Introduction

Water quantity and quality issues have increasingly become the focus of attention of United States citizens, private and public organizations, and units of government striving to meet competing demands while protecting the environment and public health. Sound agricultural management practices are required to ensure success in maintaining a healthy and productive land and water base that sustains local communities, food and fiber production, and also protects and restores critical natural systems. Research in this National Program addresses three component problem areas: (1) agricultural watershed management; (2) irrigation and drainage management; and (3) water quality protection and management. The purpose of the Water Quality and Management National Program is to provide practical tools and techniques to meet the needs of farmers, ranchers, and other entities involved in controlling, assessing, regulating, and managing water resources.

In 2003, ARS in cooperation with the Natural Resources Conservation Service (NRCS) and other Federal and State agencies began to develop a national effort to assess conservation practices on watersheds named the Conservation Effects Assessment Project (CEAP). The purpose of CEAP is to provide the farming community, the conservation community, the general public, the Office of Management and Budget, legislators, and others involved with environmental policy issues an accounting of the environmental effects or benefits obtained from USDA conservation program expenditures.

The centerpiece of the watershed assessment program is the ARS "benchmark" watersheds. The term benchmark is used to distinguish the ARS watersheds from other non-ARS watersheds, where watershed assessment research is being initiated under CEAP. Also, the concept of benchmark watersheds is used to differentiate the larger scale ARS watersheds from field scale ARS research activity. ARS identified approximately $14 million of its current research under this National Program that contributes to the goals and objectives of the CEAP program. ARS received $1.35 million dollars from NRCS in late FY 2003 to initiate the following activities related to CEAP: the 12-benchmark watersheds ($1.0 million), the national assessment activities directly contributing to the NRCS requirements ($240 K), and a review and synthesis of current of literature ($75 K). Nine ARS locations are managing the research activity on the 12-benchmark watersheds. The location are: Ames, Iowa, Tifton, Georgia, El Reno, Oklahoma, Temple, Texas, Oxford, Mississippi, University Park, Pennsylvania, Columbia, Missouri, West Lafayette, Indiana, and Columbus, Ohio. In addition to these locations, ARS scientists from Ft. Collins, Colorado, are coordinating a portion of the modeling activities. The 12-benchmark watersheds represent primarily rainfed or non-irrigated cropland.

The research assessments on the ARS benchmark watersheds are intended to determine an optimal selection and placement of conservation management practices to achieve specific water quality and other environmental goals, as well as provide initial information important to assessing the economic and social factors that facilitate or impede implementation of these conservation practices. ARS is developing plans to partner with ERS, NRCS, and several universities to enhance the economic and social science efforts within the CEAP program. To guide the research assessments, ARS has held a coordination workshop for all ARS scientists and many of the partners participating in CEAP in Irving, Texas, on December 2-4, 2003. An ARS project plan for the 12-benchmark watersheds has been tentatively scheduled for peer review in the fall 2004, and a revised project plan is scheduled for completion by the end of the year. The first report from NRCS, with the assistance from ARS, to the Office of Management and Budget that quantifies environmental benefits for implementing conservation practices at the watershed scale is due in October 2005.

Also in 2003, the Agricultural Drainage Management Systems (ADMS) Task Force was fully implemented by ARS, NRCS, and CSREES in cooperation with land improvement contractors, drainage industry representatives, private consultants, and farm organizations in the seven Midwestern States of Iowa, Illinois, Indiana, Minnesota, Missouri, Ohio, and Wisconsin. The new era for agricultural drainage is based on removing a minimal amount of excess surface water and managing shallow water tables to achieve an optimal mix of economic and social benefits while safeguarding key ecological functions. The initial focus has been highly successful where, under the lead of ARS, NRCS and State Agriculture Extension Engineers working with farmers and cooperators, have rapidly begun to install controlled drainage systems on existing and new surface and subsurface drainage systems. Four workshops/meetings were held in 2003, and as many workshops have been planned for 2004. The ADMS Task Force has been designated as the first technical working group for the ARS, NRCS, CSREES Partnership Management Team, where a charter, action plan, flyers, posters, and several technical documents have been produced. Planning is underway to develop several educational brochures and to conduct two specialty conferences in 2004.

International activities have also been expanded in FY 2003. Three cooperative projects related to soil erosion by water and wind, were developed with the U.S.-China Center for Soil and Water Conservation and Environmental Protection. This center is located on the campus of the Northwest Sci-Tech University of Agriculture and Forestry (NWSUAF) in Yangling, China. The U.S. counterpart is located at the University of Arizona at Tucson, Arizona. An ARS-Mexico Workshop on Water and Environmental Impacts was held in Tucson, Arizona, in May 2003. Since the workshop, ARS and Mexico scientists have successfully developed five funded projects where ARS scientists will be training Mexican scientists and participating is cooperative research between both countries. In addition, an Irrigation Management Systems (IMS) project has been developed by three ARS locations in cooperation with partners from Israel, the Palestinian Territory, and Jordan. A successful IMS Workshop was held in Jordan with full participation from Middle East partners. Funding for the multi-location Middle East project has been provided by the U.S. Department of State.

Agricultural Watershed Management

Studying the differences among watersheds. ARS scientists at the Cropping Systems and Water Quality Research Unit in Columbia, Missouri, have studied the Goodwater Creek watershed in north-central Missouri for some 30 years, and ARS scientists at the National Soil Tilth Laboratory in Ames, Iowa, have studied the Walnut Creek watershed in central Iowa for some 13 years. The researchers learned that two watersheds, which are closely located geographically, could have significantly different water quality issues.

At Walnut Creek, the soils require tile drains in order to grow row crops. Because nitrate is very mobile in the soil, the water moves quickly through the drains, resulting in high levels of nitrate contamination. At Goodwater Creek, tile drains do not work well for the soils within the watershed, and subsurface drains are not needed for row crop production. Unlike nitrate, atrazine stays near the soil surface where it can be moved by surface runoff. This resulted in high atrazine levels in Goodwater Creek, but its nitrate levels were much lower. Thus, crop rotation, cover crops, and a nitrogen management plan can be beneficial in central Iowa while in Missouri, surface runoff control practices and a pesticide management plan that includes pesticide incorporation or the use of low-rate pesticides can be of assistance.

Accurate predictions of water in soil from space. ARS Scientists at the Hydrology and Remote Sensing Laboratory in Beltsville, Maryland, are leading an international team of scientists to develop methods to accurately and efficiently predict surface soil water content from space-based sensors. The ARS team has developed the first mathematical equations and databases to validate the estimated soil water content from satellites launched by both NASA and Japan (ADEOS-II). This research was conducted at ARS watersheds in Georgia, Iowa, Oklahoma, and Arizona. This research will lead to increased confidence in operational products developed by NASA and in decisions based upon using data related to water use monitoring for agriculture, hydrology (water supply forecasting, flood and drought prediction), and climate forecasting and prediction.

A model for improved water management and restoration of the Everglades. Beginning in 2000, the Everglades National Park and adjacent lands have begun undergoing a Comprehensive Everglades Restoration Plan. The Everglades Agro-Hydrology Model was developed by an ARS scientist at the Subtropical Horticultural Research Unit in Miami, Florida, in cooperation with ARS scientists from the National Soil Erosion Laboratory in West Lafayette, Indiana; the Grassland, Soil and Water Research Laboratory in Temple, Texas; and the Southeast Watershed Laboratory in Tifton, Georgia. The model currently is being considered for linkage with the regional model developed by South Florida Water Management District (SFWMD) in Palm Beach, Florida. This will significantly improve agricultural planning and decision-making with regard to Comprehensive Everglades Restoration Plan (CERP) implementation.

New tool reduces risk of soil erosion on forestlands. ARS scientists at the Southwest Watershed Laboratory in Tucson, Arizona; the Northwest Watershed Research Unit in Boise, Idaho; and the National Soil Erosion Laboratory in West Lafayette, Indiana, have worked together to develop new technology to assist the U.S. Forest Service in predicting surface runoff and soil erosion rates that results from both wild and prescribed fires in western ecosystems. This research is now helping the U.S. Forest Service Burn Areas Emergency Rehabilitation teams on how best to decide where and when emergency funding is needed to reestablish vegetation or install physical structures needed to protect the environment, streams, human life, property, or infrastructure from the ravages that are caused from flooding or soil erosion on public and private lands. The enhanced Water Erosion Prediction Project (WEPP) tool is available to U.S. Forest Service and other land managers via an interactive internet-based decision support system maintained by the U.S. Forest Service in Moscow, Idaho.

Helping States to slow sediment movement. The focus on sediment pollution criteria has been fueled by a renewed effort for states to identify pollution-impaired water bodies and develop plans for meeting Total Maximum Daily Loads (TMDLs) as specified by the Clean Water Act of 1972. Current estimates are that physical, chemical, and biological damage associated with sediment flow costs about $16 billion annually in North America. ARS scientists at the National Sedimentation

Laboratory in Oxford, Mississippi, have recently developed a two-pronged modeling approach to identify sediment movement in streams and other water bodies. The Annualized Agricultural Non-Point Source Pollutant (AnnAGNPS) watershed model first evaluates loadings within a watershed and the effect farming and other activities have on pollution control. Then, the Conservational Channel Evolution and Pollutant Transport Systems (CONCEPTS) model predicts how channel evolution and pollutant loadings will be affected by bank erosion and failures, streambed buildup and degradation, and streamside riparian vegetation. By combining the field measurements, geomorphic analysis, and the numerical models, agricultural specialists are now able to make effective recommendations on the type and placement of conservation practices either in the watershed or the stream channel that will provide the greatest benefits.

Irrigation and Drainage Management

With just a sprinkle, plants soak up more selenium. Because of their ability to sop up selenium, some plants have been enlisted in efforts to clean up soils and wastewater that have an excess of this toxic element. ARS scientists at the George E. Brown Jr. Salinity Laboratory in Riverside, California, have improved upon this "phytoremediation" practice by showing that the way contaminated irrigation water is delivered affects how much selenium plants will absorb. The researchers found that sprinkling kale and turnip plants with selenium-laden drainage waters—instead of flooding them—allowed the plants to take up almost twice as much selenium from the water. Sprinkling the leaves of plants and crops grown with recycled drainage water enhances selenium uptake and creates a place to store the element, thereby decreasing the amount of selenium that can leach into groundwater. As an additional benefit, the selenium-enriched kale and turnip plants—as well as other crops irrigated with the sprinkler method—can be used to supplement the diets of livestock raised in selenium-deficient regions of the United States. Animals need to have some of this essential nutrient for optimum growth and stress tolerance. The study's findings are also likely to aid growers who are interested in producing selenium-rich vegetables for health-conscious consumers.

Improved model for estimating irrigation-induced erosion. Scientists at the U.S. Water Conservation Laboratory in Phoenix, Arizona, have developed new and more precise equations to predict the soil erosion process and transport of fine soil particles on lands that are irrigated. This method will provide more reasonable predictions of soil erosion for agricultural soils subjected to furrow irrigation or rainfall-induced overland flow. This technology will provide a means of assessing the relative benefits of alternative management practices in improving soil quality for irrigated lands.

New pressure tester helps fine-tune irrigation systems. Currently, there are no easy, nondestructive methods for measuring pressure in drip tubing to assess uniformity. ARS scientists at the Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho, and the Water Management Research Unit in Parlier, California, recently developed a simple device called the “Squeezer” for measuring pressure in drip irrigation tubing in the field without puncturing the tube or installing special fittings. The device provides growers with a convenient means of assessing drip irrigation system performance by measuring pressure variations with the irrigation system. A patent is pending, and a California company is developing an electronic version for commercial sales.

Locating old tile lines enables better drainage management. Existing tile drain lines must be detected before controlled drainage or improved drainage management systems can be installed. ARS scientists at the Soil Drainage Research Unit Columbus, Ohio, in cooperation with Ohio State University, have successfully modified ground penetrating radar equipment to locate operational and non-operational tile lines. Extensive studies at thirteen sites throughout Ohio showed that this geophysical method located an average 72 percent of the old buried tile lines. Current estimates are that this detection method will save farmers and land improvement contractors about $10 million dollars per year throughout the United States.

Subsurface drip irrigation becomes a cost-effective alternative. Subsurface drip irrigation systems have high initial cost, which must be recovered through a combination of higher water-use efficiency and yield become cost-effective. At the Cropping Systems Research Laboratory in Lubbock, Texas, canopy temperature has been used to schedule daily subsurface drip irrigations on cotton. Among a range of water stress times and amounts, the highest water-use efficiency was achieved at near the high yield (98% of maximum) and efficient use of irrigation water (21% less than maximum amount applied). At the Conservation Production Research Laboratory in Bushland, Texas, grain sorghum yield and efficiency of subsurface drip was greater than the commonly adopted Low Energy Precision Application (LEPA) and the surface irrigation methods at 25 and 50 percent of maximum crop water use. This research at both locations demonstrates that under declining and a very limited water supply, which is the case for Ogallala aquifer, subsurface drip offers a unique opportunity to produce adequate yields while applying water more efficiently than other irrigation methods.

A low-cost solar water pumping system. Farmers and ranchers need a reliable, low-cost means of pumping water for cattle or other livestock on remote rangelands. Performance of solar panels that commonly use the “thin panels” degraded about 15% per year. Data collected by ARS scientists at the Conservation Production Research Laboratory in Bushland, Texas, found that amorphous-silicon panels, pumps and controls did not degrade over a 5-year period. At the same time, the amorphous-silicon panels cost about two-thirds what the thin-panels cost. The 1-kw solar water pumping system, with the inexpensive panels along with the pumps and controllers, has maintained their performance for 5 years.

Water Quality Protection and Management

New technology to detect pesticides in soils. ARS scientists at the Soil Drainage Research Unit in Columbus, Ohio, and the Cropping Systems and Water Quality Research Unit in Columbia, Missouri, in cooperation with colleagues in the U.S. Geological Service, have developed new technology to detect and monitor the degradation process of agricultural pesticides in the soil. This new technology will assist scientists, farmers, and the pesticide industry in understanding the methods and pathways that agricultural chemicals are degraded and help prevent accidental water contamination by these compounds.

Eradication of an invasive aquatic weed. ARS scientists at the Exotic and Invasive Weeds Research Unit in Albany, California, working with scientists in NOAA, California state agencies, and non-governmental agencies, developed a method to eradicate an invasive marine alga (Caulerpa taxifolia) that is threatening Pacific Ocean coastal ecosystems. This eradication procedure has been documented to have no apparent negative impact on native vegetation. These scientists also developed protocols to monitor the status of the eradication program and developed cost estimates and time-lines for eliminating this invasive marine alga that are being used as a model for developing rapid-response actions against other invasive aquatic species.

Vegetable oils effectively remove perchlorate from ground waters. Perchlorate presents a health risk to humans. Some crops have been shown to bioaccumulative the perchlorate anion when perchlorate contaminated irrigation water is used. The long-term, proof-of-concept studies conducted by an ARS scientist at the Soil, Plant and Nutrient Research Unit in Fort Collins, Colorado, showed that injected vegetable oil can be used to form a bio-barrier that will remove perchlorate from water by converting it to chloride. Biobarriers, formed by injecting vegetable oil emulsion into the ground may provide an inexpensive and effective method for protecting aquifers from perchlorate contamination and for removing percolate from an aquifer.

Reducing phosphorus loadings to the nations streams. ARS scientists at the Pasture Systems and Watershed Research Unit in University Park, Pennsylvania, have led the development of the national Phosphorus (P) index that is being used by the NRCS to evaluate management practices that reduce nonpoint source pollution of surface waters. These scientists have recently improved the P index tool to include considerations for adding amendments to the soil and determining the effect of these amendments on reducing water-soluble phosphorus in surface runoff. This research significantly improves the ability of this tool to conduct phosphorus risk assessments throughout the nation.

Improved methods for predicting soil erosion caused by water. ARS scientists--working at the National Sedimentation Laboratory in Oxford, Mississippi, and the Land Management and Water Conservation Research Unit in Pullman, Washington, in conjunction with NRCS, University of Tennessee, and private industry--have recently completed enhancements to the Revised Universal Soil Loss Equation (RUSLE) model. This new version is called RUSLE II and provides a more efficient and accurate method of estimating soil erosion on agricultural fields from surface runoff. Enhancements include new databases to more accurately predict crop growth and adjustments for use in predicting soil erosion from construction sites. This will help producers, extension agents, consultants, and NRCS select the most economically feasible and environmentally sound combination of management practices to reduce soil erosion and sediment loss caused by water on croplands throughout the nation.

Designing the best possible conservation buffer. Vegetative or conservation buffers that include forests can serve many different purposes all aimed at the same goal – cleaner water. ARS scientists at the Southeast Watershed Laboratory in Tifton, Georgia, in partnership with the University of Georgia, have recently completed a 9-year study to determine whether restored conservation buffer zones in wetlands next to agricultural fields can reduce the amounts of phosphorus and nitrogen that reach streams. These studies showed that the restored riparian wetland buffer retained or removed at least 60 percent of the nitrogen and 65 percent of the phosphorus that entered from the adjacent manure application site. Although conservation buffers are not a magic bullet, it has become clear that trees or forests must be part of the conservation buffer system if nitrogen and phosphorus and other pollutants are going to be effectively removed in the Southeast.

A solution to the nitrogen problem in the Western Corn Belt. Over-application of nitrogen fertilizers typically results in elevated levels of nitrate in ground and surface waters especially in continuous corn systems throughout the Western Corn Belt. ARS researchers at the Soil and Water Conservation Research Unit in Lincoln, Nebraska, have analyzed results of data from a 20-year rainfed study and 10-irrigated study that showed the soybean crop contributing an equivalent of 60 pounds of nitrogen per acre to the following corn crop. This means that at least $12 per acre cost savings can be achieved if fertilizer recommendations include this nitrogen credit for corn grown in 2-year rotations with soybean on medium to fine textured soils. For the irrigation farmer that still wants to produce continuous corn, there is a second alternative, which is to plant a winter wheat cover crop and apply only the nitrogen needed for the following corn crop. Both of these solutions should improve water quality on millions of rainfed and irrigation croplands.