schepers, J.S. Assessment of the Water Quality Impacts of Farming Systems by Integrating Databases and Simulation Models. Proceedings National Water Quality Monitoring Council. May 20-23, 2002. Madison, WI. CD ROM.

Fausey, N. Drainage: Inadequacy and crop response. Marcel Dekker, Inc. New York, NY. Encyclopedia of Water Science.2003.

Allred, B., Brown, L., Fausey, N., Cooper, R., Clevenger, W., Prill, G., La Barge, G., Thornton, C., Riethman, D., Chester, P., Czartoski, B. Water table management to enhance crop yields in a wetland reservoir subirrigation system. *Applied Engineering in Agriculture*. 2003. Vol. 19(4). pp. 407-421.

Mueller, L., Schindlar, U., Fausey, N., Lal, R. Comparison of methods for estimating maximum soil water content for optimum workability. *Soil & Tillage Research*. 2003. 72. pp. 9-20.

Allred, B., Fausey, N., Peters, L., Chen, C., Daniels, J., Young, H. Detection of buried agricultural drainage pipe using conventional geophysical methods. Applied Engineering in Agriculture. 2004. 20(3):307-318.

Fausey, N.R. Drainage Management (an emerging agricultural best management practice): Impact on hydrology and water quality in a cool, humid region. Advances in Hydro-Science and Engineering. 2004. VI: 57-58.

Fausey, N., King, K., Baker, B., Cooper, R. Controlled drainage performance on Hoytville soil in Ohio. 8th International Drainage Symposium. P. 84-88. 2004. (115# 156123).

Luckeydoo, L., Fausey, N., Clevenger, B. Vegetation establishment and management guidelines for constructed basins for agricultural water treatment. *OSU Extension Publication*. Bulletin 909 pp. 1-25

Past Accomplishments of Chi-hua Huang, Soil Scientist/Research Leader

Education:

1973	National Chung-Hsing University (Taiwan); B.S.
1977	Washington State University; M.S.
1982	Purdue University; Ph.D.

Research Experience:

1982-1984	Post-Doctoral Research Associate, Univ. of Arizona. Tucson, AZ.
1984-1987	Research Scientist, Commonwealth Scientific and Industrial Research Organization (CSIRO), Canberra, Australia.
1988-1998	Soil Scientist and Project Leader, Purdue Univ., West Lafayette, IN.
1998-present	Soil Scientist, USDA-ARS National Soil Erosion Research Lab, West Lafayette, IN
2004-Present	Research Leader, USDA-ARS National Soil Erosion Research Lab, West Lafayette, IN

Accomplishments:

Dr. Huang studied fundamental erosion processes, with a specific focus on the quantification of surface roughness and hydrologic boundary conditions that affect erosion and chemical transport. Huang's early work on the theoretical calculation of raindrop impact stresses was the first of this type of calculations applied to soil deformation under raindrop impact and led to others to study the splash phenomena. The development of laser scanner technology, from the original point-scan unit to current instantaneous profile line-scan system for collecting surface microtopography data in mm scales with sub-mm resolution broke the barrier in obtaining microtopographic data in such a fine resolution. Data sets acquired from the laser scanner also allow the introduction of a scale-dependent functional concept in quantifying soil surface roughness. Research in soil roughness effects showed that soil roughness affected flow convergence as well as divergence, and consequently, can either increase or decrease erosion as roughness is increased. Huang also developed a multiple-box system to simulate hydrologic conditions and processes in a segment of a hillslope and used it to quantify seepage (or exfiltration) effects on soil erosion. The multiple box system allows the evaluation of sediment mass-balance relationship, which forms the basis of a process-based erosion model. The development of such a system greatly enhances the state of erosion science.

Selected Publications:

Huang, C. 1995. An empirical analysis of slope and runoff factors for sediment delivery from interrill areas. Soil Sci. Soc. Am. J. 59:982-990.

Huang, C., J.M. Bradford, and J.M. Laflen. 1996. Evaluation of the detachment-transport coupling concept in the WEPP rill erosion equation. Soil Sci. Soc. Am. J. 60:734-739.

Huang, C., and J.M. Laflen. 1996. Seepage and soil erosion for a clay loam soil. Soil Sci. Soc. Am. J. 60:408-416.

Huang, C., D.S. Gabbard, L.D. Norton, and J.M. Laflen. 1998. Effects of hillslope hydrology and surface condition on soil erosion. Advances in GeoEcology 31:257-262.

Gabbard D.S., C. Huang, L.D. Norton, and G.C. Steinhardt. 1998. Landscape position, surface hydraulic gradients and erosion processes. Earth Surface Processes and Landforms. 23:83-93.

Huang, C. 1998. Sediment regimes under different slope and surface hydrologic conditions. Soil Sci. Soc. Am. J. 62: 423-430.

Huang, C., L.K. Wells, and L.D. Norton. 1999. Sediment transport capacity and erosion processes: Model concepts and reality. Earth Surface Processes and Landforms. 24:503-516.

Zheng, F., C. Huang, and L.D. Norton. 2000. Vertical hydraulic gradient and run-on water and sediment effects on erosion processes and sediment regimes. Soil Sci. Soc. Am. Journal. 64: 4-11.

Darboux, F., P. Davy, C. Gascuel-Odoux, and C. Huang. 2002. Evolution of soil surface roughness and flowpath connectivity in overland flow experiments. Catena 46: 125-139.

Huang, C., C. Gascuel-Odoux, and S. Cros-Cayot. 2002. Hillslope topographic and hydrologic effects on overland flow and erosion. Catena 46: 177-188.

Zhang, G.-H, B.-Y. M.A. Nearing, C,-H. Huang, and K.-L. Zhang. 2002 Soil Detachment by shallow overland flow. Trans ASAE 45(2): 351-357.

Darboux, F., and C. Huang. 2003. An instantaneous-profile laser scanner to measure soil surface microtopography. Soil Sci. Soc. Am. Journal. 67: 92-99.

Zheng, F., S. D. Merrill, C. Huang, D.L Tanaka, D. Darboux, M.A. Liebig, and A.D. Halvorson. 2004. Runoff, soil erosion and erodibility of conservation reserve program land under crop and hay production. Soil Sci. Soc. Am. Journal. 68: 1332-1341.

Zheng, F., C. Huang, and L.D. Norton. 2004. Effects of near-surface hydraulic gradients on nitrate and phosphorus losses in surface runoff, Journal of Environmental Quality. 33:2174-2182.

Darboux, F., and C. Huang. 2005. Does soil surface roughness increase or decrease water and particle transport? Soil Sci. Soc. Am. Journal. (accepted for publication, will appear in 2005).

Past Accomplishments of Martin A. Locke, Soil Scientist/Research Leader

Education:

1976, B.S., Southwest Missouri State University; major, Marketing.
1982, B.S., Southwest Missouri State University; major, General Agriculture.
1984, M.S., University of Missouri; major, Agronomy.
1987, Ph.D., Texas A & M University; major, Agronomy.

Experience:

2003 –present	Research Leader, Water Quality & Ecological Processes Research Unit (WQEPRU), Oxford, MS.
1996 - 2003	Research Leader, Southern Weed Science Research Unit (SWSRU), Stoneville, MS.
1989 - 1996	Soil scientist, Southern Weed Science Research Unit.
1987 - 1989	Postdoctoral research associate, Southern Weed Science Research Unit.
1984 - 1987	Research Assistant, Texas A & M University, Soil & Crops Science Dept.
1982 - 1984	Research Assistant, University of Missouri, Dept. of Agronomy.

Accomplishments:

Dr. Martin A. Locke has spent much of his career, including graduate experience, working in various aspects of soil management in conservation systems. With USDA-ARS, he has gained national recognition for research assessing environmental issues related to weed management in conservation systems. As research leader of the Southern Weed Science Unit for seven years, he was able to initiate and nurture several multi-disciplinary projects that evaluated environmental issues using integrated management approaches. He was a leader in the regional Mississippi MSEA project, serving on the Technical Steering Committee and as lead Stoneville scientist on the project. Currently, as research leader of the Water Quality & Ecological Processes Research Unit, Dr. Locke is in a key position to coordinate research over the entire landscape, from the field where many agricultural activities take place through transition zones, and into water bodies. He has made significant contributions in several specific research areas, including (1) herbicide and metabolite sorption in plant residues and soils from varying tillage systems, and subsequent mobility through soil; (2) herbicide biodegradation in soil as it relates to tillage and crop residue management;(3) movement of herbicide in surface runoff; and (4) field and watershed scale evaluations of soil characteristics that influence herbicide dissipation and weed management.

Selected Publications:

Locke, M.A., S.S. Harper, and L.A. Gaston. 1994. Metribuzin mobility and degradation in undisturbed soil columns. *Soil Sci.* 157:279-288.

Gaston, L.A., M.A. Locke, and R.M. Zablotowicz. 1996. Sorption and degradation of bentazon in conventional- and no-till Dundee soil. *J. Environ. Qual.* 25:120-126.

Locke, M.A., L.A. Gaston, and R.M. Zablotowicz. 1996. Alachlor biotransformation and sorption in soil from two soybean tillage systems. *J. Agric. Food Chem.* 44:1128-1134.

Locke, M.A., L.A. Gaston, and R.M. Zablotowicz. 1997. Acifluorfen sorption and sorption kinetics in soil. *J. Agric. Food Chem.* 45:286-293.

Locke, M.A., and C.T. Bryson. 1997. Herbicide-soil interactions in reduced tillage and plant residue management systems. *Weed Sci.* 45:307-320.

Reddy, K.N., M.A. Locke, and L.A. Gaston. 1997. Tillage and cover crop effects on cyanazine adsorption and desorption kinetics. *Soil Sci.* 162:501-509.

Zablotowicz, R. M., M.A. Locke, and R.J. Smeda. 1998. Degradation of 2,4-D and fluometuron in cover crop residues. *Chemosphere* 37:87-101.

Zablotowicz, R.M., M.A. Locke, L.A. Gaston, and C.T. Bryson. 2000. Interactions of tillage and soil depth on fluometuron degradation in a Dundee silt loam soil. *Soil and Tillage Research* 57:61-68.

Zablotowicz, R.M., M.A. Locke, R.E. Hoagland, B. Cash, and S.S. Knight. 2001. Fluorescent *Pseudomonas* isolates from Mississippi Delta oxbow lakes: *In vitro* herbicide biotransformations. *Environmental Toxicology* 16:9-19.

Gaston, L.A., M.A. Locke, R.M. Zablotowicz, and K.N. Reddy. 2001. Spatial variability of soil properties and weed populations in the Mississippi Delta. *Soil Sci. Soc. Am. J.* 65:449-459.

Staddon, W.J., M.A. Locke, and R.M. Zablotowicz. 2001. Microbiological characteristics of a vegetative buffer strip soil and degradation and sorption of metolachlor. *Soil Sci. Soc. Am. J.* 65:1136-1142.

Locke, M.A., K.N. Reddy, L.A. Gaston, and R.M. Zablotowicz. 2002. Adjuvant modification of herbicide interactions in aqueous soil suspensions. *Soil Science* 167:444-452.

Locke, M.A., R.M. Zablotowicz, and L.A. Gaston. 2003. Environmental fate of fluometuron in a Mississippi Delta lake watershed. *In* Terrestrial field dissipation studies: Purpose, design, and interpretation. E.L. Arthur, A.C. Barefoot, and V.E. Clay, eds., ACS Symposium Ser. 842, pp. 206-225.

Locke, M.A., and R.M. Zablotowicz. 2004. Pesticides in soil: Benefits and limitations to soil health. *In* P. Schjonning, S. Elmholt, and B.T. Christensen., eds., Managing soil quality – Challenges in modern agriculture. CABI Publishing, UK, pp. 239-260.

Staddon, W.J., M.A. Locke, and R.M. Zablotowicz. 2004. Spatial variability of cyanazine dissipation in soil from a conservation managed field. *In* Water quality assessments in the Mississippi Delta: Regional solutions, national scope. M.T. Nett, M.A. Locke, and D.A. Pennington, eds., ACS Symposium Ser. 877, pp. 179-193.

Zablotowicz, R.M., M.A. Locke, R. Lerch, and S.S. Knight. 2004. Dynamics of herbicide concentrations in Mississippi Delta oxbow lakes and the role of planktonic microorganisms in herbicide metabolism. *In* Water quality assessments in the Mississippi Delta: Regional solutions, national scope. M.T. Nett, M.A. Locke, and D.A. Pennington, eds., ACS Symposium Ser. 877, pp. 134-149.

Past Accomplishments of Clarence W. Richardson, Laboratory Director

Education:

1976	Colorado State University, Civil Engineering; Ph.D.
1967	Texas A&M University, Agricultural Engineering; M.S.
1964	Texas A&M University, Agricultural Engineering; B.S.

Experience:

1987-present	Laboratory Director, Research Leader and Agricultural Engineer, USDA, ARS, Temple, TX.
1980-1987	Research Leader and Agricultural Engineer, USDA, ARS, Temple, TX.
1966-1980	Agricultural Engineer, USDA, ARS, Temple, TX.
1965-1966	Instructor, Agricultural Engineering Department, Texas A&M University, College Station, TX.

Accomplishments:

Dr. Richardson's technical achievements have been in the areas of basic hydrology, water quality, soil erosion control, and mathematical models of hydrologic processes. His work developing models to simulate daily weather variables are used throughout the United States and in other countries to provide simulated, representative weather data for hydrologic models and crop growth models. He provides technical leadership to the Laboratory for which he serves as Director. Under his leadership, the Laboratory has become internationally known for pioneering research in several technical areas including mathematical models of hydrology and crop growth, soil erosion, climate change, tillage, and brush and weed control.

Dr. Richardson quantified the effects of brush removal on available water on a watershed basis. He found that chemical brush control on a clay soil increased runoff and, consequently, available water; however, mechanical brush control in a limestone area reduced surface runoff.

He has made contributions in the area of surface water quality as affected by agriculture. Dr. Richardson established that only very small amounts of arsenic used to desiccate cotton for harvest was transported from fields by runoff and that post-harvest tillage minimized arsenic loss. He also found that brush control herbicides did not accumulate in the ecosystem and rapidly degraded even after repeated application. Dr. Richardson and his colleagues defined the mechanism of movement of applied nitrogen from fields in runoff and demonstrated that quantities lost were small. He quantified the effects of reduced tillage on runoff amounts and the loss of sediment, nitrogen, and phosphorus in runoff from small watersheds with clay soils. Runoff was shown to be unaffected by tillage systems, but the loss of sediment and plant nutrients were shown to be significantly reduced with reduced tillage.

Selected Publications:

Richardson, C.W. and K.W. King. 1995. Erosion and nutrient losses from zero tillage on a clay soil. J. Agric. Engr. Res. 61:81-86.

Morrison, J.E., C.W. Richardson, J. Lemunyon, and H.C. Bogusch. 1995. Source of variation and performance of nine devices when measuring percent residue cover. Trans. ASAE 38(2):521-529.

King, K. W., C. W. Richardson, and J. R. Williams. 1996. Simulation of sediment and nutrient loss on a Vertisol with conservation tillage practices. Trans. ASAE 39(6):2139-2145.

Semenov. M. A., R. J. Brooks, E. M. Barrow, and C. W. Richardson. 1998. Comparison of the WGEN and LARS-WG stochastic weather generators in diverse climate. Climate Research 10:95-107.

Skiles, J. W. and C. W. Richardson. 1998. A stochastic weather generator model for Alaska. Ecological Modeling 110:211-232.

Tobert, H. A., K. N. Potter, D. W. Hoffman, T. J. Gerik, and C. W. Richardson. 1999. Surface residue and soil moisture affects fertilizer loss in simulated runoff on a heavy clay soil. Agron. J. 91:606-612.

Richardson, C. W. 2000. Data requirements for estimation of weather generation parameters. Trans. ASAE 43(4):877-882.

Slaughter, C. W. and C. W. Richardson. 2000. Long-term watershed research in USDA Agricultural Research Service. American Water Resources Association Research Impact 2(4):28-31.

Harmel, R. D., C. W. Richardson, C. L. Hanson, and G. L. Johnson. 2002. Evaluating the adequacy of simulating maximum and minimum temperature with the normal distribution. J. of Appl. Meteorl. 41:744-753.

Harmel, R. D., K. W. King, C.W. Richardson, and J. R. Williams. 2003. Long term-precipitation analysis for the central Texas Blackland Prairie. Trans. ASAE 46(5):1381-1388.

Past Accomplishments of M.J.M.Römkens, Soil Scientist and Laboratory Director

Education:

1968	Cornell University, Agronomy--Soil Physics (minors: Appl. Physics and Phys. Chem); PhD.
1964	Wageningen University, The Netherlands, Ir. Drainage and Soil Phys. Chem. (cum laude).
1963	Mississippi State University, Agronomy-Soil Physics; M.S.
1959	Wageningen University, The Netherlands, Cand. Ir. Agric. Engineering (cum laude).

Experience:

1996-present	Acting Director and Director, USDA ARS National Sedimentation Laboratory, Oxford, MS.
1994-present	Research Leader, USDA-ARS, Oxford, MS.
1973-present	Soil Scientist, USDA ARS, Oxford, MS.
1975-present	Adjunct Associate Professor and Professor, Mississippi State University
1989	Visiting Professor, University of Minnesota
1968-1973	Soil Scientist USDA-ARS West Lafayette, IN, Adjunct Assistant Professor Purdue University, West Lafayette, IN

Accomplishments:

M. J. M. Römkens has made many significant contributions in several disciplines including soil physics, soil physical chemistry, soil water hydrology, agricultural engineering, and in the environmental area as related to agricultural practices. He (i) pioneered the development of a data base of cotton plant growth in relation to soil water regimes which became the impetus to cotton plant growth models; (ii) quantified the relative significance of salt and water transport in thin water films on surfaces with diffuse electric double layers which affect processes of regulation in ice, frost heaving of soils, and salt retention in clay membranes; (iii) pioneered research on nutrient transport in runoff from agricultural land in different management systems; (iv) developed a new particle size based predictive relationship of the USLE soil erodibility factor and improved predictions of this factor for high clay subsoils; (v) developed equipment and techniques for soil erosion and hydrologic research; (vi) formulated a physically based soil roughness parameter and related changes of this parameter to tillage and rainfall; (vii) analyzed the effect of rainfall on surface sealing and recognized the important role soil physical, chemical and pysico-chemical properties have on surface seal development; (viii) collaborated in the development of the spectral series solution technique for the Richard's equation for given problem situations; (ix) encouraged and participated acoustical/seismic research in soil science and was instrumental in applying acoustic principles to the measurements of soil physical properties; (x) developed detailed DEM's for studies on soil erosion processes on soil surfaces; (xi) established the importance of subsurface soil water pressures on sediment concentrations in runoff; (xii) demonstrated the important role surface sealing has on sediment yield especially on limed variable charge clay soils; (xiii) cooperated in the measurements and analysis of drainage network development on upland source areas; (xiv) encouraged and cooperated on fundamental studies of gravity flow and sediment transport in shallow flow; (xv) guided experimental work on infiltration into swelling/cracking soils and soils susceptible to surface sealing.

Selected Publications:

Bennett, S. J., Alonso, C. V., Prasad, S. N. and Römkens, M. J. M. Experiments on headcut growth and migration in concentrated flows typical of upland areas. Water Resources Research 26(7):1911-1922. 2000.

Jin, C. X. and Römkens, M. J. M. Performance of a modified syntron vibra-flow sediment feeder for wide feeding. Applied Engineering in Agriculture 16(1):35-38. 2000.

Jin, C. X., Römkens, M. J. M. and Griffioen, F. Estimating Manning's roughness coefficient for shallow overland flow in non-submerged vegetative filter strips. Transactions of the ASAE 43(16):1459-1466. 2000.

Jin, C. X. and Römkens, M. J. M. Modeling deposition processes in vegetative filter strips. Int. J. Sediment Research 15(1):108-120. 2000.

Jin, C. X. and Römkens, M. J. M. Sediment trapping by vegetative filter strips. Int. J. Sediment Research 15(2):233-244. 2000.

Pal, D., Prasad, S. N. and Römkens, M. J. M. Optimal mode of sediment transport by shallow flows in upland areas. Int. J. Sediment Research (15)(2):260-267. 2000.

Prasad, S. N., Pal, D. and Römkens, M. J. M. Wave formation on a shallow layer of flowing grains. J. Fluid Mechanics 413:89-110. 2000.

Römkens, M. J. M., Helming, K. and Prasad, S. N. Sediment yield-surface topography relationships for selected Mississippi soils. Int. J. Sediment Research 15 (1):1-16. 2000.

Römkens, M. J. M., Helming, K. and Prasad, S.N. Soil erosion under different rainfall intensities, surface roughness, and soil water regimes. CATENA 46:103-123. 2001.

Vervoort, R. W., Dabney, S. M. and Römkens, M. J. M. Tillage and row position effects on water and solute infiltration characteristics. Soil Sci. Soc. Amer. J. 65(4):1227-1234. 2001.

Jin, C. X., Dabney, S. M. and Römkens, M. J. M. Trapped mulch increases sediment removal by vegetative filter strips: a flume study. Transactions of the ASAE 45(4):929-939. 2002.

Prasad, S. N. and Römkens, M. J. M. Energy formulations of head cut dynamics. CATENA 50:469-487. 2003.

Rhoton, F. E., Römkens, M. J. M., Bigham, J. M., Zobeck, T. M. and Upchurch, D. R. Ferrihydrite influence on infiltration, runoff, and soil loss. Soil Science Society of America Journal. V. 67, p. 1220-1226. 2003.

Wells, R. R., DiCarlo, D. A., Steenhuis, T. S., Parlange, J. Y., Römkens, M. J. M. and Prasad, S. N. Infiltration and surface geometry features of a swelling soil following successive simulated rainstorms. Soil Sci. Soc. Amer. J. 67(5):1344-1351. 2003.

Past Accomplishments of E. John Sadler, Soil Scientist, Research Leader

Education:

1983	Ph.D.	Texas A&M University, College Station, TX, major in Agronomy
1978	M.S.	Texas A&M University, College Station, TX, major in Agronomy
1976	B.S.	University of Missouri, Columbia, MO, major in Agronomy

Experience:

2003 – present	Supervisory Soil Scientist, Research Leader, Cropping Systems and Water Quality Research Unit, USDA, Agricultural Research Service, Columbia, MO
1983 - 2003	Soil Scientist, Coastal Plains Soil and Water Conservation Research Center, USDA Agricultural Research Service, Florence, SC

Accomplishments:

Dr. Sadler has published extensively in the fields of soil water relations, irrigation, site-specific agriculture, water quality, and process-level computer modeling. He and colleagues designed, built, and used site-specific irrigation machines to test the individual and combined effects of irrigation and nitrogen fertilization on crop yield, water conservation, and nitrogen balance in preparation for assessments of leaching risk. He contributed micrometeorological, electronic instrumentation, and physics expertise to a team that designed, constructed, validated performance through extensive tests, and used an enclosure-based system to measure ammonia volatilization from constructed wetlands receiving swine lagoon effluent.

Awards:

Fellow, American Association for the Advancement of Science
Fellow, American Society of Agronomy

Selected Publications:

Bauer, P. J., Frederick, J. R., Bradow, J. M., Sadler, E. J and Evans, D. E. Canopy photosynthesis and fiber properties of normal- and late-planted cotton. Agron. J. 92 (3):518-523. 2000.

Camp, C. R., Sadler, E. J., Evans, D. E. and Usrey, L. J. Variable-rate, digitally-controlled metering device. Applied Engr. in Agric. 16 (1):39-44. 2000.

Sadler, E. J., Bauer, P. J. and Busscher, W. J. Site-specific analysis of a droughted corn crop. I. Growth and grain yield. Agron. J. 92 (3):395-402. 2000.

Sadler, E. J., Bauer, P. J., Busscher, W. J. and Millen, J. A. Site-specific analysis of a droughted corn crop. II. Water use and stress. Agron. J. 92 (3):403-410. 2000.

Sadler, E. J., Gerwig, B. K., Evans, D. E., Busscher, W. J. and Bauer, P. J. Site-specific modeling of corn yield in the SE Coastal Plain. Agric. Systems 64:189-207. 2000.

Schepers, J. S., Sadler, E. J. and Raun, W. R. Grantsmanship Hints. Agron. J. 92 (1):1-5. 2000.

Sadler, E. J., Camp, C. R., Evans, D. E. and Usrey, L. J. Variable-rate, digitally-controlled fluid metering device. US Patent No. 6,293,429. September 25, 2001.

Camp, C. R. and Sadler, E. J. Irrigation, deep tillage, and nitrogen management for a corn-soybean rotation. Trans ASAE 45 (3):601-608. 2002.

Johnson, R. M., Downer, R. G., Bradow, J. M., Bauer, P. J. and Sadler, E. J. Variability in cotton fiber yield, fiber quality and soil properties in a Southeastern Coastal Plain field. Agron. J. 94:1305-1316. 2002.

Poach, M. E., Hunt, P. G., Sadler, E. J., Matheny, T. A., Johnson, M. H., Stone, K. C. and Humenik, F. J. Ammonia volatilization from constructed wetlands that treat swine wastewater. Trans ASAE. 45 (3):619-627. 2002.

Sadler, E. J., Camp, C. R., Evans, D. E. and Millen, J. A. Corn canopy temperatures measured with a moving infrared thermometer array. Trans ASAE. 45 (3):581-591. 2002.

Sadler, E. J., Camp, C. R., Evans, D. E., and Millen, J. A. Spatial variation of corn response to irrigation. Trans. ASAE. 45(6):1869-1881. 2002.

Carbone, G. J., Mearns, L. O., Mavromatis, T., Sadler, E. J., and Stooksbury, D. 2003. Evaluating CROPGRO-Soybean performance for use in climate impact studies. Agron. J. 95: 537-544. 2003.

Lu, Y.-C., Camp, C. R., and Sadler, E. J. Efficient allocation of irrigation water and nitrogen fertilizer in corn production. J. of Sustainable Agriculture. (Accepted 8/12/03)

Poach, M.E., Hunt, P.G., Vanotti, M.B., Stone, K.C., Matheny, T.A., Johnson, M.H., and Sadler, E.J. Improved nitrogen treatment by constructed wetlands receiving partially nitrified swine manure. Ecological Engineering, 20:183-197. 2003.

Poach, M.E., Hunt, P.G., Stone, K.C., and Sadler, E.J. Ammonia volatilization from marsh-pond-marsh constructed wetlands treating swine wastewater. J. Environmental Quality. 33:844-851. 2004.

Szogi, A. A., Hunt, P. G., Sadler, E. J., and Evans, D. E. Characterization of oxidation-reduction processes in constructed wetlands for swine wastewater treatment. Appl. Engineering in Agric. 20(2):189-200. 2004.

Lu, Y.-C., Sadler, E. J., and Camp, C. R. Economic feasibility study of variable irrigation of corn production in Southeast Coastal plain. J. of Sustainable Agriculture. (Accepted with revision April 2004).

Past Accomplishments of Jean L. Steiner, Soil Scientist, Research Leader

Education:

1982, Kansas State University, Agronomy, Ph.D.
1979, Kansas State University, Agronomy, M.S.
1974, Cornell College, Mt. Vernon IA, Geology, B.A.

Experience:

2001-present	Research Leader, USDA-ARS, Grazinglands Research Laboratory, El Reno, OK.
1994 to 2001	Center Director, Research Leader. USDA–ARS, J. Phil Campbell, Sr., Natural Resource Conservation Center, Watkinsville, GA.
1983 to 1994	Research Soil Scientist. USDA–ARS, Bushland, TX.
1982 to 1983	Research Scientist. CSIRO Centre for Irrig. Res., Griffith, NSW, Australia.
1978 to 1982	Graduate Research Assistant and Research Assistant. Kansas State University.

Accomplishments:

Co-leader in developing major energy and water balance research facilities at USDA-ARS, Bushland, TX. Identified limitations to widely used equations for estimating evaporative potential in highly advective environments such as that of the Southern High Plains. Daily water requirements for wheat in late spring were shown to exceed mid-summer water requirements for corn and sorghum, due to higher windspeed, vapor pressure deficit, and radiation load, along with lower leaf resistance to water loss.

Led development of a crop residue decomposition model based on simple climatic indices of limiting factors to biological and chemical processes that limit decomposition. The model was designed to be applicable throughout the USA, as part of the USDA Wind Erosion Prediction System and was the first model to maintain pools for standing and flat surface residues.

Conducted field, laboratory, and simulation research to quantify crop residue impacts on soil and plant microclimate and water conservation, use, and quality in rainfed agriculture in semiarid and humid conditions. Edited a special issue of Theoretical and Applied Climatology on Crop Residue Effects at the Earth: Atmosphere Interface that highlighted wide-ranging impacts of residues on physical and biological processes, synthesized key findings, and identified areas where theory is incomplete.

As Research Leader, established an hierarchal watershed research program scaling from plot to field to catchment to stream to river for analysis of water quality as impacted by land management in the Upper Oconee River watershed in Georgia. The interdisciplinary research program gained support from Southern Region SARE, Georgia Dept. of Natural Resources, USDA-CREES-NRI, AWWARF, and US-EPA and involved diverse partnerships with University of Georgia and Fort Valley State University research and extension, action agencies at local, state, and federal levels, land owners, producer organizations, educators, and others.

Organized a 1997 Soil and Water Conservation Society Conference on Investigating Ecosystem Dynamics at a Watershed Level and led in development of a white paper that identified key requirements for such analysis and research, education, and policy needs to support this broad integrated approaches to ecosystem and natural resources research.

Selected Publications:

Endale, D.M., H.H. Schomberg, and J.L. Steiner. 2000. Long term sediment yield and mitigation in a small Southern Piedmont watershed. Internat. J. Sediment Res. 15:60-68.

Fisher, D.S., J.L. Steiner, D.M. Endale, J.S. Stuedemann, H.H. Schomberg, A.J. Franzluebbers, and S.R. Wilkinson. 2000. The relationship of land use practices to surface water quality in the Upper Oconee watershed of Georgia. Forest Ecol. and Mgt. 128:39-48.

Steiner, J. L., H. H. Schomberg, P. W. Unger, and J. Cresap. 2000. Biomass and residue cover relationships of fresh and decomposing small grain residue. Soil Sci. Soc. Am. J. 64:2109-2114.

Endale, D. M., D. E. Radcliffe, J. L. Steiner, M. L. Cabrera,. 2002. Drainage characteristics of a Southern Piedmont soil following six years of conventionally tilled or no-till cropping systems. Trans. Am. Soc. Agr. Eng. 45:1423-1432.

Franklin, D. H., M. L. Cabrera,, J. L. Steiner, D. Endale, and W. P. Miller. 2002. Evaluation of percent flow captured by a small, in-field runoff collector. Trans. Am. Soc. Agr. Eng. 44:551-554.

Franklin, D. H., M. L. Cabrera,, J. L. Steiner, E. L. Usery. 2002. Distribution of inorganic nitrogen and phosphorus concentrations in stream flow of two Southern Piedmont watersheds. J. Env. Q. 31:1910-1917.

Steiner, J. L. 2002. Soil Climatology and Meteorology. Entry 5.24.01.07 *In* Agricultural Sciences, Lal, R. [ed.], in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publ., Oxford ,UK, [http://www.eolss.net]

Steiner, J. L. D. Goodrich, S. Hardegree, M. R. Burkart, T. C. Strickland, C.V. Alonso, R. B. Bryant, and M .A. Weltz. 2003. Information Technology: Applications in the ARS Watershed Network. pp. 62-67 In. In. Renard, K.G., S. A. McElroy, W. J. Gburek, H. E. Canfield, and R. L. Scott, [eds]. 1st Interagency Conf. on Res. in the Watersheds, Oct. 27-30, 2003. USDA, Ag. Res. Serv. [http://www.tucson.ars.ag.gov/icrw/proceedings.htm]

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Past Accomplishments of Timothy C. Strickland, Research Leader

Education:

1985	University of Georgia, Microbiology, Ph.D.
1980	University of Georgia, Microbiology, B.S.

Experience:

2000 –present	Research Leader, Southeast Watershed Research Laboratory, Tifton, GA
1999-2000	National Program Leader for Water Quality, USDA-CSREES, Washington, DC
1992-1997	Program Director (Water Quality, Soil Science, Ecosystem Science, Agricultural Systems), National Research Initiative, USDA-CSREES, Washington, DC
1987-1992	Project Scientist, ManTech Environmental Technologies, Inc., Corvallis, OR
1985-1987	Post Doctoral research Associate, Department of Forest Science, Oregon State University, Corvallis, OR

Accomplishments:

Dr. Timothy C. Strickland's published research has focused on mechanisms regulating nutrient transfer in ecosystems; the use of stable and radioisotope methodologies, as well as the application of microbial culturing and biochemical techniques to environmental research; mechanisms of organic matter recalcitrance and sequestration; pesticide degradation processes, and ecosystem response to disturbance and management. Dr. Strickland has also been a leader in the development of national plans to integrate research and monitoring into policy-relevant analyses. He was a co-developer of the White House Office of Science and Technology Policy's National Environmental Monitoring and Research Framework; coordinated the USDA's contributions to the National Science and Technology Council's Committee on Environment and Natural Resources; served as the Executive Secretary for USDA's Water Quality Coordination Committee; and was a recipient of the Clean Water Action Plan Principals Award (2000) for service on the multi-departmental team that developed the Coastal Research and Monitoring Strategy.

Selected Publications:

Strickland, T.C., J.W. Fitzgerald, J.T. Ash and W.T. Swank. 1987. Organic sulfur transformations and sulfur pool sizes in soil and litter from a southern Appalachian hardwood forest. Soil Sci. 143: 453-458.

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Wauchope, R. Don; Timothy C. Strickland; and Martin A. Locke. 2004. National Needs, Regional Solutions: The Development of Site-Specific Assessments of Pesticides in Water Resources. In: American Chemical Society Symposium Series #877; *Water Quality Assessments in the Mississippi Delta – Regional Solutions, National Scope.* Mary T. Nett, Martin A. Locke and Dean A. Pennington (eds). American Chemical Society, Washington, D.C. pp. 251-263.

Strickland, T.; Potter, T.L.; Joo, H. 2004. Tebuconazole dissipation and metabolism in *Tifton* loamy sand during laboratory incubation. *Pest. Manage. Sci*. 60: 703-709.

Past Accomplishments of Gerald W. Whittaker, Research Hydrologist

Education:

1971	Oregon State University, major, Chemistry, B.S.
1978	Northwestern School of Law ,Lewis and Clark College, J.D.
1981,	Oregon State University, major, Resource Economics, M.S.

Research Experience:

1999-Present	Research Hydrologist, National Forage Seed Production Research Center, USDA-ARS, Corvallis, OR
1988-1999	Economist, Resource Economics Division, Economic Research Service, USDA, Washington, DC
1985-1988	Senior Economist, Data Resources Inc./McGraw-Hill, Washington, DC
1982-1984	Research Assistant, Agricultural and Applied Economics, University of Minnesota, St. Paul, MN
1979-1982	Research Assistant, Agricultural and Resource Economics, Oregon State University, Corvallis, OR

Accomplishments:

Developed methods of data envelopment analysis (DEA) using linear programming to analyze U.S. farm programs participation. Developed new methods of application of DEA to policy analysis, including pollution permit trading and policy efficiency of economic incentive methods of nonpoint source pollution abatement. Developed new application and extension of nonparametric regression to geographic visualization and analysis of economic and natural phenomena. Developed a methodology to link economic models through spatial statistics to physical process models, enabling a complete environmental policy analysis from the financial effects on producers to the water quality results in a single integrated system. Constructed a Beowulf cluster parallel computer and developed a parallel computational methodology for estimation of risk and uncertainty using the Soil and Water Assessment Tool (SWAT).

Selected Publications:

Whittaker, G. Use of a Beowulf Cluster for Estimation of Risk Using SWAT. manuscript is scheduled to appear in the Sept.-Oct. 2004 (Vol. 96, No. 5) issue of *Agronomy Journal*.

Whittaker, G. Use of SWAT in evaluation of salmon habitat remediation policy. *Hydrological Processes*. (in press) 2003.

Whittaker, G., R Färe, R. Srinivasan, and D.W. Scott. Spatial evaluation of alternative nonpoint nutrient regulatory instruments. Water Resour. Res. Vol. 39 No. 4, WES 1-1 to WES 1-9. 2003.

Färe, R. S. Grosskopf, and G.Whittaker. Distance Functions with applications to DEA. in *Handbook of DEA* edited by WW Cooper, L. Seiford, and J. Zhu, Kluwer Academic Publishers. Forthcoming. 2003.

Färe, R. S. Grosskopf, and G.Whittaker. On Value Efficiency and Data Envelopment Analysis. Indian Economic Review. (in press) 2003.

Whittaker, G. and D.W. Scott. Nonparametric Regression for Analysis of Complex Surveys and Geographic Visualization.” Sankhya, Series B., 61: 202-227. 1999.

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 Procedures – Not relevant

Laboratory Hazards – All hazardous materials will be handled with appropriate protective clothing and used in fume hoods as required. All pipetting is done mechanically.

Occupational Safety & Health – Not relevant

Recombinant DNA Procedures – Not relevant

While preparing the Project Plan, I (Clarence Richardson) have carefully examined all aspects of the planned research to ensure that appropriate safety concerns are addressed, all necessary permits have been identified, and that environmental issues have been considered in making the National Environmental Policy Act (NEPA) decision documented in the statement. All permits are in hand or have been requested. Documentation supporting NEPA decision is in the appropriate MU project files and available for review upon request.

Appendix A. Participating Scientists

Carlos Alonso, Research Hydrologic Engineer, Research Leader, Oxford, MS
Ronald Bingner, Agricultural Engineer, Oxford, MS
Robert Cullum, Agricultural Engineer, Oxford, MS
Seth Dabney, Research Agronomist, Oxford, MS
Scott Knight, Ecologist, Oxford, MS
Roger Kuhnle, Research Hydrologic Engineer, Oxford, MS
Eddy Langendoen, Hydrologic Engineer, Oxford, MS
Martin Locke, Research Leader, Oxford, MS
Mathias Romkens, Soil Scientist, Laboratory Director, Oxford, MS
Douglas Shields, Research Hydrologic Engineer, Oxford, MS
Andrew Simon, Geologist, Oxford, MS
Glenn Wilson, Hydrologic Engineer, Oxford, MS
Mike Burkart, Hydrologist, Ames, IA
Dan Jaynes, Research Leader, Ames, IA
Douglas Karlen, Soil Scientist, Ames, IA
Robert Malone, Agricultural Engineer, Ames, IA
Tom Moorman, Microbiologist, Ames, IA
Mark Tomer, Soil Scientist, Ames, IA
Cynthia Cambardella, Soil Scientist, Ames, IA
Gene Alberts, Soil Scientist, Columbia, MO
Robert Kremer, Microbiologist, Columbia, MO
Robert Lerch, Soil Scientist, Columbia, MO
John Sadler, Research Leader, Columbia, MO
Norman Fausey, Soil Scientist, Research Leader, Columbus, OH
Kevin King, Agricultural Engineer, Columbus, OH
Dennis Flanagan, Agricultural Engineer, West Lafayette, IN
Gary Heathman, Soil Scientist, West Lafayette, IN
Chi-hua Huang, Soil Scientist, West Lafayette, IN
Douglas Smith, Soil Scientist, West Lafayette, IN
Diane Stott, Microbiologist, West Lafayette, IN
Elizabeth Warnumuende, Research Hydrologic Engineer, West Lafayette, IN
Ray Bryant, Research Leader, University Park, PA
William Gburek, Hydrologist, University Park, PA
Tamie Veith, Agricultural Engineer, University Park, PA
Lafpat Ahuja, Soil Scientist, Research Leader, Fort Collins, CO
Olaf David, Fort Collins, CO
Timothy Green, Agricultural Engineer, Fort Collins, CO
Liwang Ma, Soil Scientist, Fort Collins, CO
James Ascough, Research Hydrologic Engineer, Fort Collins, CO
Philip Heilman, Research Hydrologist, Tucson, AZ
Gerald Whittaker, Research Hydrologist, Corvallis, OR
David Bosch, Research Hydrologic Engineer, Tifton, GA
Richard Lowrance, Ecologist, Tifton, GA
Thomas Potter, Research Chemist, Tifton, GA
Timothy Strickland, Soil Scientist, Research Leader, Tifton, GA
Don Wauchope, Research Chemist, Tifton, GA
Dana Sullivan, Soil Scientist, Tifton, GA
Jeffrey Arnold, Agricultural Engineer, Research Leader, Temple, TX
Colleen Green, Soil Scientist, Temple, TX

Daren Harmel, Agricultural Engineer, Temple, TX
Kenneth Potter, Soil Scientist, Temple, TX
Clarence Richardson, Agricultural Engineer, Laboratory Director, Temple, TX
Jin-Song Chen, Hydrologist, El Reno, OK
Jurgen Garbrecht, Research Hydrologic Engineer, El Reno, OK
Jean Steiner, Soil Scientist, Research Leader, El Reno, OK
Patrick Starks, Soil Scientist, El Reno, OK
Mike Van Liew, Hydrologist, El Reno, OK
John Daniel, Geologist, El Reno, OK

Appendix B. Watershed descriptions.

B1. South Fork of the Iowa River, Iowa

Characteristics. The watershed of interest is the South Fork of the Iowa River (Hardin and Hamilton Counties, Iowa) (Fig. B1). The total drainage area of this watershed is approximately 78,000 ha, and the watershed area to be evaluated is about 76,250 ha. Major sub-basins or Tipton Creek (19,850 ha), Beaver Creek (18,200 ha), and the upper South Fork (25,600 ha) are instrumented with separate gaging stations. Instrumentation of two small drainage districts (500 – 2500 ha) in Tipton Creek is planned for 2005.

The Clarion-Nicollet-Webster soil association (Typic Hapludolls – Aquic Hapludolls – Typic Haplaquolls) dominates the landscape, with Harps soils (Typic Calciaquolls) occupying glacial potholes with the Webster soil. The landscape is composed of glacial till deposited 10-15,000 years ago. The terrain is poorly dissected and internally drained "prairie potholes" are common in the upper parts of the watershed. The low relief creates poor drainage conditions, and hydric soils occupy 54% of the watershed area. A major lateral moraine of the Des Moines Lobe crosses the upper part of the watershed.

Subsurface tile drains and ditches were installed beginning more than 100 years ago. The artificial drainage accelerates transport of several dissolved contaminants. Normal annual precipitation is 750 mm with 60% falling during May through August in relatively short, but intense events. Annual baseflow constitutes 60% of the total stream discharge. Much of the remaining runoff is derived from subsurface drain inlets.

About 85% of the watershed is under corn and soybean rotation, and about 6% in grass (CRP) and pasture. Most of the remainder is roadways and developed land cover, only about 1% is forest or wetland. There are about 100 confined swine-feeding operations, most of which are located in Tipton Creek and the upper South Fork.

Environmental Impacts.

1. Water Quality: Nitrate loads from subsurface drainage systems, phosphorus, and sediment in runoff, and pathogens in streamflow are major water quality concerns.
2. Soil Quality: Trends in carbon sequestration as practices are implemented, and buildup of phosphorus in soils receiving frequent manure applications.

Management Practices.

1. Conservation tillage (329A and 329B)
2. Riparian Buffers (391)
3. Nutrient management (590)
4. Waste utilization (633)
5. Constructed wetlands (656)
6. Grass waterway (412)
7. Subsurface Drainage (606)

Research Objectives.

General: Evaluate watershed and river basin responses to conservation practices including those supported by USDA conservation programs.

Specific:

1. Evaluate loads of sediment, nitrate, phosphorus, and E. *coli* from the South Fork watershed and the capacity of the above conservation practices to reduce those loads.
2. Identify locations where conservation practices should be most effective in meeting water quality goals.
3. Assess the impact of current tillage and cropping practices on soil quality using the NRCS Soil Conditioning Index (SCI) and the Soil Management Assessment Framework (SMAF) being developed by the ARS and NRCS Soil Quality Institute.

Approaches. The capacity of in-field and edge-of-field conservation practices to achieve water quality goals will be evaluated in large watersheds. Landscape assessment will use terrain-modeling techniques, applied to widely available data on topography, soils, and climate to conceptualize areas where conservation practices will be most effective. A comprehensive evaluation of the distribution of existing conservation practices in the watershed will be undertaken, with assistance from NRCS. Synoptic sampling and long-term monitoring will be used to determine nutrient, sediment, and pathogen loads in streams draining watersheds at nested scales, and assess retentions and losses associated with conservation practices. The distribution of practices and sensitive areas within the watershed and its sub-basins will guide the final experimental design. Increased funding for new conservation practices (e.g., EQIP), if available, along with collaboration with the Southfork Alliance will help encourage implementation of new conservation practices. Paired watershed comparisons and/or water quality trends will evaluated to determine the impact of new practices that producers volunteer to implement. Results will also be used to parameterize models (EPIC, SWAT) that predict the effects of management systems on watershed processes and water quality.

Soil quality assessments will be made using existing data, and employing two different approaches. First, recognizing that soil organic matter is a primary indicator of soil quality and an important factor in carbon sequestration and global change, the NRCS Soil Conditioning Index (SCI) will be used to assess the consequences of the tillage and cropping systems being used within the watershed. The SCI will provide estimates on whether the applied conservation practices are maintaining or increasing soil organic matter. The predictions will be verified with the available data being collected by either the farmer-cooperators (i.e. through their soil test records) or other researchers contributing to the overall CEAP database. A more comprehensive assessment of soil quality will be made using the Soil Management Assessment Framework (SMAF) that is currently being developed by the ARS and the NRCS Soil Quality Institute. SMAF is designed to evaluate the dynamic impact of soil management practices on soil function and consists of three steps: indicator selection, indicator interpretation, and integration into an index. Designed as a framework, SMAF allows researchers to continually update and refine the interpretations for many soils, climates, and land use practices. Therefore, in addition to providing soil quality assessments for CEAP, the project will provide data for further improvements of the SMAF. This will occur by applying decision rules based on management goals and other site-specific factors in the selection step for each watershed. The interpretation step will provide site-specific indicator scores. Individually and collectively (through the index), the indicator scores will be correlated to critical endpoints including crop yield, water quality (i.e. nitrate, phosphorus, and sediment loads), and air quality indicators.

Selected references.

Tomer, M.D., and D.E. James. 2004. Do soil surveys and terrain analyses identify similar priority sites for conservation? Soil Sci. Soc. Am. J. 68:1905-1915.

Tomer, M.D., D.E. James, and T.M. Isenhart. 2003. Optimizing the placement of riparian practices in a watershed using terrain analysis. J. Soil & Water Conserv. 58(4):198-206.

Collaborators and Cooperating Agencies and Groups. The **Southfork Watershed Alliance**, a local organization, is working to encourage implementation of conservation practices that can protect and improve water quality.

NRCS has identified the physiographic region as the focus of their CREP program in Iowa and is using methods developed by NSTL to locate appropriate sites for wetland restoration.

USGS maintains continuous discharge stations at two sites where the NAWQA program found nitrate concentrations to be among the highest observed in the US. Measurements of pharmaceuticals have been a subject of recent research.

USEPA has expressed interest in coordinating ORD research with that of ARS to answer questions related to Clean Water Act program administered by Region VII.

NRCS Soil Quality Institute (Dr. Susan Andrews) will work with the SMAF, contributing refinements in and developing new scoring curves for critical indicators within the various watersheds.

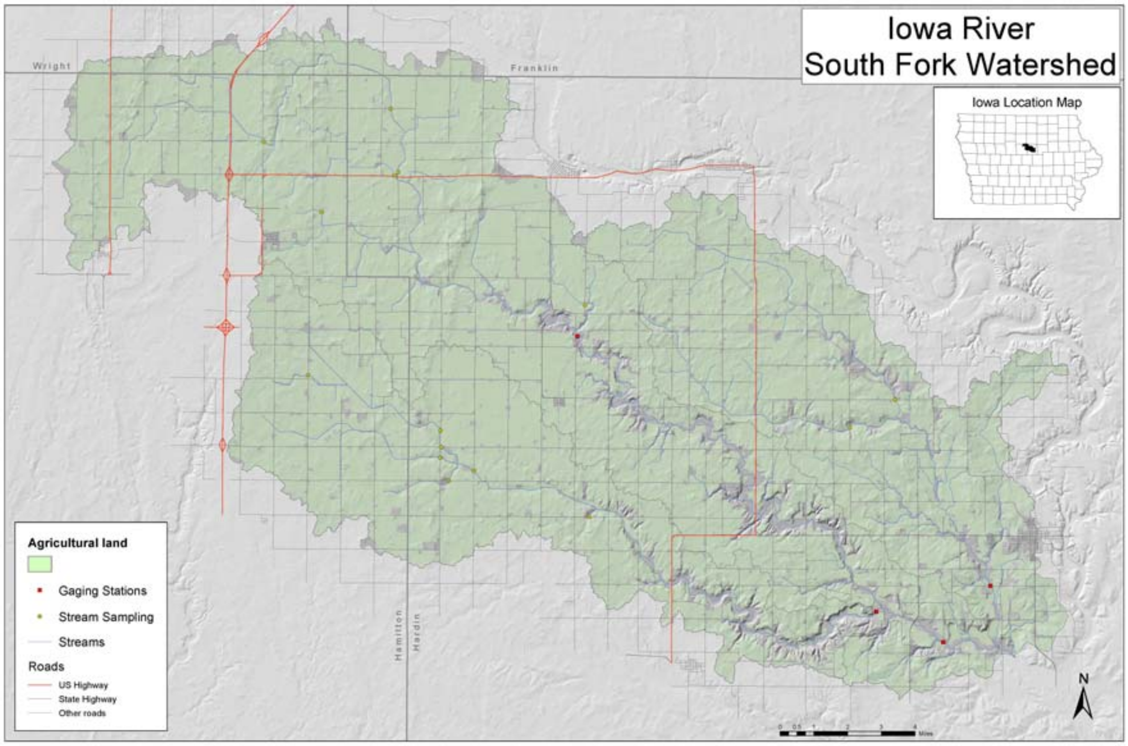

Figure B1. South Fork of the Iowa River, IA.

B2. Walnut Creek, Iowa

Characteristics. Walnut Creek in Boone and Story counties Iowa drains 5,130 ha in the Central Iowa and Minnesota Till Prairies (MLRA) and Des Moines Lobe physiographic regions (Fig. B2). The landscape is underlain by glacial till deposited 10-15,000 years ago. The maximum relief on the poorly dissected terrain is generally less than 5 m with internally drained prairie potholes common in the upper parts of the watershed. Aquic soils occupy 60% of the watershed area. The Clarion-Nicollet-Webster soil association dominates the landscape, with Okoboji and Harps soils occupying potholes. Subsurface tile drains and ditches installed over the past 120 years accelerate drainage and transport of several dissolved contaminants. Normal annual precipitation is 818 mm with 52% falling during May through August in relatively short, but intense events. Annual base flow, which includes tile flow, constitutes 75% of the total stream discharge. Much of the remaining runoff is derived from inlets into the subsurface drain system. About 80% of the watershed is under corn and soybean rotation; 3% in forage crops, 3% in pasture; 4% in woodland; and the remainder in small grains, transportation, and farmsteads. The only animal production operations in the watershed are a seasonal beef pasture area and a small horse farm.

Environmental Impacts. *Stream Flow.* Discharge from Walnut Creek has been extremely variable during the past 12 yrs. Annual discharge varied from a low of 7 mm in 2000 to a high of 865 mm in 1993. This represents a range of 1 to 67% of the annual precipitation. Discharge from the watershed is dominated by base flow in all years and all months. Average monthly discharge is greatest during the March-July period and runoff is the largest percentage of total discharge in March due to snowmelt and rainfall on frozen ground.

Surface Water Quality. During the past 12 years, atrazine and metolachlor have been detected at concentrations $> 0.2\ \mu g\ L^{-1}$ in about half of all surface water samples, while alachlor and metribuzin have been seldom detected. Atrazine and metolachlor concentrations have rarely exceeded health advisory limits and mean yearly concentrations have been below $2\ \mu g\ L^{-1}$ for all locations within the watershed. In contrast, nitrate concentrations have often exceeded $10\ mg\ N\ L^{-1}$ during April - July. Total nitrate losses from the watershed have ranged from 1 to $66\ kg\ N\ ha^{-1}\ yr^{-1}$ which are equivalent to 1.5 to 115% of the fertilizer N applied in any year. Thus, nitrate is the primary pollutant of concern related to agricultural activities within the watershed.

Research Objectives.

General. To evaluate alternative methods for reducing nitrate concentrations in the surface water of an intensively tile-drained agricultural watershed.

Specific.

1. Quantify the impact of intensive row crop agriculture on the water quality of a small watershed.
2. Quantify the impact of adopting the late spring nitrogen test (LSNT) best management practice for nitrogen fertilizer application to corn on NO_3^- concentration and load in subsurface drainage at the watershed scale.
3. Improve the management of N in soil by: determining the temporal dynamics of N mineralization/immobilization in soil as affected by soil microbial biomass/activity, shoot and root residue inputs, labile organic matter pools, N fertility status, and

tillage; and improving synchronization between N availability in soil and N requirement by crop.

4. Modify and evaluate the SWAT watershed model for simulating hydrology and water quality in an intensively tile-drained watershed and apply the model to evaluate the water quality and economic impact of adopting various N control strategies.
5. Assess the impact of current tillage and cropping practices on soil quality using the NRCS Soil Conditioning Index (SCI) and the Soil Management Assessment Framework (SMAF) being developed by the ARS and NRCS Soil Quality Institute.

Approaches. Long-term monitoring of a watershed with intensive row crop production and little animal agriculture will provide a baseline of crop production impacts on surface water quality. The LSNT N management system will be applied to a subbasin within Walnut Creek and compared to two companion subbasins by a paired watershed approach. This study will spur further research into accounting for N mineralization when making N fertilizer recommendations and in developing sidedress technology to help increase the adoption of this N management approach. A limitation in adjusting N fertilization rates for soil mineralization (and in the LSNT) is a lack of understanding of how N and C cycle through soil and the effect of various plant residues on the rate of cycling. Objective 3 will investigate in detail the dynamics of plant residue decomposition with the long-term intention of designing systems that synchronize the release of organic bound N with crop uptake. This work will also concentrate on ways to improve soil tests for estimating N mineralization, including the use of near infrared reflectance spectroscopy to replace or improve the performance of the LSNT. Finally, we recognize that even the best efforts of managing N may result in unacceptably high NO_3^- concentrations and loads in drainage waters leaving corn fields. Thus, new technologies are needed for treating these drainage waters to remove NO_3^-.

The first phase of calibration and testing of the SWAT model will use Walnut Creek stream and county drain data from 1992-1996. Evaluation of model performance will include comparison at daily and monthly time scales of water discharge and nitrate concentration and loads. Multiple comparison criteria including maximum error, root mean square error, coefficient of determination, modeling efficiency and coefficient of residual mass will be used to evaluate SWAT model performance. After initial calibration and testing of the model, the model will be used to predict watershed response for the years 1997-2004 to test the robustness of the model - calibrated parameter set to accurately predict watershed response for a range of weather patterns. If satisfactory, the model will be used to test the impact of various N management practices on water quality within Walnut Creek. Initially, the model will be used to investigate the effect of switching from a fall to spring N-fertilizer application with LSNT scenario and predictions compared to the results of the watershed project currently underway within Walnut Creek using this strategy.

Soil quality assessments will be made using two different approaches. First, recognizing that soil organic matter is a primary indicator of soil quality and an important factor in carbon sequestration and global change, the NRCS Soil Conditioning Index (SCI) will be used to assess the consequences of the tillage and cropping systems being used within the watershed. The SCI will provide estimates on whether the applied conservation practices are maintaining or increasing soil organic matter. The predictions will be verified with the available data being collected by either the farmer-cooperators (i.e. through their soil test records) or other researchers contributing to the overall CEAP database. A more comprehensive assessment of soil quality will be made using the Soil

Management Assessment Framework (SMAF) that is currently being developed by the ARS and the NRCS Soil Quality Institute. SMAF is designed to evaluate the dynamic impact of soil management practices on soil function and consists of three steps: indicator selection, indicator interpretation, and integration into an index. Designed as a framework, SMAF allows researchers to continually update and refine the interpretations for many soils, climates, and land use practices. Therefore, in addition to providing soil quality assessments for CEAP, the project will provide data for further improvements of the SMAF. This will occur by applying decision rules based on management goals and other site-specific factors in the selection step for each watershed. The interpretation step will provide site-specific indicator scores. Individually and collectively (through the index), the indicator scores will be correlated to critical endpoints including crop yield, water quality (i.e. nitrate, phosphorus, and sediment loads), and air quality indicators.

Cooperating agencies and groups. USGS, EPA, and Iowa State University have been active in this watershed in the past. Currently, the watershed is included on the Iowa list of impacted waters. Current cooperators include Jeff Arnold (ARS) and Ali Saleh (TIAER) looking at applying SWAT. Susan Andrews with the NRCS Soil Quality Institute will work with the SMAF, contributing refinements in and developing new scoring curves for critical indicators within the various watersheds.

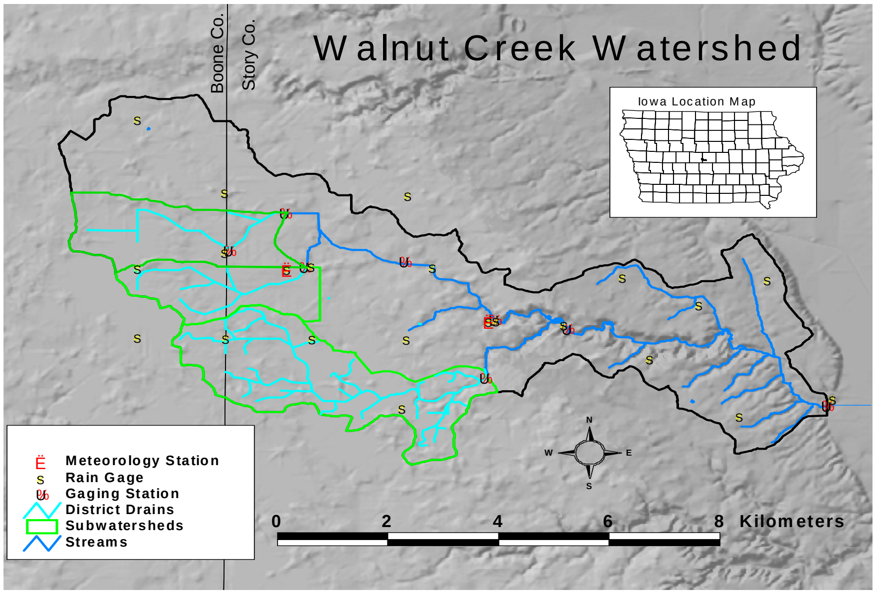

Figure B2. Water monitoring, tipping bucket, meteorological station, district drains, and sub-watershed locations within Walnut Creek, IA.

B3. Salt River/Mark Twain Reservoir, Missouri

Characteristics. The Salt River Basin in northeastern Missouri is the source of water to the Mark Twain Lake, an 18,600-acre Army Corp of Engineers reservoir that is the major public water supplier in the region. The Salt River system, as depicted in Figure B3 encompasses an area of 2,518 mi^2 within portions of 12 northeastern Missouri counties. Sub-watershed areas monitored will range from 28 mi^2 to 460 mi^2. Soils within the basin were formed in Wisconsin and Illinoian loess overlying pre-Illinoian glacial till. Illuviation of the high clay content loess resulted in the formation of argillic horizons containing 40-60% smectitic clays. Topography within the watershed is flat to gently rolling, with most areas having 0-3% slopes. The Adco-Putnam-Mexico soil association predominates in the flatter upland areas, and these soils tend to be less eroded and have greater depths to the claypan than the terrace areas. The Mexico-Leonard soil associations occur in more sloping terrace and alluvial areas where the depth to claypan is often <15 cm on side slopes because of erosion. The claypan is not present within alluvial areas immediately adjacent to streams. The naturally formed claypan represents the key hydrologic feature of the basin, and it is the direct cause of the high runoff potential of these soils. Most soils within the basin are classified as Hydrologic Group C or D by NRCS. Land use is predominately agricultural within the basin. The primary row-crops are soybeans, corn, and sorghum. Forage production is mainly tall fescue. Livestock production is mainly beef cattle, but swine operations are increasing, particularly in the Middle and Elk Fork watersheds. Average annual precipitation is about 1000 mm per year, and stream flow (based on Goodwater Creek data) accounts for about 30% of precipitation. Runoff accounts for about 85% of total stream flow. Despite high runoff potential and poorly drained soils, sub-surface drainage is not employed because of the difficulties of installation in or below the claypan.

Environmental Impacts.

Water Quality. Runoff contaminated with sediments, nutrients (P, NO_3^-, NH_4^+), pesticides, and water-borne pathogens.

The basin has a known and well-documented history of herbicide and sediment contamination problems. The naturally formed claypan soils that predominate within the basin create a barrier to percolation and promote surface runoff. This results in a high degree of vulnerability to surface transport of sediment, herbicides, and nutrients. Mark Twain Lake serves a public drinking water supply for approximately 42,000 people, and consistently high spring and summer time atrazine levels have been an on-going concern. More recently, late summer algal blooms have created the need for more extensive water treatment to reduce odor and taste problems in drinking water, and may be a reflection of increased nutrient transport within the basin. Water-borne pathogen contamination of the major sub-watersheds of the Salt River basin has not been extensively studied to date. It is anticipated that this may be a problem in those sub-watersheds with significant animal feed operations.

Management Practices. Studies are currently underway at field and plot scales to study the water quality impact of several different conservation practices. These studies include implementation of a precision agricultural system on an 88-acre field (590, 329A), plot-scale studies of the effectiveness of grass filters and grass hedges on contaminant mitigation from edge-of-field runoff and parallel tile outlet discharge (393), alternative weed management systems focused on reducing herbicide inputs (595), measuring soil quality under different cropping systems, and the potential for enhanced herbicide degradation in contour grass buffer strips (332). In addition, hydrologic simulation models will be used to predict water quality at multiple scales, determine contaminant source areas within watersheds, and serve as decision support aids for BMP implementation.

Research Objectives

Prevailing and traditional agronomic practices for row crop production have degraded soil and water resources in the midwestern claypan soils region. Soil and water quality are inextricably connected, and surface runoff is the key hydrologic process that physically links them. Individual research projects are integrated by the development, implementation, and assessment of Best Management Practices (BMPs) to improve soil and water quality. An additional level of impact stems from the development of watershed models as tools for BMP assessment and watershed planning.

Specific objectives are to: 1) assess soil biological activities for describing soil quality under different agricultural practices; 2) develop criteria, evaluate performance, and determine economic impacts for implementation of alternative BMPs associated with herbicide, nutrient, and sediment contamination; 3) validate and improve watershed models to better assess the impact of field- watershed-scale management practices on surface water quality.

Approaches. The implementation of Best Management Practices (BMPs) to improve soil and water quality must be balanced with the need for socially acceptable practices that sustain profitable crop production. Our vision to meet this challenge entails an array of conservation, agronomic, and soil management practices. The proposed research encompasses three main approaches: (1) studies addressing the parameters and practices that control soil and water quality; (2) studies designed to test the effectiveness and economic impact of various BMPs and alternative weed management strategies; and (3) application of computer models to simulate the impact of BMPs on surface water quality at field and watershed scales. These broad objectives are divided into nine individual projects tied together by a common goal: the effective implementation of BMPs to improve and sustain soil and water resources. Projects include studies ranging from assessment of soil and water quality to application of genetic-based techniques for detection of water-borne pathogens to development and testing of new agronomic and conservation management practices. Expected results include improved indexing of soil quality parameters, new and profitable BMPs for field crop production that protect or improve soil and water quality, and a validated model for improved surface water quality assessment and planning.

Measurements In Place and Planned. Water quality monitoring at Goodwater Creek and at an 88-acre farm field within Goodwater Creek watershed will continue during CEAP. The field and watershed monitoring stations are equipped with v-notch weirs and automatic samplers. The automatic samplers are equipped with pressure transducers to measure the height of the water column for computing stream discharge. At the field scale, samples are collected for all runoff events. Shallow groundwater is also collected at two locations within the field twice each year and analyzed for dissolved nitrate levels. At the watershed scale, grab samples are collected weekly, and all runoff events are sampled by the automatic sampler. In addition, the USGS has an extensive network of hydrologic monitoring stations at nearly all major watersheds that discharge into Mark Twain Reservoir, as well as a monitoring station at the reservoir outlet (Fig. B3). Thus, stream discharge into and out of the reservoir is well characterized. In order to have a complete water quality monitoring network for computing the mass balance of contaminants into and out of the reservoir, additional monitoring stations will need to be established at Black Creek and Otter Creek (Fig. B3). In addition, two new monitoring sites will be established within the Long Branch Creek watershed to provide a multi-scale assessment of water quality. At all surface monitoring sites, contaminant monitoring will include commonly used corn and soybean herbicides, dissolved and total N and P, and sediment. Newly established sites will have rating curves developed to compute discharge. Enumeration of fecal coliforms and detection of pathogenic bacteria will be conducted periodically to assess the extent of pathogen contamination in the major sub-watersheds of the Salt River.

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Collaborators and Cooperating agencies and groups. There are numerous agencies and groups currently involved in some type of CEAP-related activities within the Mark Twain/Salt River Basin as a whole. The following list indicates potential partners; * indicates confirmed project collaborators.

Federal partners: NRCS*, USGS, EPA, and possibly COE.

State partners: MO Departments of Natural Resources, Conservation, and Agriculture; University of Missouri Water Quality Extension (including the MO Watershed Information Network); Food & Agricultural Policy Research Institute (FAPRI)*.

Local/regional partners: CCWWC, Soil and Water Conservation Districts, Mark Twain Water Quality Initiative.

Non-profit advocacy partners: MO Corn Growers Association*, Environmental Resources Coalition*, MO Cattleman's Association.

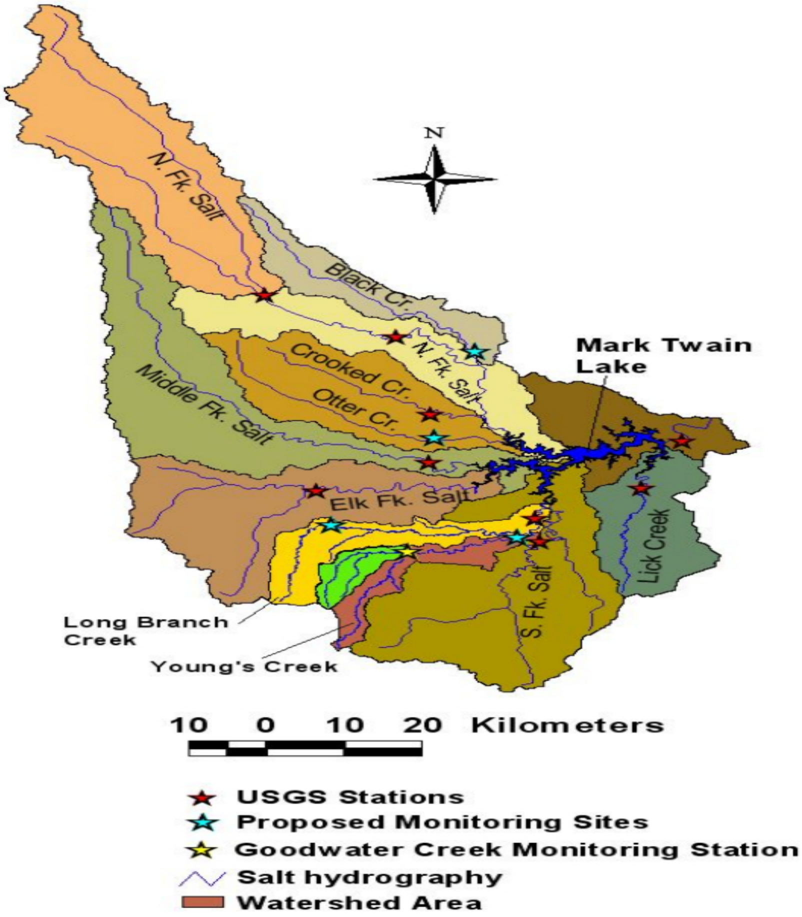

Figure B3. Salt River basin and major watersheds to Mark Twain Lake.

B4. Upper Washita River, Oklahoma

Characteristics. The Upper Washita River Hydrologic Unit in southwest Oklahoma drains an area of 8260 km^2 (827,000 ha). The Washita River is a tributary to the Red River, flowing into Lake Texoma, the largest reservoir in Oklahoma. Monitoring and assessment for CEAP will focus on two subwatersheds, (approximately 11-digit HUC size), the Little Washita River and Fort Cobb Lake watersheds. The region is sparsely populated with predominantly agricultural land use, consisting of mixed cropland and grazingland. Localized areas of irrigated cropland exist in association with water supply from reservoirs or groundwater. The region is underlain primarily by Permian sandstone, siltstone, and claystone. Both watersheds receive about 76 cm of precipitation annually, with most of the precipitation occurring during the spring and fall months.

The Fort Cobb Lake - Lake Creek subwatershed (78,800 ha) has mixed agricultural land use, including rangeland/pasture (41%), dryland crops (41%), irrigated crops (10%), forests (6%), and water (2%). Irrigation in the Fort Cobb Lake watershed is by center pivot systems on sandy soils, supplied by groundwater. Cattle grazing, predominantly stocker cattle, utilize the range and pasture lands. Confined swine operations are located in the upper portions of the watershed. The reservoir provides public water supply, fishing, boating, and wildlife habitat. Over 80% of the soils in the watershed are fine sandy loams, with the remaining 17% having loamy and silt loam textures.

The 61,000 ha Little Washita River Experimental Watershed (LWREW) is also a mixed landuse watershed with pastures and grasslands (60 %), cropland (20 %), and miscellaneous land-use (20 %). There are 45 USDA-funded flood control structures within the Little Washita River subwatershed. There are 64 defined soil series in the LWREW, with fine sand, loamy fine sand, fine sandy loam, loam and silty loams being the predominant textures of the soil surface. In general, soils with moderate infiltration rates cover approximately 70% of the watershed.

Environmental Impacts.

1. Sedimentation and nutrient (phosphorous and nitrogen) loading.
2. Channel instability in some of the tributaries.
3. Impaired water bodies for municipal water supply, recreation, and fish and wildlife.
4. Degradation of wildlife habitat.

Management Practices.

1. Pasture and hay planting (512)
2. Grassed waterway (412)
3. Fencing (382)
4. Use exclusion (472)
5. Grade stabilization structure (410)
6. Critical area planting (342)

Research Objectives.

General: The overall goal is to develop better understanding of the integrated effects of land use, land management (including conservation practices) and climate variations on hydrologic processes at watershed to regional scales. The Southern Great Plains is subject to recurring climate extremes, particularly drought, which slows economic growth mainly due to limited and unreliable water supplies. Because agriculture dominates land use, conservation and other agricultural management practices have a large impact on water resources.

Specific:

1. Quantify hydrologic processes that affect regional surface water supplies as a basis for development of strategies and methodologies to better meet the water quantity and quality needs of downstream users.
2. Determine infiltration, ground water recharge and return flows to ascertain impacts on ground water supplies And surface/groundwater interactions.
3. Integrate remote sensing estimates of surface soil water content with other spatial data sets to monitor and predict root zone soil water content and availability at regional scales to improve watershed and regional water balance calculations.

Approaches. World-class instrumented watershed facilities, state-of-the-art simulation models, field studies, and remotely sensed data are utilized in this project to address the three interrelated objectives noted above. Hydrologic data collected between 1961-85 from various sub-basins within the Upper Washita Watershed are available for model calibration. Weir sites from prior studies still exist and could be re-instrumented, if needed and pending land owner approval. Substantial monitoring of climate and streamflow is supported by ARS, the Oklahoma Mesonet, and USGS in the LWREW and Fort Cobb watershed. Extensive monitoring was conducted from 2000 to 2002 by USGS in the Fort Cobb watershed. Beginning in 2005, a bi-weekly cycle of stream water quality measurement will be initiated by ARS, including: pH, dissolved oxygen, conductivity, salinity, total dissolved solids, temperature, turbidity, oxygen reduction potential, nitrate concentration, ammonia concentration, suspended sediment, and phosphorus. The Great Plains RC&D will work collaboratively with ARS to contact farmers to obtain conservation and production management information relevant to the assessments. The Oklahoma Conservation Commission will conduct a habitat assessment of selected stream segments. The suite of EPIC/APEX/SWAT models will be used in scaling analyses to determine linkages of conservation practices, soil properties, edge-of-field responses, and watershed scale responses. The SWAT and SWAT/MOD models will be used for assessing the impacts of conservation practices on surface and groundwater, respectively, at the watershed scale. CONCEPTS will be used to assess the role of stream bank stability and channel processes within the watershed. Land use, soil, remotely sensed estimates of surface soil water content, and other spatial data sets will be utilized to produce regional estimates of soil water content in the root zone. Impacts of conservation practices on soil physical, biological, and chemical properties will be evaluated collaboratively with the National Soil Erosion Laboratory. Geohydrologic data will include groundwater data sets from historic ARS wells, USGS groundwater wells from surrounding areas, and historical and current stream gages. The historical database contains data for 34 drill holes, for which 21 were used to monitor ground water levels within the LWREW. The other 13 drill holes were used for stratigraphic control. In addition, historical databases from hundreds of monitoring wells from other experimental watersheds in this region, and in similar geologic terrain, are also available. Areas within the LWREW and Ft. Cobb watersheds that have little stratigraphic control will be drilled, cored, and some will be completed as groundwater monitoring wells to provide insight in regions where information is scarce.

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Collaborators and Cooperating Agencies and Groups:
USDA-ARS National Soil Erosion Laboratory, Natural Resources Conservation Service, United States Geological Survey, Environmental Protection Agency, Oklahoma Climatological Survey, University of Oklahoma, Oklahoma State University, Oklahoma Conservation Commission, Great Plains RC&D, Local Landowners

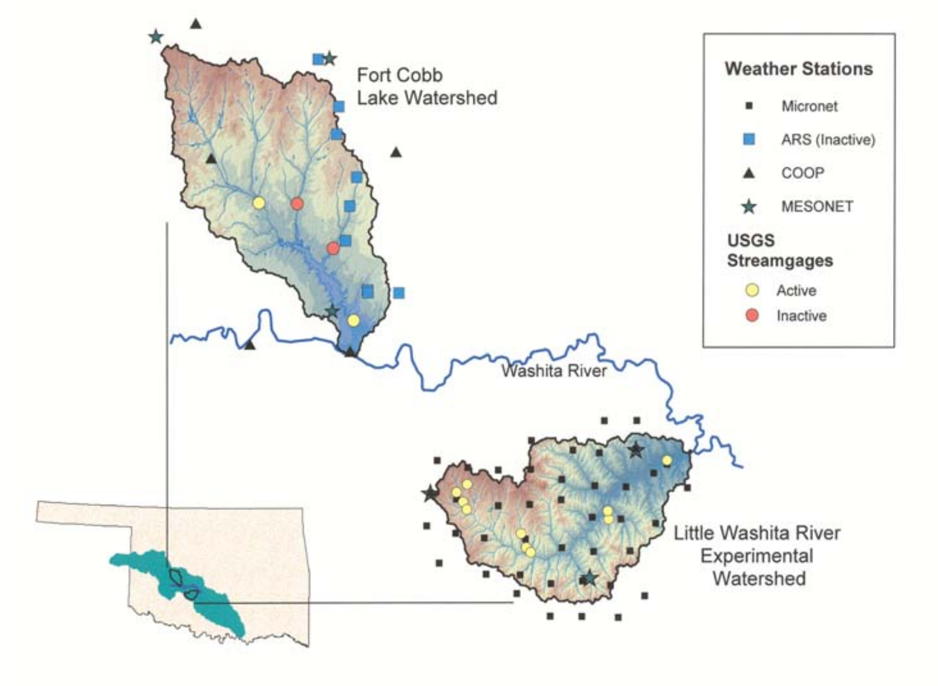

Figure B4. Little Washita River and Fort Cobb Lake watershed.

B5. Goodwin Creek, Mississippi

Characteristics. Goodwin Creek drains 2132 ha in Panola County which is in the north central part of the state of Mississippi. Drainage is westerly to Long Creek which flows into the Yocona River, one of the main rivers of the Yazoo River Basin, a tributary of the Mississippi River. The watershed is divided into 13 subwatersheds, which range in size from 28 to 1292 ha. The watershed is located in the loess-covered, bluff hills province just east of the Mississippi River flood plain. Elevation on the watershed ranges from 71 m (233 ft) to 128 m (420 ft) above sea level, with an average channel slope of 0.004 m. The soils on the watershed consist of two major associations. One soil association is the Collins-Falaya-Grenada-Calloway association that is mapped in the terrace and flood plain locations. These soils are poorly to moderately well drained and include much of the cultivated area in the watershed. The other soil association, the Loring-Grenada-Memphis association, developed on the loess ridges and hillsides. These soils are moderately well to well drained on gently sloping to very steep surfaces and include most of the pasture and wooded area of the watershed. The soils are silty in texture and quite easily eroded when the vegetation cover is removed. The climate on the watershed is humid, with average daily maximum temperatures of about 30^0 C in the summer and 10^0 C in the winter. Most major runoff events occur during winter and spring seasons. Average annual rainfall of the watershed, measured at the climatological station near the center of the watershed, is 1440 mm, while the mean annual runoff has been determined to be 145 mm at the watershed outlet. Land use on the watershed has changed from nearly equal portions of cultivated, pasture, and wooded in 1980 to 10% cultivated at the present time. Cultivated land is primarily composed of cotton, soybeans, and corn.

Environmental Impacts.

1. Water Quality: Runoff contaminated with sediment, phosphorus, and fecal coliforms.
2. Fish and Wildlife Habitat: Aquatic habitat impaired by unstable substrate, lack of pool habitat, and by highly suspended sediment concentrations, which has caused reduced sizes and species composition of fish and invertebrates.
3. Soil Quality: Soil quality has been adversely affected by excessive erosion.

Management Practices.

1. Conservation reserve program (CRP, 327).
2. Channel stabilization (584)
3. Grade stabilization structures (410)
4. Stream habitat improvement and management (395)
5. Channel bank vegetation (322)

Research Objectives. Evaluate watershed and channel responses to conservation practices over the period of record of the watershed. Conservation practices on this watershed include conversion of erodible cropland to the conservation reserve program (CRP,327), channel stabilization (584), grade stabilization structures (410), stream habitat improvement and management (395), channel bank vegetation (322).

Approaches. The research related to CEAP on Goodwin Creek will combine field, laboratory, and computer modeling components. The field and laboratory studies will concentrate on the accurate measurement and prediction of sediment transport rates by the channels of the watershed. This capability is critical for the accurate determination of sediment amounts, sources, and contaminants. A key factor that will be studied on Goodwin Creek is the determination of the sources of sediment and its effects on the environment. Previous studies have shown that channel erosion provides a significant contribution to the total sediment load of the watershed. Samples of fine sediment will be automatically collected at the measurement stations of the watershed. These will be combined with experimental measurements of sediment concentration collected using acoustic backscattering to yield a record of sediment load. Soil properties of the watershed will be quantified and used for sediment source determinations and modeling inputs.

Completed (historical) studies have documented the effects of channel and bank stabilization on stream fishes and invertebrates. In particular, populations within reaches stabilized using traditional structures and reaches with structures modified to produce more pool habitat have been compared over 3-10 year periods. Some of these studies have documented the temporal variation in bed material size with channel erosion and deposition and the hydraulic retention at baseflow of reaches with and without small beaver dams.

Sediment source information will be determined in the suspended sediment of Goodwin Creek during runoff events using activities of ^{7}Be and ^{210}Pb. Activities of ^{7}Be and ^{210}Pb are measured from precipitation, soil, bank, and suspended sediments in the Goodwin Creek watershed. Gamma spectroscopy is used to determine the activities of ^{7}Be and ^{210}Pb in all samples. Suspended sediment in Goodwin Creek is a mixture of landscape derived and bank derived sediment. The activities of ^{7}Be and ^{210}Pb of the surface soils will be significantly higher than corresponding activities of the bank sediments. The radionuclide signature of the suspended sediment will lie intermediate along a mixing line between the signatures of the two end-member sources of sediment. Thus, fine suspended sediment in Goodwin Creek has an intermediate radionuclide signature that is quantified in terms of the relative contribution of landscape derived and bank sediment. This data will be valuable in evaluating source information from CONCEPTS and AnnAGNPS.

Continuous monitoring of hydrologic, hydraulic and geotechnical controls of streambank failures is being conducted along an active meander bend and at edge of field gullies. The data from these studies are used to enhance a deterministic model of bank stability, to support finite-element modeling of seepage, and to develop a predictive model of gully migration and erosion. Top-bank vegetative treatments are being monitored to quantify the hydrologic and mechanical effects of riparian vegetation on bank stability and their potential role as a conservation measure. These efforts will provide data for enhancements to routines in CONCEPTS and AnnAGNPS.

The historical and newly acquired conservation data from NRCS will be used with AnnAGNPS and CONCEPTS to evaluate watershed and channel responses to conservation practices over the period of record of the watershed. The simulated values will be verified using field-collected data on sediment concentrations, sediment sources, and bank retreat rates. This will assure that the models are adequately representing the processes acting on the watershed. Model simulations using AnnAGNPS and CONCEPTS will be made to evaluate different scenarios of conservation practices and sources of sediment. Changes in water quality parameters from 1985 through 2005 will be evaluated in terms of the conservation practices used on the watershed.

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Collaborators and Cooperating Agencies and Groups. NRCS has established two SCAN (soil climate analysis network) sites on Goodwin Creek. These sites provide long-term geographically distributed soil climatology data. One wooded and one pasture site were chosen where soil moisture and temperature at several different depths were being measured.

NOAA has identified Goodwin Creek for co-location of solar surface radiation budget (SURFRAD) and surface thermal energy and CO2 exchange (FLUXNET) monitoring stations as part of nationwide networks. Data on those parameters is collected on a continuous basis and related to other watershed processes.

University of Mississippi National Center for Physical Acoustics (NCPA) has been involved in ongoing cooperative projects to use acoustics to improve the measurement of sediment transport on Goodwin Creek.

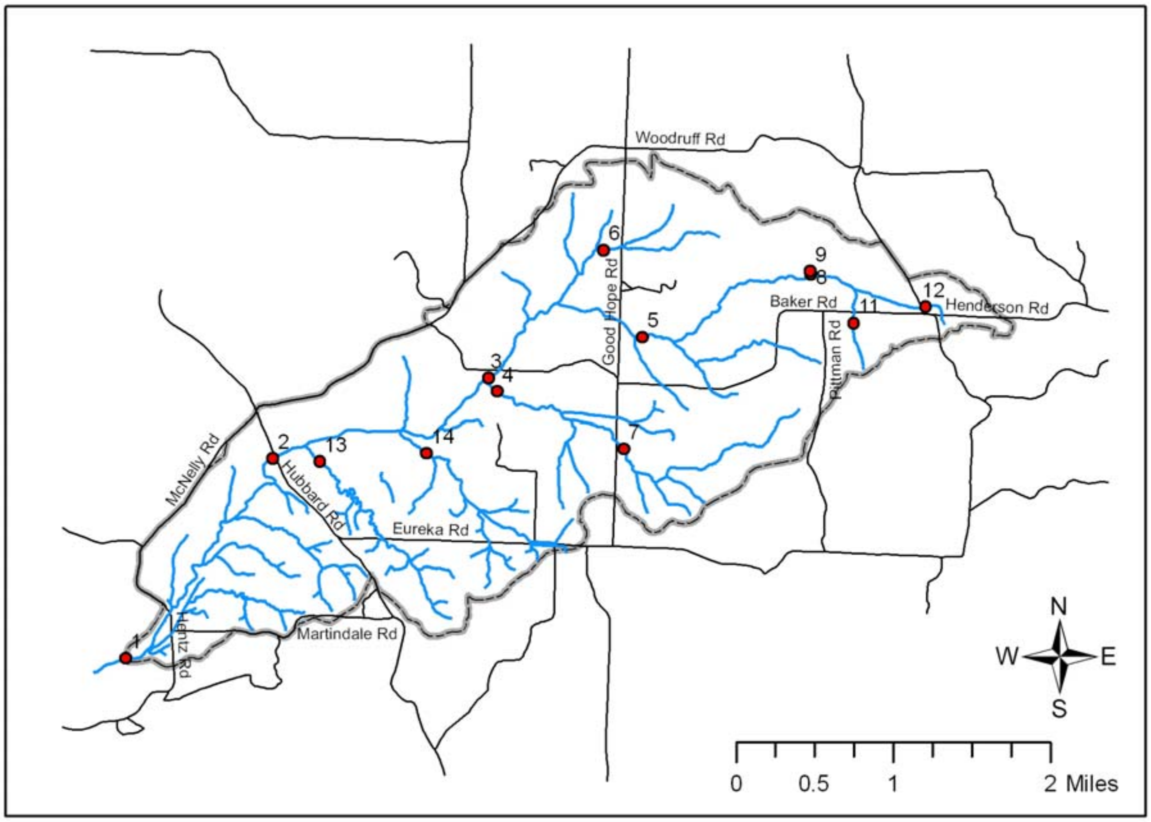


Figure B5. Goodwin Creek Watershed, MS.

B6. Yalobusha, Mississippi

Characteristics. The Yalobusha and Skuna Rivers are the major contributors to Grenada Lake in North Central Mississippi. The Upper Yalobusha River Watershed (YRW), which covers 168,750 ha (651 square miles), was defined from a point in Grenada Lake upstream of the confluence of the Yalobusha and Skuna Rivers. The National Sedimentation Laboratory has focused research in YRW on the Little Topashaw Creek since 2000. CEAP activities will target this 4,000 ha subcatchment and, specifically, a series of about 2-5 ha field sites along a reach of the Little Topashaw Creek instrumented upstream and downstream of the field sites (Fig. B6).

The land use of the YRW consists of 18% cropland, 19% pasture or grassed areas, 53% forested areas, 6% wetland that is largely forest, and 4% surface water or urban areas. A geologic section taken longitudinally along the Yalobusha River shows the Midway Group as the dominant formation. Regional geology is characterized by dispersive silt soils interbedded with sand and clay layers that overlie consolidated clay material. It is the presence of the resistant, clay bed material that makes the Yalobusha River System somewhat unique in comparison to other adjusting stream systems in the mid-continent region. The Major Land Resource Area (MLRA) for the YRW is MLRA 133A - Southern Coastal Plain. Major features of the river system include: (1) relatively erosion-resistant cohesive streambeds overlying sandbeds and with no lithologic bed controls; (2) almost an entire channelized stream network; (2) the straightened and enlarged Yalobusha River main stem terminates in an unmodified, sinuous reach with a much smaller cross section and conveyance; and (4) the lower end of this channelized reach is ked by a plug of sediment and debris.

Environmental Impacts. The Yalobusha River Watershed experiences deposition and flooding problems in downstream reaches, erosion via headward-progressing knickpoints, and massive bank failures in upper reaches. These general patterns are found throughout the region, and are associated with the consequences of accelerated erosion stemming from land mismanagement and channelization. As a consequence of channel adjustment processes related to channelization in the late 1950's and early 1960's, upstream-migrating knickpoints have caused deepening of upstream reaches and tributary channels. Sufficient deepening occurred to cause significant channel widening by mass failure of channel banks. Woody vegetation, previously growing on these channel banks, delivered to the flow was transported downstream to form large debris plugs. The debris plugs function as dams, causing higher water levels and slower flow velocities than previously measured. This, in turn, causes even greater rates of deposition, further reducing channel capacity, and increasing the magnitude and frequency of floods.

Management Practices.

1. Conservation tillage (NRCS codes 329A and 329B)
2. Riparian Forest Buffer (391)
3. Vegetated Barriers (601) e.g., Stiff Grass Hedges
4. Drop-Pipe Structures (410)
5. Willow Establishment in channels (322)

Research Objectives.

General: The overall objective is to evaluate watershed responses to field, edge of field, and channel conservation practices.

Specific:
1. Define the variability of hydrologic and biogeochemical processes that influence the effectiveness of conservation practices processes at different scales within the YRW.
2. Identify and quantify the effects of specific management / conservation practices and systems on contaminant and water transport.

Approaches.

Subobjective: 1a. Compile the information collected to date in the Yalobusha River system on land use, conservation practices, and soil characteristics. Through a position funded with the Mississippi State University Cooperative Extension office, we will work with USGS, NRCS, CoE and other agencies to develop a detailed land-use inventory, identify and locate conservation practices, acquire digitized soils data, and conduct surveys of farmers.

Subobjective 1b. Compile the information collected to date in the Yalobusha River system on streamflow and sediment, nutrient and pesticide concentrations at baseflow and during storm events. Continuous measurements of stream discharge have been made by USGS at six locations within the defined YRW. These measurements include three locations on the main channel of the Yalobusha River Canal, two on the Topashaw Creek Canal and one on Bear Creek. Continuous measurements of stream discharge have been made by USGS at six locations within the defined YRW. These measurements include three locations on the main channel of the Yalobusha River Canal, two on the Topashaw Creek Canal, and one on Bear Creek. Through the MSU extension position, we will compile historical hydrologic and water quality data from the USGS stream gaging stations.

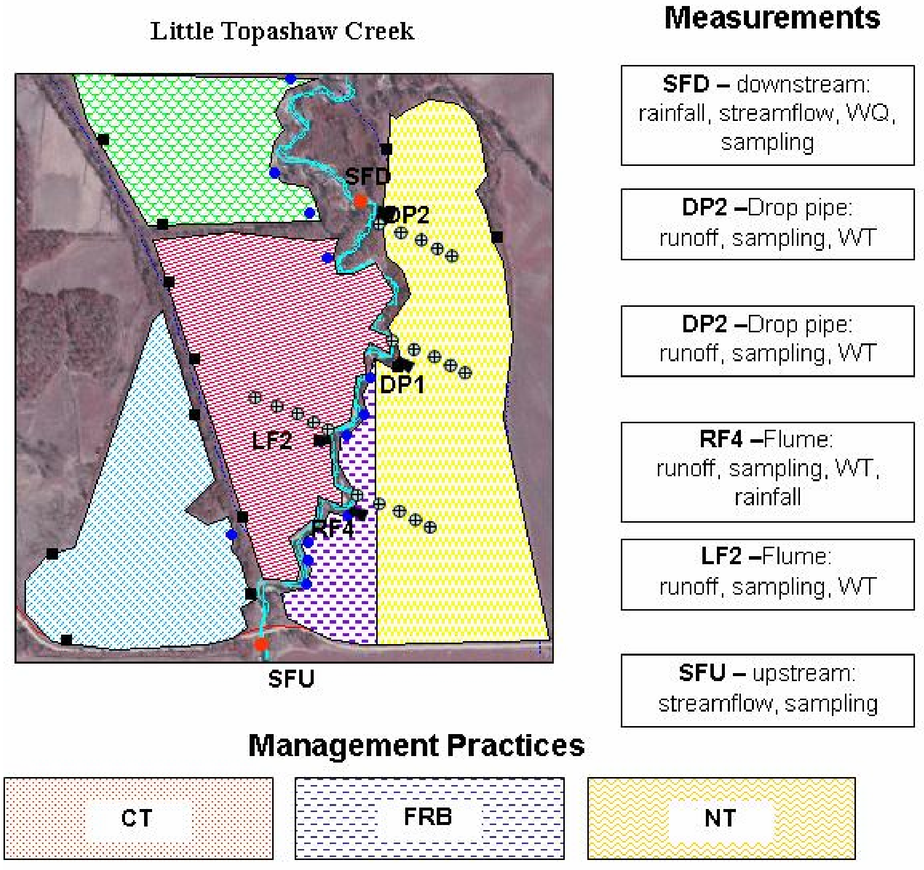
Subobjective 2a. Determine the effects of specific management / conservation practices and systems on contaminant and water transport processes at different scales within the YRW. The historical hydrologic and water quality data compiled by the MSU extension position will be used to evaluate correlations with historical land use and conservation practices for various sized subwatersheds where USGS gages exists.

Subobjective 2b. Determine the effectiveness of riparian buffers, grass hedges, and drop-pipe structures at controlling the magnitude of sediments and contaminants contributed by surface runoff from agricultural areas to stream. The National Sedimentation Laboratory has made continuous measurements of stream discharge at one location on Little Topashaw Creek since 2000 along with measurement of runoff from two edge-of-field gully sites downstream of the stream gage location. Plans for CEAP are to expand this effort, as depicted in Figure B6, by modifying the instrumentation of the two edge-of-field gully sites, adding instrumentation for monitoring two drop pipe structures, and adding instrumentation for stream monitoring downstream of these field sites. This will provide upstream-downstream monitoring with edge of field monitoring from both sides of this stream reach. Field sites on both sides of this stream reach are currently under conventional tillage agricultural production. Landowners will be asked to convert these fields into conventional tillage, no-tillage, and forest riparian buffer areas with and without drop pipe structures as depicted in Figure 1. Stream monitoring instrumentation will include flow velocity meters for stream stage and sediment velocity measurements, Acoustic Doppler current profiler, 5 in 1 DataSonde sensors for real-time water quality measurement, and flow-proportional samplers for transient/composite sampling of stream sediment deliveries. Edge-of-field sites will be instrumented with flow velocity meters and bubblers for runoff measurement, and flow-proportional samplers for transient/ composite sampling of sediment and water quality. Each edge of field site will include a rain gage and a transect of groundwater wells that extend from the streambank adjacent to the edge of field monitoring station out into the adjacent field perpendicular to the stream. Samples will be analyzed for sediment and nutrient (N and P) concentrations. To determine sediment source areas and trapping efficiencies of riparian buffers and drop pipes, each field will be sampled by transects to account for soil variability from differences in hydropedologic properties.

Subobjective 2c. Evaluate mechanisms of seepage erosion and its contribution to stream bank failure and the impact of soil conservation practices on these processes. Subsurface flow and corresponding erosion of bank sediment will be quantified at multiple locations along the Little Topashaw Creek and the associated soil physical and hydraulic properties will be characterized. Laboratory experiments will quantify the hydraulic properties controlling the seepage erosion process associated with streambank failure. These data will be used to model contributions of subsurface flow and seepage erosion on stream flow and bank failure, respectively under various conservation practices.

Collaborators and Cooperating agencies and groups.

US Geological Service; Natural Resources Conservation Service; US Army Corps of Engineers, Vicksburg District; Local landowners and drainage districts; Mississippi State University, Cooperative Extension Service; University of Mississippi



CT-conventional tillage, NT-no-tillage, FRB-forest riparian buffer, SFU-streamflow upstream, SFD-streamflow downstream, LF-left flume runoff, RF-right flume runoff, DP-drop pipe runoff, ⊕- groundwater well

Figure B6. Yalobusha Watershed.

B7. Beasley Lake, Mississippi

Characteristics. Beasley Lake watershed is located in Sunflower County, MS, and is part of the Big Sunflower River watershed (Hydrologic Unit Code 08030207) within the Yazoo River Basin. The Beasley Lake watershed has a total drainage area of approximately 850 ha (2,100 acres), and the surface area of the receiving oxbow lake is about 25 ha (62 acres) (Fig. B7). Beasley is an oxbow lake, a cutoff meander of the Big Sunflower River. The Sunflower River defines the northern part of the watershed boundary, and a large forested wetland (125 ha) is riparian to the eastern side of the lake. As may be expected adjacent to a meandering river with historical stream-floodplain interaction, soil texture varies from sandy loam to heavy clay. Soil survey data show that Dundee (fine-silty, mixed, thermic Typic Endoaqualfs), Forestdale (fine, smectitic, thermic Typic Endoaqualfs), Dowling (very-fine, smectitic, thermic Vertic Epiaquepts) and Alligator (very-fine, smectitic, thermic Alic Dystraquerts) are major soil series represented. The difference in elevation from the top of the watershed boundary to the lake surface is about 5.5 m. From 1995 to 2001, 660 ha of the watershed were predominantly cropped with cotton (70% of cropped area), corn, and soybean. Under an October 2002 contract, 91 ha were removed from crop production and planted to hardwoods under CRP. From 2002 to present, soybean is the dominant crop on the remaining cropland. This watershed was part of the Mississippi Delta MSEA Project (MD-MSEA) (1994-2002), and background information on the MSEA Project relative to Beasley Lake is found in Locke (2004).

Environmental Impacts.

1. Water Quality: Runoff contaminated with sediments, nutrients (P, NO_3^-, NH_4^+), and pesticides.
2. Fish and Wildlife Habitat: Receiving water body impacted by suspended sediments that suppressed primary and secondary productivity.
3. Soil Assessments: Changes in soil characteristics as practices are implemented.

Management Practices.

1. Conservation tillage (NRCS codes 329A and 329B)
2. Grade Stabilization Structures (410), e.g., Slotted Board Risers, Slotted Pipes
3. Constructed Wetlands (656)
4. Riparian Forest Buffer (391)
5. Vegetated Barriers (601) e.g., Stiff Grass Hedges
6. Field Border (386) e.g., Grassed Buffers
7. Grassed Waterways (412)
8. Channel Vegetation (322)
9. Filter Strip (393)
10. Tree/Shrub Establishment (612)
11. Subsurface Drainage (606)

Research Objectives. The original hypothesis for the Beasley oxbow lake watershed (under MD-MSEA) was that implementation of physical structures such as Grade Stabilization Structures (410) combined with grassed field borders and filter strips would be sufficient to improve lake water quality. Studies determined that this was not the case. Therefore, the current hypothesis under CEAP is that additional innovative management practices will improve lake water quality and fishery productivity.

General: Assess the effects of integrated BMPs on water quality and ecology.
Specific:

1. Monitor lake water quality to assess the effectiveness of BMPs to reduce contaminants and improve lake ecology.
2. Edge-of-field
    a. Evaluate the efficiency of vegetative barriers, with and without subsurface tile drains, to reduce sediment and contaminant delivery through grade control pipes.
    b. Evaluate effectiveness of constructed wetlands in mitigating contaminants associated with agricultural / CRP runoff.
    c. Evaluate the results of CRP establishment and other BMPs on water quality, ecology, and soil characteristics.
    d. Determine the mitigation potential of a vegetated drainage ditch carrying contaminated agricultural runoff.
3. Utilize models such as AnnAGNPS to assess the effects of management and water quality changes at the watershed scale.

Approaches.

Lake Water and Runoff Water Quality: For water quality evaluations, lake water is sampled in three locations every two weeks. Samples are processed and evaluated for sediment, TOC, nutrients, and pesticides (Knight et al., 2001a; Cooper et al., 2003; Cullum et al., 2003; Smith and Cooper, 2004). Autologger sensors will be used to collect a temperature profile at a single site to determine time and duration of thermal stratification. Lake ecology will be assessed by collecting biological samples, assaying the bi-weekly lake water samples for plankton, microbiology, and enzymatic activities, and evaluating longer-term fisheries indicators, e.g., Knight et al., 2001b.

Runoff monitoring sites, some of which will be associated with BMPs, will be at selected points in close proximity to the lake. Automated equipment will collect surface water samples during rainfall and irrigation-induced runoff events. Samples will be analyzed for sediments, nutrients, and pesticides. Trapping efficiencies of BMPs for sediments and various agrichemicals will be determined by comparing concentrations at sampling sites with and without BMPs. Vegetative buffers, conservation tillage, and conversion of row cropland to CRP (e.g., cottonwood trees) will be studied. Instrumentation includes area-velocity flow logger/meters to provide a record of discharge hydrographs and composite samplers to provide flow-weighted water samples from storm runoff events.

Wetlands and Ditches: The hypothesis being tested is that wetland areas (Zablotowicz et al., 2001; Shankle et al., 2004) and vegetated drainage ditches (Moore et al., 2001) have the ability to improve the water quality of agricultural runoff via sediment entrapment and agrichemical (pesticide and nutrient) retention, degradation, and processing.

Research will determine (a) type of vegetative material that can effectively trap contaminants in water; (b) trapping efficiencies; and (c) necessary drainage ditch length for contaminant mitigation. Vegetated ditch studies similar to that of Moore et al. (2001) will provide additional information on the contribution of these BMPs to water quality. A section of vegetated drainage ditch (e.g., 50 m) within the Beasley lake watershed will be analyzed for background concentrations of targeted pesticides in water, sediment, and plant samples. A simulated storm runoff event using pumped water will load pesticides into the ditch, and their fate and effects will be monitored over several months.

A small sediment basin and a two-cell constructed wetland were established in 2002 upstream of an inlet to Beasley Lake for trapping sediments and processing contaminants. Subdivisional cross-sections allow water, sediment, and plant samples to be collected across the entire wetland. Standpipes are used to maintain 30 to 40 cm of standing water in each cell. Instrumentation consists of a Doppler area-velocity flow logger/meter and an automated composite water sampler placed at the inlet and outlet of the constructed wetland. Grab samples of water will be collected at existing wetland transects to determine transport of agricultural contaminants and the effectiveness of wetland processing. Comparison between vegetated drainage ditches and constructed wetlands for agricultural runoff mitigation will be evaluated.

Edge-of-Field BMP Effects on Quality of Water Leaving the Field: The hypothesis to be tested is that improvement in edge-of-field water quality can be demonstrated via specific combinations of field management practices (Rebich, 2001; Rebich et al., 2001; Smith et al., 2002). Improvement in edge of field water quality will primarily be evaluation based on the reduction of sediments, since many of the contaminants of interest entering the streams are attached to these particles. Entrapment of contaminants in edge-of-field barriers may enhance their processing, thereby reducing further movement (Staddon et al., 2001). Grade control pipes, with and without such vegetated barriers immediately upslope, will be evaluated. Subsurface drains under the thalweg of some pipes with vegetative barriers will also be assessed. Flow-proportional composite samples will be collected based on measured velocity (acoustic Doppler) and depth in the pipes. To date, six pipes have been instrumented: two controls, two with vegetative barriers, and two with barriers and tiles. Instrumentation to quantify and sample water leaving the tiles will be installed in 2005. Runoff samples are being analyzed for sediment, nutrients, pesticides, and total organic carbon (TOC). Sediment concentrations will be determined by ultrafiltration (0.45µm), and suspended solids via laser diffraction. Pesticide analysis will be by gas chromatography with confirmation via gas chromatography/mass spectrometry using already developed methods (Bennett et al., 2000; Smith, 2001; Smith et al, 2001). Nutrient analysis (soluble NO_3^+, PO_4^{-3}, Cl^-) will be by ion chromatography. Flow-through colorimetry will be used for soluble NH_4^+ and total Kjeldahl N and total P. Analytical instrumentation will include state-of-the-science GC/MS, ion chromatography, ICP/MS, automated flow injection analyzer, automated laser scattering particle size distribution analyzer, and automated TOC analyzer. Within-field management practices chosen by the cooperating farmers will affect the performance of these edge-of field BMPs. These management practices, which include crop rotation, conservation tillage, and cover crops, will be documented and their effects will provide needed comparisons for improved system performance assessments. Additional new research will be initiated using triplicate slotted-inlet pipe sites on both CRP and cropped land.

Soil Assessments: Approaches are still being developed for assessing changes in soil characteristics as influenced by management practice. Prior research in the Beasley watershed evaluated the spatial distribution of soil characteristics (Gaston et al., 2001) and their effects on herbicide dissipation (Locke et al., 2002) under conventional tillage cotton production. Parameters for assessing soil changes with conversion of land use from row crop to CRP will be developed and soil evaluations will be made. Sub-watersheds under CRP versus non-CRP areas will be surveyed and soil will be sampled in grids within these areas and characterized.

Previous work in Beasley Lake watershed demonstrated the effects of vegetative buffers on soil characteristics (Staddon et. al, 2001). Land owners within the watershed plan to establish quail habitat buffers around various fields. Soils in these buffer areas will be sampled and characterized prior to buffer establishment, followed by monitoring over time for any changes.

Modeling and Economic Assessments: Some modeling assessments have been made in similar watersheds (Yuan et al., 2002), and efforts in this area will develop over time.

Complementary CEAP Related Research Activities Within the Yazoo River Basin: There are three additional sites within the Yazoo River Basin (where Beasley Lake is located) where the WQERU is conducting research that directly relates to the assessment of conservation management practices. The topography and agriculture at these sites are highly representative of the Mississippi Delta landscape, and research results are completely compatible with conditions in Beasley Lake watershed. The three additional sites include:

1. Stoneville, MS: Small field scale (0.25 ha) replicated runoff plots for evaluating water quality as influenced by tillage, cover crop, and buffer strip.
2. DCDC: Field and vegetative ditch studies
3. Coldwater River watershed: Habitat ecology in river bendways

Additionally, WQERU has fostered assessment and success of conservation practices in upland source watersheds of the Yazoo Basin. Projects include variations of conservation tillage, tillage effects on shallow groundwater contamination potential, documentation and design options of water retention structures from field-sized devices to watershed lakes, and edge-of-field vegetation.

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Collaborators and cooperating agencies and groups.

1. Mississippi Dept Wildlife Fisheries and Parks: Lake re-stocking

2. Mississippi State University: Documention of farmer practices
3. Arkansas State University: Assessment of vegetated ditch and wetland ecology
4. Delta Wildlife: Buffer establishment

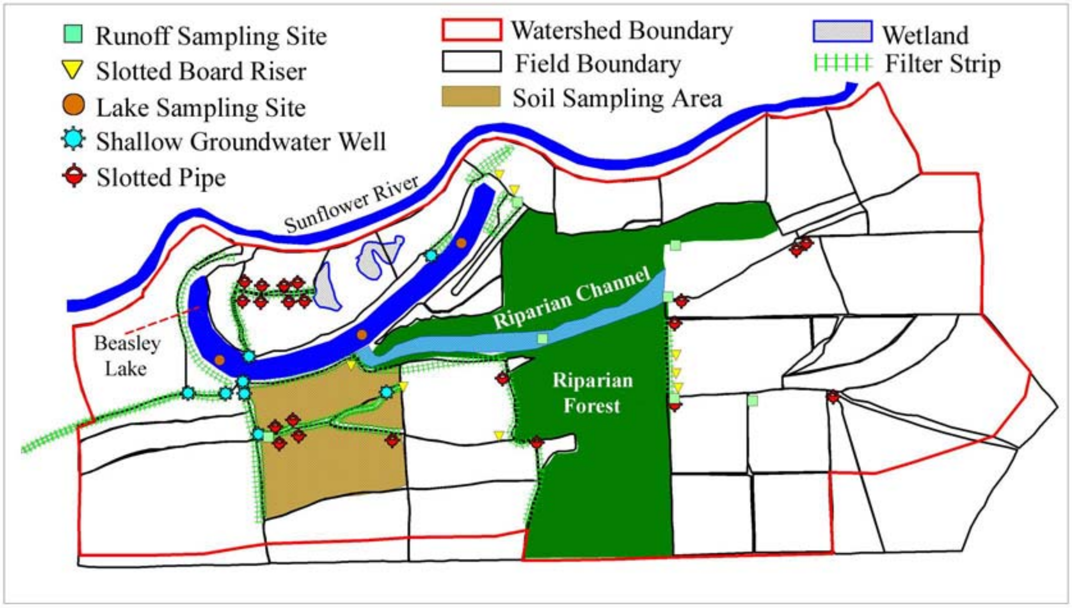

Figure B7. Beasley Lake watershed, Sunflower County, MS.

B8. Leon River, Texas

Characteristics. The upper Leon River, above Lake Belton, consists of 735,600 ha, predominately in the Grand Prairie MLRA and West Cross Timbers (Fig. B8). The watershed area to be evaluated is 607,000 ha above Gatesville in Coryell County Texas. The area is well dissected with steams. Numerous small flood control dams (exact number unknown at this time) have been constructed in the watershed. Two reservoirs, Lake Leon and Lake Proctor, are located in the watershed. The watershed drains into Lake Belton, a large reservoir that provides domestic water for about one-half million people. Soils in the watershed are divided into two major groups. In the upper portion of the watershed, soils are generally lighter textured with loamy fine sands and sand soils occurring near the streams. In the lower portion of the watershed, soils are finer textured, with clays and clay loam soils occurring most often. About 68% of the land area is either in pasture or rangeland. Agricultural cropland makes up about 10% of the total watershed land area, although this amount is decreasing due to a decrease in peanut production in the area. Forestland makes up 17% of the land area. Mean annual rainfall decreases from east to west, but averages about 800mm per year near the center of the watershed. There are 55 confined animal feeding operations (CAFOs) in the watershed, mostly dairy operations or replacement heifers. There are about 66,000 dairy cattle in the watershed. Most of the dairy operations are in Erath County in the eastern portion of the watershed located on tributaries of Resley Creek.

Environmental Impacts. Environmental concerns in the watershed are generally associated with the CAFO units and the management and disposal of animal wastes, and municipal wastewater. Land application of the animal wastes can potentially have many positive aspects, including increasing soil organic matter content with associated increased soil aggregation, water holding capacity, and improved soil fertility. There are potentially problems of over application of waste products with excess application of phosphorus and nitrogen, resulting in excessive nutrient loss in surface runoff, and also the potential of pathogen contamination of surface waters. As a result, the environmental issues of concern and under evaluation are:

1. Water Quality: Runoff contaminated with pathogens and /or nutrients.
2. Soil Quality: Carbon and nutrient availability and distribution in the soil. Changes in soil water holding capacity.

Management Practices.

1. Nutrient Management (590)
2. Prescribed Grazing (528A)
3. Brush Management (314)
4. Grassed Waterway (412)

Research Objectives.

The objective is to quantify the effects of management practices on soil quality and water quality and quantity. Watersheds with a wide range of sizes (0.5 to 607,600 ha) are being studied to examine scale impacts and transport mechanisms. Paired watersheds have also been established to determine the field-scale effects of selected management practices.

Approaches. The upper Leon River Watershed is a new area for ARS research, and few structures are in place. The USGS has a long history of monitoring flow in the Leon

River with records dating back to 1925. Monitoring stations have been operated by the USGS in to watershed, resulting in a nest of sub-watersheds of 68,400, 124,000, and 489,700 ha. These records will be invaluable in developing and evaluating models of the hydrology of the watershed. Instruments for sampling stream flow and for measuring flow from smaller areas will be installed to determine how conservation practices associated with manure and nutrient management impact water and soil quality. A watershed model will be used to evaluate the watershed and potential management scenarios.

Soil Properties: Selected soil properties will be determined for a range of management properties, concentrating on manure management and tillage practices. If possible, properties for a range of management intensity and length of management on similar soils will be determined. In one particular study, recently sampled soil properties will be compared to those of archived soil samples that are over 50 years old. The data obtained will provide a basis for computer simulation modeling and/or to verify model results.

Water Quality: In the Mustang Creek watershed (a subwatershed in the Leon Basin), water quality and quantity are being measured for three 1 ha tilled field plots, two 0.5 ha pasture field plots, and one 17 ha tilled field with previous animal byproduct application. Two monitoring sites (1467 and 5506 ha) have also been installed on Mustang Creek. In addition, two large-scale monitoring sites (approximately 500,000 and 600,000 ha) have been established on the Leon River. At each of these sites, automated samplers are collecting storm data on the following parameters: dissolved nutrients (NO_3-N, NH_4-N, PO_4-P), particulate N, particulate P, and suspended sediment. Grab samples for bacteria and dissolved nutrients are being collected on weekly or biweekly schedule. All data will be used to support the CEAP modeling efforts.

Collaborators and Cooperating agencies and groups.

USGS, USDA-NRCS, Brazos River Authority, Texas Agricultural Experiment Station, Texas Cooperative Extension, Texas Soil and Water Conservation Board.

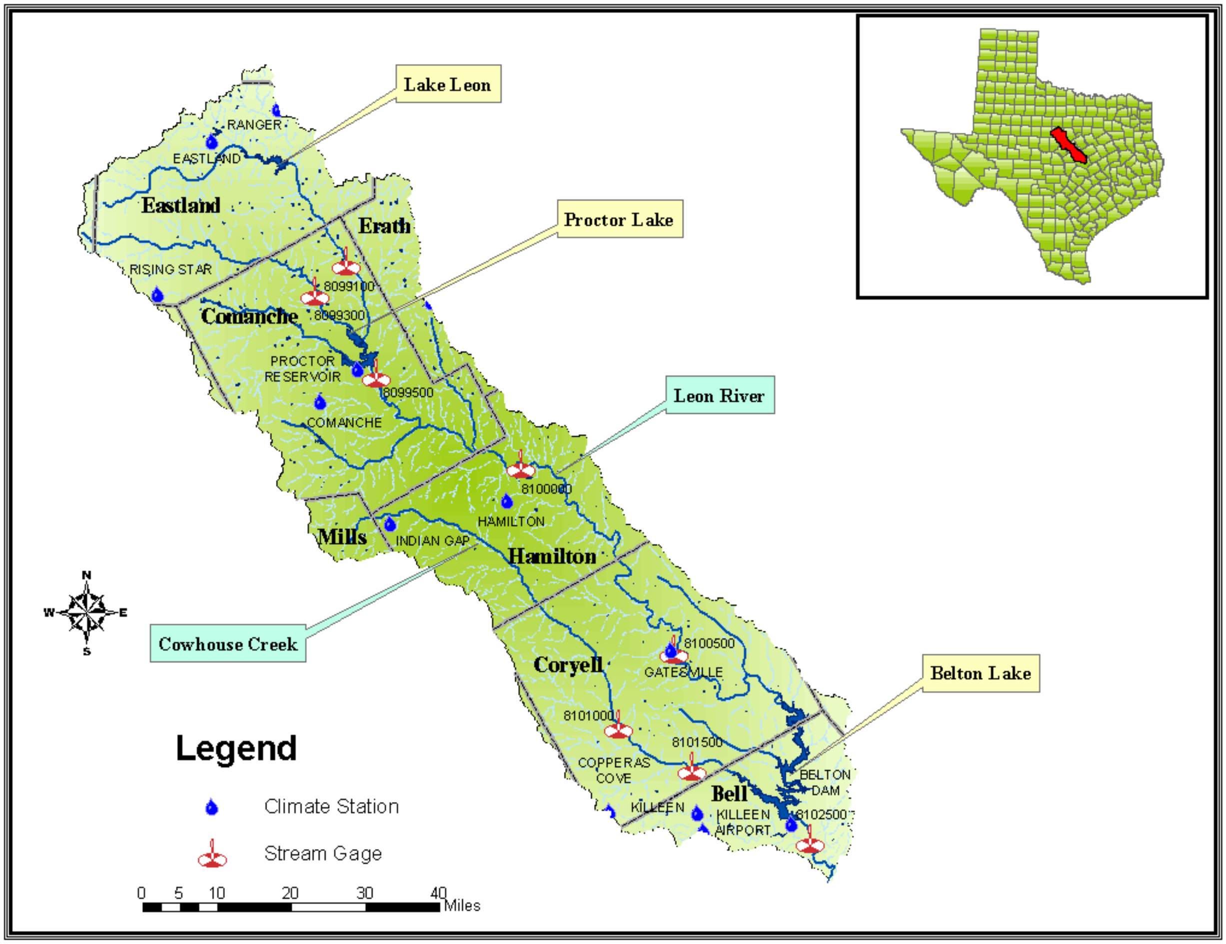

Figure B8. The upper Leon River Watershed location and existing stream gages. County names and major streams are identified.

B9. Little River, Georgia

Characteristics. The USDA-ARS Southeast Watershed Research Lab has collected hydrologic and climatic data on the 334 km^2 Little River Watershed (LRW) (Figure 1) near Tifton, Georgia since 1968. The watershed is typical of the heavily vegetated, slow-moving stream systems in the Coastal Plain Region of the U.S. Land use within the watershed is approximately 40% woodland, 36% row crops (primarily peanuts and cotton), 18% pasture, and 4% water. The LRW is located in the Southern Coastal Plain physiographic province in the Tifton Upland subprovince. The watershed is located on sands, silts, and clay underlain by limestones that form the Floridian aquifers. The major soil series within the watershed are loamy sands with infiltration rates of approximately 5 cm/hr. Upland slopes within the watershed are 2 to 5% while channel slopes are on the order of 0.1 to 0.5%. Precipitation occurs almost exlusively as rainfall, with an annual mean at Tifton, Georgia of 1200 mm. Distribution of rainfall within the year is highly variable, although the fall months are typically dry. Water balance studies on the watershed indicate streamflow is around 30% of annual rainfall, evapotranspiration is 70%, and percolation to deep groundwater is negligable. The streamflow is composed of direct surface runoff (6% of annual rainfall) and return flow from the shallow aquifer (24% of annual rainfall). Deep seepage and recharge to regional groundwater systems is impeded by the Hawthorn geologic material 0 to 6 m below the land surface, promoting lateral movement of excess water from uplands downslope as shallow return flow to surface drainage systems. While sediment and agrochemical losses from upland cultivated fields can be high, filtering within the dense riparian buffers which surround the watershed streams reduces the loading to streams substantially. Based upon GA-EPD monitoring, many streams within the Coastal Plain are impaired by low disssolved oxygen. Prelininimary assessments indicate that on the average, a 40% reduction in nitrogen and phosporous loading must be achieved in the impaired watersheds. Because of their widespread use within the region, pesticides in streamflow are also a concern.

Environmental Impacts. Environmental concerns include: low dissolved oxygen; high Fecal coliform and other bacterial indicators; nutrient enrichment; pesticides and sediment in field runoff; drought impacts on irrigation water supplies; erosion; and carbon storage in the soil.

Management Practices.

1. Riparian Buffers (NRCS practice code 391)
2. Vegetated filter strips (393)
3. Nutrient management (590)
4. Manure management (590)
5. Precision farming (449, 590, 595)
6. Pest Management (595)
7. Residue Management (344)
8. Conservation Tillage (329A)
9. Terraces (600)
10. Cover crops (327)
11. Irrigation Scheduling (449)

Research Objectives.

General: Evaluate field and watershed responses to agricultural practices and develop beneficial agricultural management strategies.

Specific:

1. Evaluate controlling relationships between landscape characteristics and hydrologic and water quality responses for Suwannee River Basin water quality and water resource management.
2. Determine water quality impacts of conservation buffers and Best Management Practices at field, farm, and watershed scales on nutrient, pesticide, and sediment transport.

Approaches. Characterize the quantity and quality of water within watersheds in the Coastal Plain Region through enhancement of current landscape and watershed scale studies. Relate water quantity and quality to geophysical, climatic, and management features. Large-scale studies will assess the impact of spatially distributed antecedent moisture condition on runoff quantity and aquifer recharge. Evaluate the interaction between low gradient streams landscape and watershed scale models based upon their ability to simulate hydrologic, chemical, and ecological processes. Develop a systems model for determining the potential impact of conservation initiatives, proposed land use changes, and water resource requirements for the Little River Watershed (defined by USGS 8-digit Hydrologic Unit Code).

Use plot and small watershed experiments to examine the effects of both infield and buffer BMPs on chemical and sediment transport in both Georgia Coastal Plain and South Florida agroecosystems. Incorporate pesticide transport algorithms into the Riparian Ecosystem Management Model (REMM) and test using data from plot, field, and small watershed studies in the Coastal Plain and from other agricultural regions of U.S. through work with other ARS units. Link REMM with the USEPA fate and transport models PRZMEXAMS to provide a more complete model of pesticide risk assessments. Use from a long-term watershed research project to test the linkage of REMM and the ARS watershed model AnnAGNPS. Use water quality data from farms and watersheds of the Suwannee River Basin to determine effects of BMPs on nonpoint source pollution that relate to TMDL assessments. Compare dissolved oxygen (DO) levels in impaired farm scale watersheds streams that drain similar sized areas with little or no agriculture. Develop carbon pool and flux estimates for riparian buffer systems to estimate carbon sequestration.

Collaborators and Cooperating Agencies and Groups.

University of Georgia, Georgia Technical Institute, Georgia-EPD, Georgia Cotton Commission, NRCS, USGS

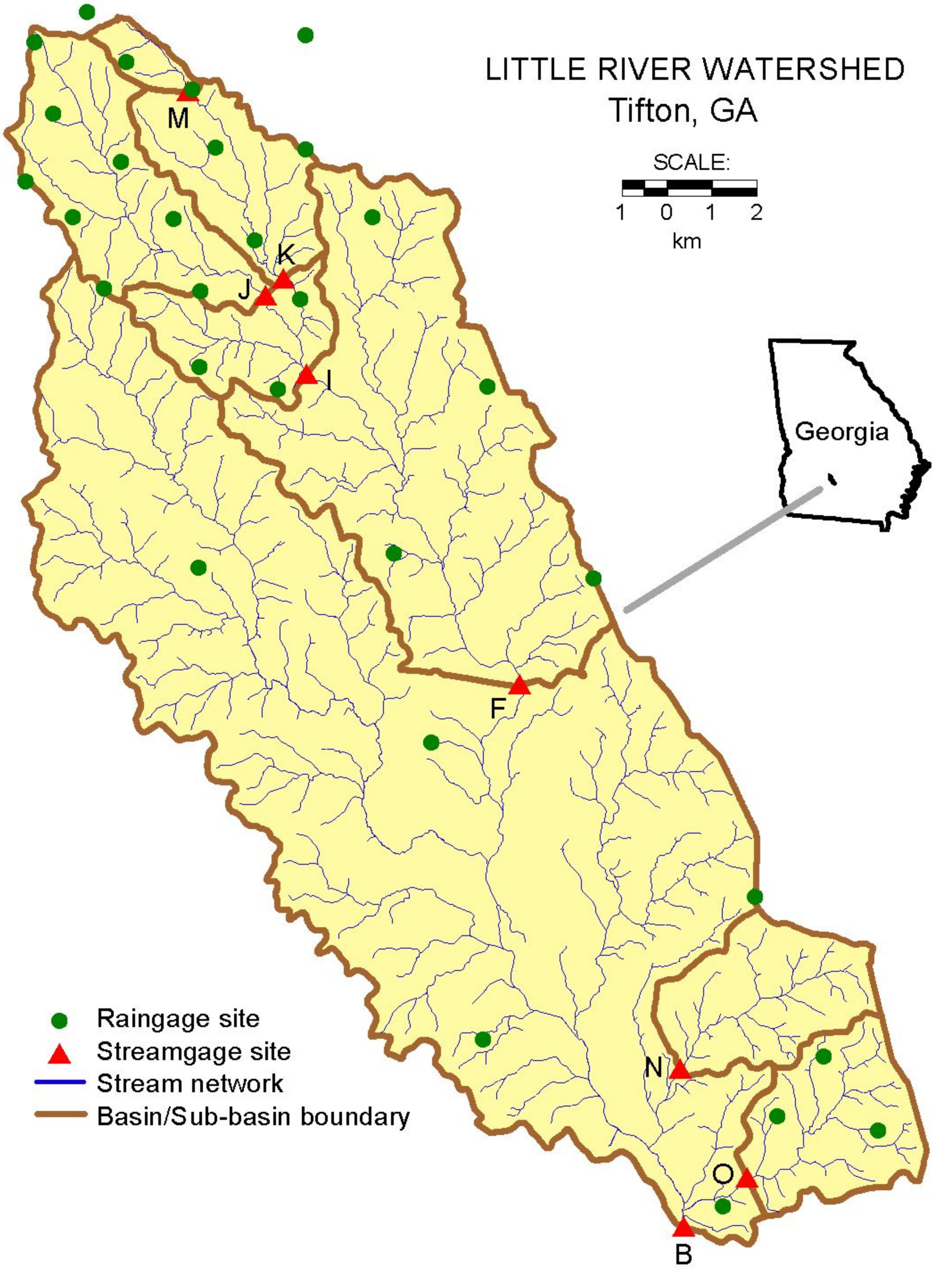

Figure B9. Little River watershed, Georgia.

B10. Town Brook and Cannonsville Reservoir Watersheds, New York

Characteristics. The Cannonsville Reservoir (Fig. B10), one of the major reservoirs of New York City's water supply system, has been designated as phosphorus (P)-restricted due to algal blooms that interfere with the non-filtered water treatment processes desired. Dairy agriculture, the dominant land use within the watershed, is thought to be a major source of the P affecting the reservoir, with this P loss occurring in both soluble and sediment-sorbed forms. The Watershed Agricultural Council (WAC; www.nycwatershed.org) and Delaware County, NY (www.cce.cornell.edu/delaware/watershed.html) are attempting to reduce P inputs to the reservoir by implementing a comprehensive whole-farm planning process and associated Best Management Practice (BMP) strategy over the contributing watershed area. The WAC is a non-profit organization funded by New York City, USDA Forest Service and other federal and foundation sources whose mission is to support the economic viability of agricultural and forestry through the protection of water quality and the promotion of land conservation in the New York City watershed region.

In the most basic sense, land use planning is focused on reduction of P loss to the Cannonsville Reservoir. The whole-farm planning and implementation process, a major component of the Watershed Agricultural Program (WAP) administered by the WAC and implemented by the WAC and Delaware County, contains education, extension, and technical assistance components to accomplish this goal. The technical assistance component of the WAP consists of BMP design and installation under a 100% cost share program.

The 917-km^2 Cannonsville Reservoir Basin (CRB) is the source of water for the Cannonsville Reservoir. The CRB is a portion of the Northern Delaware River 8-digit HUC (02040101). There is a history of data collection at multiple scales and some limited research within the CRB, but more intensive data collection and research has been conducted within the 37-ha Town Brook Watershed (TBW), a representative upland subarea of the CRB. The TBW lies within the 11-digit Upper West Branch Delaware River HUC (02040101010).

Watershed topography is characteristic of the Glaciated Central Region Physiographic Province. Within the CRB, the rolling hills and low, rounded mountains forming the major watershed divides are at elevations of approximately 1000 m (msl). Elevations of the upland watershed valley floors are on the order of 600 m, while those of the alluvial valleys are about 400 m.

Climate is continental; average annual temperature is about 7^o C, with average January temperature of about -4^o C and average July temperature of about 20^o C. Average annual precipitation is about 1070 mm, with about 180 cm of snow. Average annual runoff is approximately 600 mm.

Glacial deposits over the watershed are typically few to several meters thick, and are the primary source of ground water and subsurface flow to the streams. The underlying bedrock is not considered to be a major source of water. Soils within the upland watersheds, such as the TBW, typically have fragipans and are members of the well-drained, steeply-sloping Willowemoc, Lackawanna, and Mardin series and the somewhat-poorly drained, gently sloping Onteora, Volusia, and Norwich series. In the alluvial valleys of the larger CRB, soils are formed in deep, coarse-textured alluvial deposits and are typified by the nearly level, well-drained Barbour and Chenango series.

Land use within the CRB consists of cropland (2% corn and alfalfa), pasture (48% pasture and hay), agro-forestry (49%), and other (1% built-up and roads). There are approximately 230 animal feeding operations within the CRB (roughly 2/3 dairy and 1/3 beef), and seven major animal operations within the TBW (6 dairy and one veal production), with no CAFOs. In total, these farms represent about 13,000 dairy cows and 1,200 beef cattle. Most of the dairy farms operate as confined or semi-confined operations – there is currently minimal emphasis on managed grazing.

The seven primary farms within the TBW are enrolled in the CREP and/or the EQIP programs. Within the CRB, approximately 160 of the 230 farms are now actively participating in the whole-farm planning process, and of these, there are currently about 60 enrolled in the CREP program and 40 enrolled in the EQIP nutrient management credit program. The goal of the WAC is ultimately to have 85% participation. Extensive education activities are conducted in association with the whole-farm planning process, and technical assistance consists of design and installation of approved BMPs under a 100% cost-share program supported directly by New York City.

Environmental Impacts. Environmental concerns are, most simply, water quality and soil quality. The specific water quality concern is phosphorus loss from dairy agriculture as it impacts eutrophic status of the Cannonsville Reservoir. An important subset of this concern, erosion from corn silage land use, unaddressed to date in the whole-farm planning effort, is now becoming of major concern to the planners. An ancillary, but critical, concern, is sustainability and economic viability of the farms as they are impacted by P management measures.

Management Practices. Management practices either in use as part of the whole-farm-planning process, being studied in detail for their individual effectiveness, or being considered as part of future, more comprehensive BMP implementation strategies within the CRB are listed following. Numbers in parentheses are their NRCS designations.

1. Conservation cover (327)
2. Conservation crop rotation (328)
3. Contour buffer strips (332)
4. Cover crops (332)
5. Fencing (382)
6. Filter strips (393)
7. Forage harvest management (511)
8. Grassed waterways (412)
9. Nutrient management (590)
10. Prescribe grazing (528)
11. Residue management (329a)
12. Runoff management system (570)
13. Stream bank development (580)
14. Use exclusion (472)
15. Vegetative barrier (601)
16. Waste utilization (633)
17. Waste storage facility (313)
18. Waste treatment lagoon (359)

Research Objectives.

General: The research focus is on quantifying the loss of P from dairy agriculture, evaluating the effectiveness of the current BMPs and conservation practices in reducing this loss, and development of new or improved BMP/conservation practice strategies. *Specific:* The research emphases are on: 1) efficacy of structural BMPs, 2) evaluation of the CREP program in reducing impacts of cattle in the streams, 3) reduction of the P imbalance at the farm scale by increased use of homegrown forage, 4) reduction of erosion from land in corn silage to reduce sediment-sorbed P loss, and 5) development of techniques for cost-effective targeting of BMPs at farm and watershed scales to derive maximum benefit at minimum cost.

Approaches: The primary watershed agricultural planning activity is development and implementation of whole-farm plans to address actual and potential problems relative to P loss to the environment. The plans consist of an on-farm assessment of P balance, modification of farm activities that are perceived to result in excessive P loss to the environment, and development of comprehensive BMP and nutrient management strategies tailored for each farm to reduce the perceived P loss. More recent activities are focusing on reducing the P imbalances at the farm level by improved feeding strategies and increased use of homegrown forage; farm- and watershed-scale research and demonstration efforts related to these activities are either planned or now underway. All land within the watersheds is under private ownership, but because of the excellent working relationships between the watershed planners and the farmers though, research is easily implemented on most farms.

High-quality GIS data layers are available related to all aspects of the watersheds, including a 10-m DEM, hydrography, soils mapped and digitized at the SURGO level, farm and field boundaries also mapped and digitized, and land use and management by farm and field updated annually. Further, comprehensive whole-farm plans for most farms, including both already-implemented and proposed BMPs, are also available.

Streamflow, sediment, and phosphorus data are being routinely collected at the CRB and TBW outlets. Climate data is being collected to compliment these observations. Additionally, one agricultural and one forested subwatershed of the TBW are being monitored, and a bi-weekly synoptic sampling effort is underway at all major stream confluences within the TBW. As part of the whole-farm planning process, soil test P levels are measured once every three years on all agricultural fields within the CRB, and the whole-farm plans, which include rough estimates of the farm-scale P balance, are also updated at this same three-year interval.

The SWAT model is now being applied to the TBW and the CRB to characterize present levels of P loss. A unique part of this work is coupling SWAT with a BMP tool developed by ARS at University Park, PA to evaluate reductions in P loss expected as a result of implementation of the BMP strategy. The SWAT modeling results are also being used in association with mathematical optimization techniques to determine specific areas of the watershed where implementation of BMPs could realize maximum reductions in P loss at minimum cost.

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Collaborators and Cooperating Agencies and Groups. ARS at University Park, PA is leading a multi-agency research and demonstration effort within the CRB. Collaborators are the WAC, NRCS, New York State Department of Environmental Conservation, New York City Department of Environmental Protection, Cornell Cooperative Extension, and the Delaware County Soil and Water Conservation District. To date, ARS, representing a coordinated research group consisting of personnel from Cornell Agricultural Engineering, USGS, and New York City DEP, has received a total of $750K in Safe Drinking Water Act funds through New York State.

The highly effective collaboration with the WAC, NRCS, and the Extension and County planning entities allows our research and demonstration results related to effectiveness of BMPs to be implemented and evaluated at field, farm, and watershed scales under real-world conditions. Because of this same collaboration, we also have the ability to track the effectiveness of the BMP implementations with time at all scales in both near and distant future.

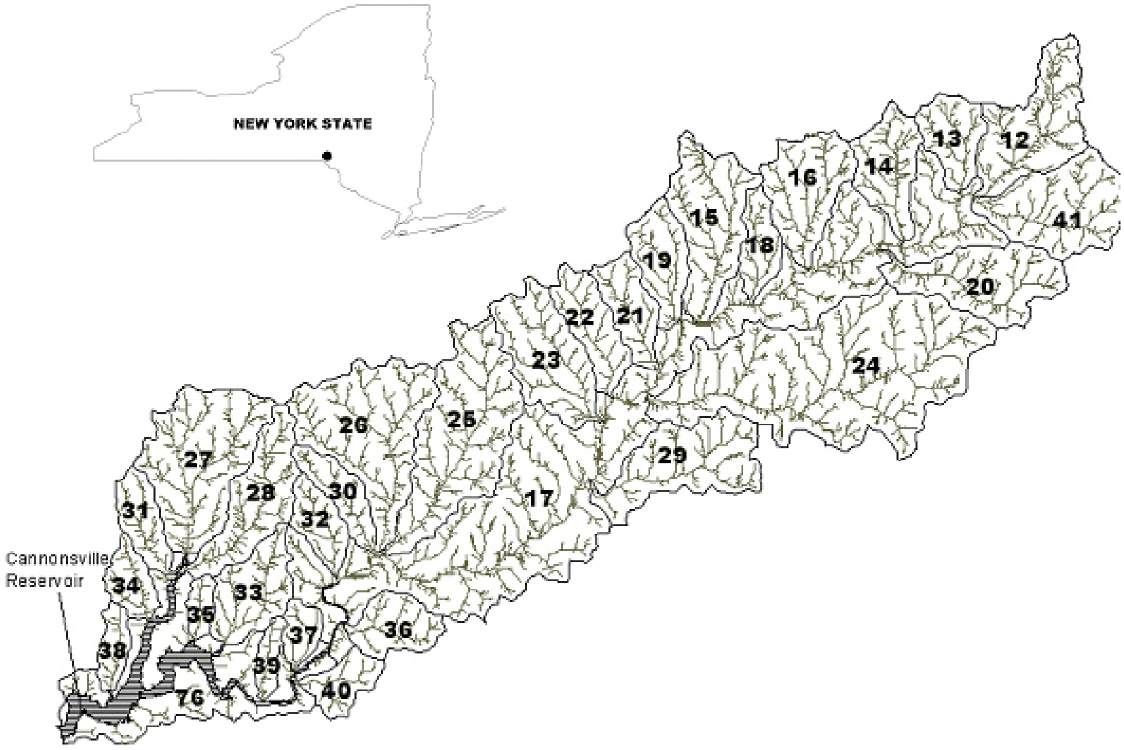

Figure B10. Cannonsville Reservoir Basin and its 31 sub-basins. Town Brook is subbasin 41.

B11. St. Joseph River, Indiana

Characteristics: St. Joseph River (DeKalb County, IN) - The total drainage area of this basin is approximately 281,000 ha overlapping Michigan, Indiana, and Ohio, emptying into the Maumee River in Ft. Wayne, Indiana (Figure B11, HUC04100003). The area to be evaluated is the Cedar Creek watershed, encompassing 71,000 ha, defined from the point where Cedar Creek empties into the St. Joseph River, just northeast of Ft. Wayne, IN. The majority of this watershed is within DeKalb County, Indiana. Three small sub-watersheds within the Cedar Creek watershed have been selected for detailed monitoring.

The watershed is primarily agricultural, with approximately 64% in cropland and 15% in pasture or forage. Woodlands and wetlands are found on 10%, while the remaining 11% consist of urban, industrial, farmsteads, airports, golf courses, and other land uses. Of the cropland, approximately 54% is in corn, 37% in soybeans, and 9% in wheat. Primary cropping consists of corn-soybean rotations and varying tillage practices. Cultivation practices in DeKalb County from 1990 to 2004 are summarized: (a) corn: 27% No-till, 65% Conventional Till; and 8% Reduced Till; soybean: 67% No-till, 26% Conventional Till, and 7% Reduced Till (3).

The topography of the watershed varies from rolling hills in Hillsdale, Williams, Noble, and Steuben counties to nearly level plains and closed depressions in DeKalb and Allen counties. The St. Joseph River follows the Fort Wayne moraine, and flows past numerous low bluffs and terraces. This indicates that the river was once much wider and deeper. Much of the St. Joseph River bed is composed of sand and gravel deposits. The average slope of the river's bottom is 1.6 feet per mile.

Soils in the watershed were formed from compacted glacial till. The predominate soil textures are silt loam, silty clay loam, and clay loam. Soil associations include Miami-Morley, Morley-Glynwood-Blount, and Blount-Pewamo. Erosion and over-saturation are the major soil limitations.

Water balance data (1) for Cedar Creek Watershed include: Annual Rainfall - 39.08 in; annual Runoff - 3.53 in. Hydrological characteristics for Cedar Creek Watershed include discharge data from 1947-2002 (3): Maximum - 5580 cfs; Minimum – na; Mean - 255 cfs; Median – na.

Environmental Impacts.

1. Water Quality: Runoff contaminated with sediments, nutrients (P, NO_3^-, NH_4^+), and pesticides. The St. Joseph River serves as the drinking water supply for the 200,000 people of Fort Wayne. Fort Wayne's Three Rivers Filtration Plant processes 34 million gallons of water daily from the St. Joseph River.
2. Fish and Wildlife Habitat: streams and ditches impacted by suspended sediments that suppressed primary and secondary productivity.
3. Soil Quality: Changes in carbon sequestration as practices are implemented

Management Practices.

1. Conservation Crop Rotation 328
2. Cover Crop 340
3. Deep Tillage 324
4. Drainage Water Management 554
5. Fence 382
6. Field Border 386
7. Filter Strip 393
8. Grassed Waterway 412

9. Pasture and Hay Planting 512
10. Pest Management 595
11. Residue Management 329A and 329B
12. Riparian Forest Buffer 391
13. Subsurface Drainage 606
14. Surface Drainage, Field Ditch 607
15. Surface Drainage, main or Lateral 608
16. Water and Sediment Control Basin 638

Research Objectives.

1. *Water Quality:* Determine the impact of voluntary, practical, and scientifically based BMPs on pesticide, nutrient, and sediment loads in source water on a watershed basis. The ARS research objective is a part of the Source Water Protection Initiative (SWPI) being implemented in Ohio, Indiana, and Missouri.
2. *Modeling:* Development of the spatial/historical database necessary to run the SWAT model uncalibrated, calibrated and validated for the Cedar Creek watershed and ultimately for the St. Joseph River watershed. SWAT will be used to assist in the assessment of the benefits of conservation practices. Determine to what extent the information obtained from the remotely sensed data can be related to soil profile hydraulic properties.
3. Dissolved Organic Carbon (DOC) and Soil Quality Assessment: Determine effects of different practices on DOC/carbon sequestration.

Approaches.

Water Quality: The research is using paired sub watersheds at different scales within the St. Joseph River Watershed at DeKalb County, Indiana, to compare surface runoff, subsurface drainage, and stream level water quality parameters with and without CORE 4 BMPs and/or other BMPs considered effective for this resource need (as agreed upon and implemented by NRCS and growers); and using watershed water quality models and long term climatic data to generate probability estimates of the water quality benefits achievable through comprehensive implementation of these conservation practices throughout these watersheds. Since 2002, ARS has identified eleven sub watersheds, ranging in size from 6 to 10,600 ac, for water quality monitoring.

Modeling: A network of real-time weather stations is currently being constructed that will provide input to SWAT and will provide insights into the spatial variability and uncertainty of weather input data. Remotely sensed soil moisture data will be used to characterize drainage patterns at the watershed scale and thus determine surface soil hydraulic properties over large areas. Data is being gathered from producers that will provide input information from each tract within the monitored watersheds regarding management practices and timing.

Dissolved Organic Carbon (DOC) and Soil Quality Assessment: DOC has been measured for 2003 and 2004 at each sampling point (Figure 3). Experimentation is also ongoing regarding the loss of C and N with eroding sediments, and the possible enrichment of eroding aggregates with labile C and N. In addition, soil quality sampling is currently being conducted on the small AS1 and AS2 watersheds and will begin in the Upper Big Walnut (Ohio) watershed in 2005.

Small Watershed, Field and Plot Scale Experiments. Scientists at the National Soil Erosion Research laboratory are also designing and implementing additional experiments at the St Joseph River Watershed to address specific research issues related to water quality. These research results will help improve the basic science in watershed hydrology and be used to interpret the water quality results from monitored sub-watersheds. A list of these research projects is shown below:

1. Rainfall simulation studies at the field plot scale to quantify effects tillage on nutrient, pesticide and sediment losses. Tillage treatments include: conventional no-till, precision-till, and conventional tillage. In conjunction with the tillage treatment, pesticides studied include atrazine, metolachlor, glyphosate and aminomethyl-phosphonic acid (AMPA), the primary metabolite of glyphosate. Runoff samples are also analyzed for: nitrate, ammonium, total nitrogen, orthophosphate and total phosphorus.
2. Compare the hydrologic response and water quality results from the controlled field plot rainfall simulation studies to data collected from monitored subwatersheds (Figure 3) to address the scaling issue in watershed hydrology.
3. Examine water quality impacts from different surface inlet designs. In the pothole topography of the St Joe River Watershed, surface inlets are commonly used to provide drainage of excessive water from depressions. This rapid surface drainage may carry pollutant-laden runoff to drainage tiles and ditches. Beginning in 2005, a pair of closed depressions each draining approximately 3 ha (AD1 and AD2, Figure 3) will be installed with tile riser (current practice, or control treatment) and blind inlet (proposed BMP). Special flumes will be installed in the drain line to monitor flow and water quality. Additional depressional areas will be identified and instrumented as the research progresses.
4. Evaluate practices to control in-stream transport of nutrients in managed drainage ditches and potential physical and chemical treatments of drainage ditch sediments to reduce downstream delivery of nutrients.

Collaborators and Cooperating agencies and groups. *St Joseph River Watershed Initiative* is a local non-profit organization that cooperates with ARS in maintaining the water quality sampling sites, preserving the collected samples, collecting land use and management practice data in the study area and communicating with land owners and farm operators for the SWPI/CEAP project. *NRCS* (State and Field Offices) is providing technical assistance and program support for identified conservation practices to be implemented in the watershed. *City of Ft Wayne* is analyzing the weekly grab samples collected from the watershed for pesticides. *America's Clean Water Federation* is coordinating the SWPI Project and assisting the congressional support. *Purdue University:* Agricultural Economics Department is conducting a social-economic assessment of conservation effects in the watershed. *State and Local Agencies:* SWCDs, Indiana Dept of Natural Resources, Indiana Dept of Environmental Management, Purdue University Cooperative Extension, and other organizations have been involved in promoting BMPs for improved water quality.

Selected references.

1. Indiana T by 2000 Watershed Soil Loss Transects
2. Long-Term Hydrologic Impact Assessment model, Pandey, S., Harbor J., Engel B., A Web-Based Tool to Assess Impacts of Land Use Change. Urban and Regional Information Systems Association, Annual Conference Proceedings. 2001.
3. US Geological Survey, Water Resources Data http://nwis.waterdata.usgs.gov/in/nwis/

Figure B11. St. Joseph River Watershed, 281,000 ha

B12. Upper Big Walnut Creek, Ohio

Characteristics. Upper Big Walnut Creek Watershed is an 11-digit HUC (05060001-130) located in central Ohio. The watershed is approximately 492km^2 and is situated in Delaware (66%), Franklin (1%), Morrow (21%), Licking (9%), and Knox (3%) counties in Ohio. The watershed is comprised of 467 perennial and intermittent stream miles that drain into Hoover Reservoir. Hoover Reservoir has a residence time of 180 days and serves as source water for approximately 800,000 residents in and around Columbus. Average annual precipitation over the watershed is 1020 mm.

Four major soil associations are distributed throughout the watershed. The four associations are the Amanda-Centerburg (3.5%), Bennington-Pewamo-Cardington (60.0%), Cardington-Alexandra (14.8%), and Centerberg-Bennington (19.7%). Soils in the Upper Big Walnut Creek watershed can generally be described as nearly level, clayey, and poorly drained.

Crop production agriculture comprises the largest land use classification within the watershed. The primary agricultural crops are corn, soybeans, and wheat. An extensive portion of the watershed used for agricultural production is systematically tile-drained. Without the tile systems, agricultural production would be limited. In addition to crop production agriculture, a significant transition from agriculture to urban land use is occurring in the watershed. Delaware County is rated in the top 10 most rapidly urbanizing counties in the United States. The urban land use component is comprised of single- and multi-unit dwellings as well as parks and golf courses. These land use changes may significantly alter the hydrology and water quality characteristics of the watershed.

Environmental Impacts. Average annual levels of atrazine in the reservoir have fluctuated around the established MCL of 3μg L^{-1}, and the Columbus Division of Water has cited atrazine as well as other agrichemicals as potentially problematic in the future. There exists a considerable potential for soil erosion in the watershed; however, based on recent studies the projected life of the reservoir has been increased by 100 to 200 years (a positive that needs to be understood and accentuated).

Management Practices.

1. drainage water management (554)
2. filter strips (393)
3. subsurface drainage (606)
4. nutrient management (590)
5. pesticide management (595)
6. waste utilization (633)

Research Objectives.

General: Determine the watershed scale impact of voluntary, practical, and scientifically based conservation practices.

Specific:

1. Evaluate the impact of specific conservation practices (CORE4, water table management, soil amendments, point source/structural filters, etc.) on source water quantity and quality.

   Hypotheses:

   a. Installation of a specified conservation practice will have a significant impact on hydrology and pollutant loading.
   b. Subsurface drainage is a significant component of the hydrologic balance and pollutant transport.

    c. The impact of a conservation management practice is inversely proportional to the scale at which the impact is measured.
    d. The physical and cropping characteristics (slope, time of concentration, cropping rotation, etc.) of the landscape significantly affect the impact of a conservation management practice.
    e. The benefit of implementing conservation practices within a defined area is proportional to the percentage of treated area.
2. Quantify the influence of differing landscapes, land uses, and land conversion on water quantity and quality.
   Hypotheses:
    a. Conversion of agricultural lands to urban/suburban landuse significantly alters the hydrology and water quality of a watershed.
    b. Commercial turfgrass systems significantly increase the amount of nutrients and pesticides transported to surface water.
3. Assess the impact of land management practices on aquatic and terrestrial habitat.
   Hypotheses:
    a. A conservation management practice will increase the diversity of the terrestrial and aquatic habitat.
    b. Significant increases in aquatic and terrestrial wildlife populations occur along riparian corridors.
4. Determine the impact of conservation management practices on soil quality.
   Hypothesis:
    a. Conservation management practices will impact the physical and chemical properties of the soil.

Approaches. This research program will be conducted in the Upper Big Walnut Creek Watershed in Ohio (Fig. B12). The research approach includes field measurements from plots and nested, paired watersheds and incorporates model predictions. Three primary spatial scales will be investigated: edge-of-field (acres), small watershed (100s of acres), and large watershed (1000s of acres). Hydrology and water quality field data will be collected using automated samplers with and without control volumes. In each study area, storm event and base flow samples will be collected and analyzed, using standard methods, for pesticides, nutrients, and sediments. Each sampler will be programmed to record continuous 10-minute flow readings. Water quality samples including storm and base flow will be collected using a flow-proportional technique. Water samples will be collected from March 1st to November 30th using a frequency interval equivalent to 1 mm volumetric depth. During January, February, and December, grab samples will be collected weekly when the streams are not frozen. Hydrology measurements will be collected throughout the year. The modeling approach will be carried out using the SWAT (Soil and Water Assessment Tool) model.

Hypothesis 1a: Field and modeling approaches will be used to assess the impact of a specific practice on hydrology and water quality. The field portion of this research will primarily be conducted on individual plots and fields. Baseline data on hydrology and water quality will be collected for a period of at least one year prior to the change in or installation of a specific management practice. After installation, hydrology and water quality data will be collected for a period equivalent to the life of the practice. The modeling portion of the assessment will be completed using the SWAT model. Different practices will be tested to identify those that potentially offer the most benefit once installed.

Hypothesis 1b: This hypothesis will be tested using field measurements. Hydrologic and water quality data will be collected at strategic points within the small watersheds. The strategic points will include tile outlets, with and without surface inlets as well as the watershed outlet. This will permit the partitioning of excess water and chemical transport between surface runoff and subsurface drainage.

Hypothesis 1c: This research will be accomplished by collecting hydrology and water quality data at three different scales: edge-of-field (acres), small watershed (100s of acres), and large watershed (1000s of acres). Hydrologic and water quality instruments will be installed at the three different scales. A specific practice or combination of practices will be implemented at the field level. After installation, the hydrology and water quality impacts of that practice or practices will be measured at the three identified points. The resulting data will permit the cascading impact of the practice(s) to be determined.

Hypothesis 1d: This research will be conducted using individual fields and small watersheds. Four small watersheds (2-pair), with a target drainage area of 1000 acres each, have been instrumented with automated hydrologic and water quality sampling equipment. Each pair of watersheds is characterized by different physical properties. The impact of crop rotation will be tested using an individual pair of watersheds. The impact of characteristics such as slope and time of concentration will be tested by implementing identical conservation practices on contrasting watersheds. In each case, water quality and hydrology will be measured over time to document different responses.

Hypothesis 1e: This research will be conducted at the small watershed (approximately 1000 acres) scale and will include both field and modeling efforts. The field assessment will take advantage of the paired design. In each watershed pair, one watershed will be designated a control and one a treatment. In the control watershed, implementation of conservation practices will be held to a minimum. In the remaining watershed, conservation practices will be promoted. The selected practices will be agreed upon and implemented by NRCS and operators. In addition to the small watershed scale assessment, watershed water quality models and long term climatic data will be used to generate probability estimates of the water quality benefits achievable through comprehensive implementation of specific conservation practices throughout these watersheds.

Hypothesis 2a: Two similar watersheds within the larger UBWC watershed have been selected for this assessment. Agriculture accounts for 75-80% of the landuse in each watershed. One watershed will be designated a treatment watershed and the second will serve as a reference watershed. The treatment watershed is scheduled to undergo significant development (2000 plus single unit dwellings) over the next 5-10 years. Baseline data will be collected for as long as possible. Comparisons of the hydrologic and water quality data will be made to the baseline data as well as data collected from the reference watershed. Samples will be analyzed for a suite of chemicals commonly found in agriculture and urban areas.

Hypothesis 2b: This hypothesis will be tested on a commercial turfgrass/golf course facility within the larger UBWC watershed. The facility is approximately 200 acres in size and is managed at a moderately intense level. Surface water from the adjacent agricultural areas enters the course at two locations. The two inputs converge on the course and exit through one outlet. Inflow and outflow data will be collected and compared.

Hypothesis 3a: To be determined.

Hypothesis 3b: To be determined.

Hypothesis 4a: This hypothesis will be tested at the small watershed (approximately 1000 acres) scale. Four small watersheds have been instrumented for hydrologic and water quality measurements. In each of these watersheds, detailed management data is also being gathered. Each watershed contains three primary soil types and three primary operators. Soils samples will be collected from three depths (0-6”, 6-12”, and >12”) at two different locations for each soil type and operator, resulting in a total of 216 soil samples across the four watersheds. Soil samples will be taken from the same locations every three years. The physical and chemical properties of the samples will be related to the management over time.

Collaborators and Cooperating Agencies and Groups.

Local landowners and operators, UBWC water quality partnership, Delaware County Soil and Water Conservation District, The Ohio Environmental Council, Ohio State Extension Service, Ohio EPA , Ohio Dept. of Natural Resources, City of Columbus, Ohio State University, NRCS, FSA

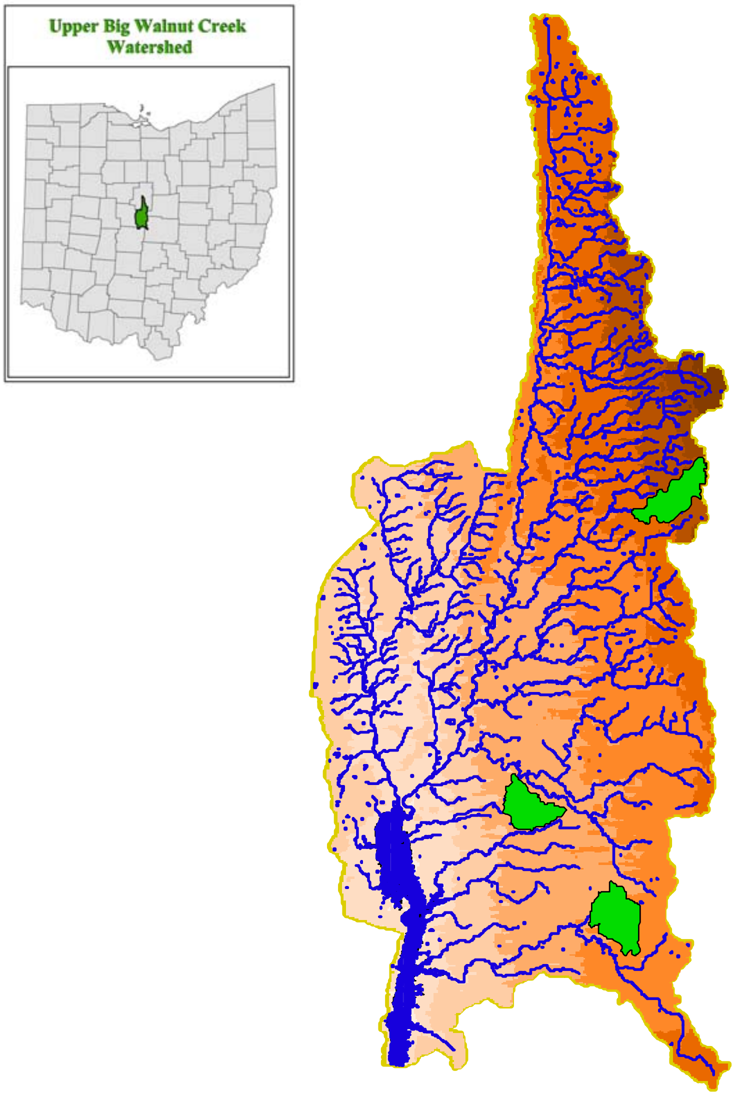

Figure B12. Upper Big Walnut Creek Watershed in Central Ohio with three sub watershed areas highlighted where intensive water and soil quality measurements will be made.