United States Department of Agriculture
Natural Resources Conservation Service

Conservation Effects Assessment Project (CEAP)

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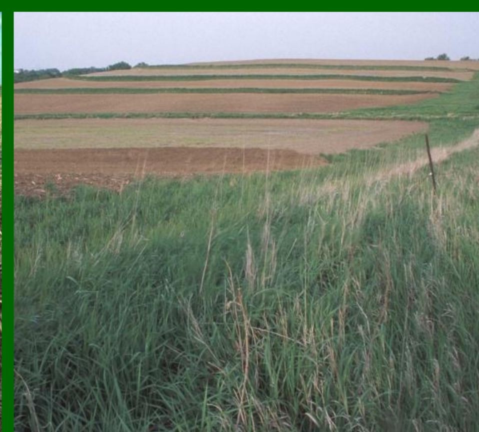
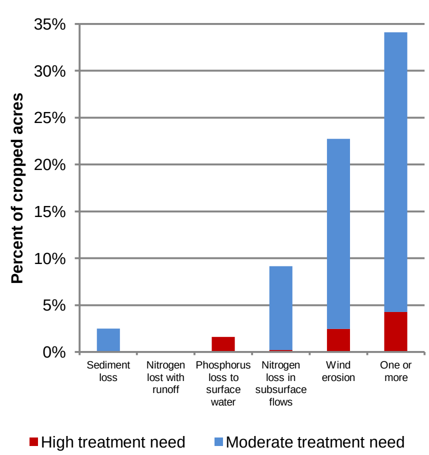
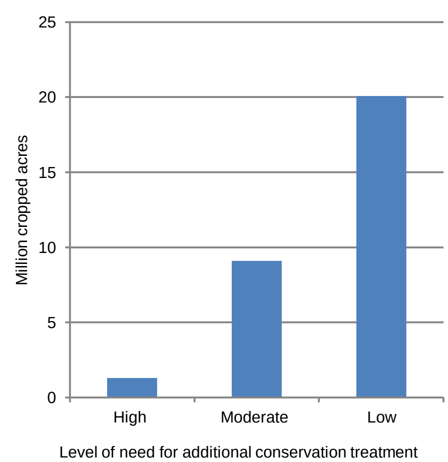
Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Arkansas-White-Red Basin







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Cover photos by (clockwise from top left) **Charlie Rahm, Gary Kramer, Tim McCabe,** and **Bob Nichols,** USDA Natural Resources Conservation Service

CEAP—Strengthening the science base for natural resource conservation

The Conservation Effects Assessment Project (CEAP) was initiated by USDA's Natural Resources Conservation Service (NRCS), Agricultural Research Service (ARS), and Cooperative State Research, Education, and Extension Service (CSREES—now National Institute of Food and Agriculture [NIFA]) in response to a general call for better accountability of how society would benefit from the 2002 Farm Bill's substantial increase in conservation program funding (Mausbach and Dedrick 2004). The original goals of CEAP were to estimate conservation benefits for reporting at the national and regional levels and to establish the scientific understanding of the effects and benefits of conservation practices at the watershed scale. As CEAP evolved, the scope was expanded to provide research and assessment on how to best use conservation practices in managing agricultural landscapes to protect and enhance environmental quality.

CEAP activities are organized into three interconnected efforts:

- *Bibliographies, literature reviews, and scientific workshops* to establish what is known about the environmental effects of conservation practices at the field and watershed scale.
- *National and regional assessments* to estimate the environmental effects and benefits of conservation practices on the landscape and to estimate conservation treatment needs. The four components of the national and regional assessment effort are *Cropland*; *Wetlands*; *Grazing lands*, including rangeland, pastureland, and grazed forest land; and *Wildlife*.
- *Watershed studies* to provide in-depth quantification of water quality and soil quality impacts of conservation practices at the local level and to provide insight on what practices are the most effective and where they are needed within a watershed to achieve environmental goals.

Research and assessment efforts were designed to estimate the effects and benefits of conservation practices through a mix of research, data collection, model development, and model application. A vision for how CEAP can contribute to better and more effective delivery of conservation programs in the years ahead is addressed in Maresch, Walbridge, and Kugler (2008). Additional information on the scope of the project can be found at http://www.nrcs.usda.gov/technical/nri/ceap/.

This report was prepared by the Conservation Effects Assessment Project (CEAP) Cropland Modeling Team and published by the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). The modeling team consists of scientists and analysts from NRCS, the Agricultural Research Service (ARS), Texas AgriLife Research, and the University of Massachusetts.

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The team also acknowledges the many helpful and constructive suggestions and comments by reviewers who participated in the peer review of earlier versions of the report.

Foreword

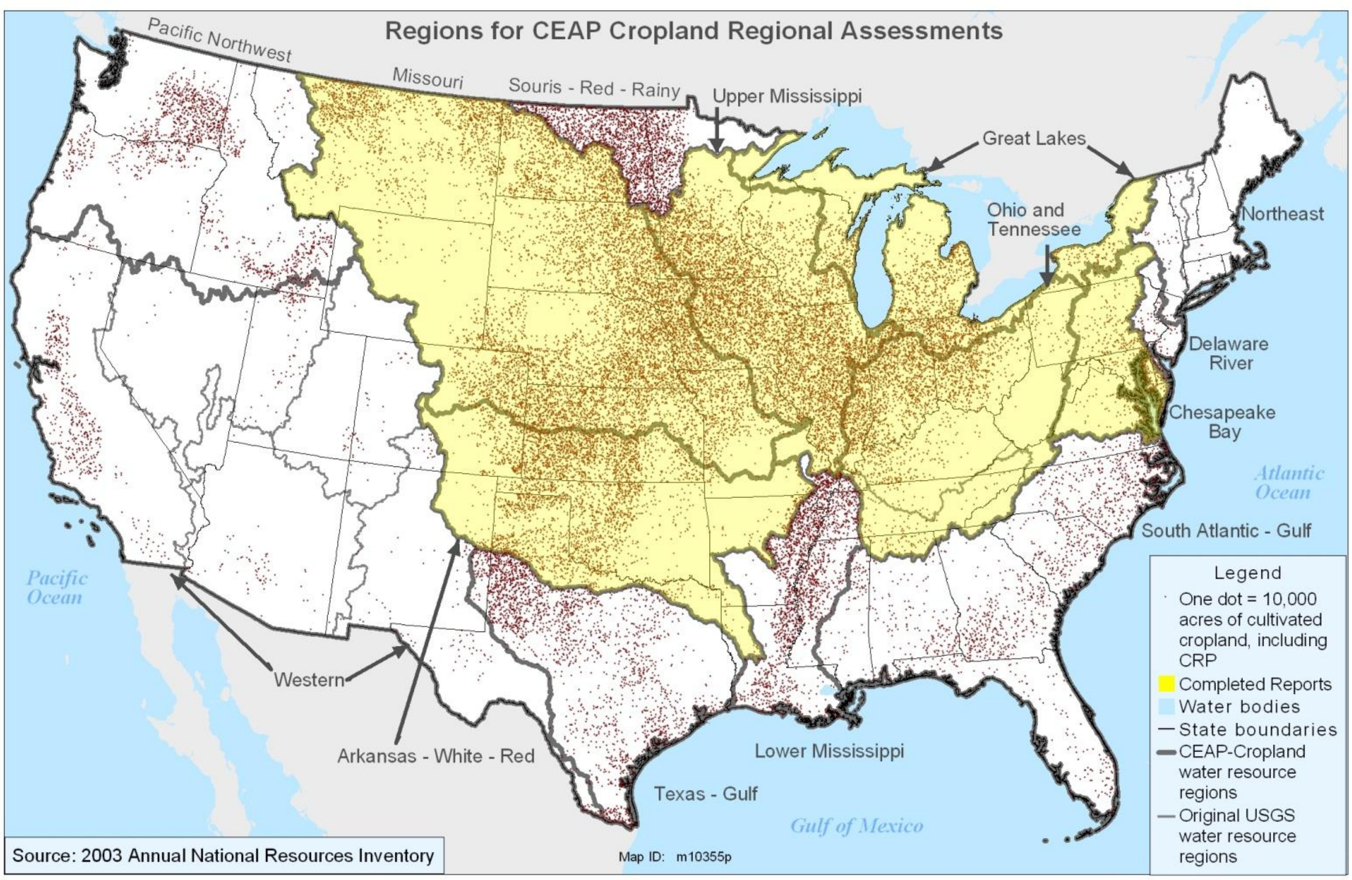
The United States Department of Agriculture has a rich tradition of working with farmers and ranchers to enhance agricultural productivity and environmental protection. Conservation pioneer Hugh Hammond Bennett worked tirelessly to establish a nationwide Soil Conservation Service along with a system of Soil and Water Conservation Districts. The purpose of these entities, now as then, is to work with farmers and ranchers and help them plan, select, and apply conservation practices to enable their operations to produce food, forage, and fiber while conserving the Nation's soil and water resources.

USDA conservation programs are voluntary. Many provide financial assistance to producers to help encourage adoption of conservation practices. Others provide technical assistance to design and install conservation practices consistent with the goals of the operation and the soil, climatic, and hydrologic setting. By participating in USDA conservation programs, producers are able to—

- install structural practices such as riparian buffers, grass filter strips, terraces, grassed waterways, and contour farming to reduce erosion, sedimentation, and nutrients leaving the field;
- adopt conservation systems and practices such as conservation tillage, comprehensive nutrient management, integrated pest management, and irrigation water management to conserve resources and maintain the long-term productivity of crop and pasture land; and
- retire land too fragile for continued agricultural production by planting and maintaining on them grasses, trees, or wetland vegetation.

Once soil conservation became a national priority, assessing the effectiveness of conservation practices also became important. Over the past several decades, the relationship between crop production and the landscape in which it occurs has become better understood in terms of the impact on sustainable agricultural productivity and the impact of agricultural production on other ecosystem services that the landscape has potential to generate. Accordingly, the objectives of USDA conservation policy have expanded along with the development of conservation practices to achieve them.

The Conservation Effects Assessment Project (CEAP) continues the tradition within USDA of assessing the status, condition, and trends of natural resources to determine how to improve conservation programs to best meet the Nation's needs. CEAP reports use a sampling and modeling approach to quantify the environmental benefits that farmers and conservation programs are currently providing to society, and explore prospects for attaining additional benefits with further conservation treatment. CEAP findings are being released in a series of regional reports for the regions shown in the following map.



Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Arkansas-White-Red Basin

Contents

Documentation Reports

There are a series of documentation reports and associated publications by the modeling team posted on the CEAP website at: http://www.nrcs.usda.gov/technical/nri/ceap. (Click on "Cropland" and then click on "documentation reports and associated publications.") Included are the following reports that provide details on the modeling and databases used in this study:

- The HUMUS/SWAT National Water Quality Modeling System and Databases
- Calibration and Validation of CEAP-HUMUS
- Delivery Ratios Used in CEAP Cropland Modeling
- APEX Model Validation for CEAP
- Pesticide Risk Indicators Used in CEAP Cropland Modeling
- Integrated Pest Management (IPM) Indicator Used in CEAP Cropland Modeling
- NRI-CEAP Cropland Survey Design and Statistical Documentation
- Transforming Survey Data to APEX Model Input Files
- Modeling Structural Conservation Practices for the Cropland Component of the National Conservation Effects Assessment Project
- APEX Model Upgrades, Data Inputs, and Parameter Settings for Use in CEAP Cropland Modeling
- APEX Calibration and Validation Using Research Plots in Tifton, Georgia
- The Agricultural Policy Environmental EXtender (APEX) Model: An Emerging Tool for Landscape and Watershed Environmental Analyses
- The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Directions
- Historical Development and Applications of the EPIC and APEX Models
- Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for the CEAP National Cropland Assessment
- Manure Loadings Used to Simulate Pastureland and Hayland in CEAP HUMUS/SWAT modeling
- Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling

Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Arkansas-White-Red Basin

Executive Summary

Agriculture in the Arkansas-White-Red Basin

The Arkansas-White-Red Basin covers about 248,000 square miles (158 million acres) and includes all of Oklahoma and parts of Arkansas, Colorado, Kansas, Louisiana, Missouri, New Mexico, and Texas. The basin lies just south of the Missouri River Basin and discharges into the Lower Mississippi River Basin at three points: 1) the outlet of the Upper White River Basin in the north near Newport, AR, 2) the outlet of the Lower Arkansas River Basin near Pine Bluff, AR, and 3) the outlet of the Red River Basin in the south near Alexandria, LA.

Agricultural land makes up most of the area in this region—22 percent cultivated cropland, 3 percent permanent hayland, and 45 percent grazing land (pasture and rangeland). The bulk of the cultivated cropland is located in the central part of the basin in Kansas, Oklahoma, and northern Texas. Only about 5 percent of the basin area is urban land. Forestland makes up most of the remaining 25 percent.

The value of Arkansas-White-Red Basin agricultural sales in 2007 was about $30 billion—about 21 percent from crops and 79 percent from livestock. Farms in the Arkansas-White-Red Basin make up about 13 percent of all land on farms in the Nation. Wheat, hay, corn, and sorghum are the principal crops grown. About 22 percent of the Nation's wheat acres and 34 percent of the Nation's sorghum-for-grain acres are in this region. Cattle sales in the region totaled $16.6 billion in 2007 and represented 27 percent of all cattle sales nationally. Poultry and egg sales were also important, totaling $5.1 billion in sales in 2007 and representing 14 percent of the Nation's poultry and egg sales.

The 2007 Census of Agriculture reported 216,085 farms in the Arkansas-White-Red Basin, about 10 percent of the total number of farms in the United States. The average farm in this region is larger than in most areas of the country—539 acres compared to an average farm size of 418 acres for the Nation. Farms with total agricultural sales greater than $250,000 accounted for 9 percent of the farms in the region. About 44 percent of the farms primarily raise crops, about 49 percent are primarily livestock operations, and the rest produce a mix of livestock and crops.

Agriculture in this region is not as inherently productive as in the Upper Mississippi River Basin or the Ohio-Tennessee River Basin because of lower precipitation and generally less fertile soils. Precipitation in the Arkansas-White-Red Basin averages 27 inches per year, compared to 34 inches per year in the Upper Mississippi River Basin and 42 inches per year in the Ohio-Tennessee River Basin. In the western portion of the region, precipitation averages only 21 inches per year. (The eastern and western portions of the region each contain about half of the land base. However, 37 percent of the cropped acres are in the eastern portion and 63 percent are in the western portion.) Overall, about 20 percent of cropped acres are irrigated in the Arkansas-White-Red Basin. The bulk of the irrigated acres—80 percent—are in the western portion of the basin.

Focus of CEAP Study Is on Edge-Of-Field Losses from Cultivated Cropland

The primary focus of the CEAP Arkansas-White-Red Basin study is on the 22 percent of the basin that is cultivated cropland. The study was designed to—

- quantify the effects of conservation practices commonly used on cultivated cropland in the Arkansas-White-Red Basin during 2003–06,
- evaluate the need for additional conservation treatment in the region on the basis of wind erosion and edge-of-field sediment and nutrient losses, and
- estimate the potential gains that could be attained with additional conservation treatment.

The assessment uses a statistical sampling and modeling approach to estimate the effects of conservation practices. The National Resources Inventory (NRI), a statistical survey of conditions and trends in soil, water, and related resources on U.S. non-Federal land conducted by USDA's Natural Resources Conservation Service, provides the statistical framework for the study. Physical process simulation models were used to estimate the effects of conservation practices that were in use during the period 2003–06. Information on farming activities and conservation practices was obtained primarily from a farmer survey conducted as part of the study. The assessment includes not only practices associated with Federal conservation programs but also the conservation efforts of States, independent organizations, and individual landowners and farm operators. The analysis assumes that structural practices (such as buffers, terraces, and grassed waterways) reported in the farmer survey or obtained from other data sources were appropriately designed, installed, and maintained.

The national sample for the farmer survey consists of 18,700 sample points with 1,280 of these sample points located in the Arkansas-White-Red Basin. This sample size is sufficient for reliable and defensible reporting at the regional scale and for most of the 14 subregions in the Arkansas-White-Red Basin, but is generally insufficient for assessments of smaller areas.

The modeling strategy for estimating the effects of conservation practices consists of two model scenarios that are produced for each sample point:

1. A baseline scenario, the "baseline conservation condition" scenario, provides model simulations that account for cropping patterns, farming activities, and conservation practices as reported in the NRI-CEAP Cropland Survey and other sources.
2. An alternative scenario, the "no-practice" scenario, simulates model results as if no conservation practices were in use but holds all other model inputs and parameters the same as in the baseline conservation condition scenario.

The effects of conservation practices are obtained by comparing the difference in model results between the two scenarios. The need for additional conservation treatment was evaluated using a common set of criteria and protocols applied to all regions in the country to provide a systematic, consistent, and comparable assessment at the national level.

Voluntary, Incentives-Based Conservation Approaches Are Achieving Results

The Arkansas-White-Red Basin encompasses much of the Shortgrass Plains, a windswept region with a semiarid climate. In the early 1900's homesteading was prevalent, increased global demand for American wheat and beef was elevating prices, and improved agricultural mechanization enabled extensive sodbusting of the Plains. Then, an unfortunate confluence of the Great Depression, falling global demand for U.S. agricultural goods, and prolonged drought left large areas of the Arkansas-White-Red Basin vulnerable to erosion. The Oklahoma panhandle was the epicenter of the Dust Bowl, with significant erosion in most of the western portion of the Basin.

Given the long history of conservation in the Arkansas-White-Red Basin, it is not surprising to find that nearly all cropped acres in the region have some conservation practice use, including soil erosion control practices and nutrient management practices on most acres. Model results show that farmers in the Arkansas-White-Red Basin have made substantial progress in reducing sediment, nutrient, and pesticide losses from farm fields through conservation practice adoption. Because of the relatively low annual precipitation in this region and the widespread use of soil erosion control practices, nutrient management practices, and increased irrigation efficiencies, the per-acre losses at the field level throughout much of this region are low compared to those in most other regions, with the important exception of wind erosion.

Conservation Practice Use

The farmer survey found, for the period 2003–06, that producers use either residue and tillage management practices or structural practices, or both, on 87 percent of the acres.

- Structural practices for controlling water erosion are in use on 46 percent of cropped acres. Thirty-two percent of cropped acres are designated as highly erodible land; structural practices designed to control water erosion are in use on 39 percent of the highly-erodible land in the western portion of the region and 66 percent of the highly-erodible land in the eastern portion.
- Structural practices for controlling wind erosion are in use on 7 percent of cropped acres.
- Mulch till is common in the region; 44 percent of the cropped acres meet criteria for mulch till.
- However, no-till is not as common as in other regions; only 14 percent of cropped acres meet criteria for no-till.
- Thirty-four percent of cropped acres are conventionally tilled.

The farmer survey also found that nutrient management practices are frequently used on cropped acres in the Arkansas-White-Red Basin. Cropping systems are less intensely fertilized with lower application rates, drier planting seasons, and more crops harvested during the summer.

- Appropriate *timing* of nitrogen applications is in use on about 78 percent of the acres for all crops in the rotation, and appropriate *timing* of phosphorus applications is in use on about 65 percent of the acres for all crops in the rotation.
- Appropriate *methods* of nitrogen application are in use on about 62 percent of the acres for all crops in the rotation, and appropriate *methods* of phosphorus application are in use on about 59 percent of the acres for all crops in the rotation.
- Appropriate *rates* of nitrogen application are in use on about 59 percent of the acres for all crops in the rotation, and appropriate *rates* of phosphorus application are in use for the crop rotation on about 40 percent of the acres.
- Although most cropped acres meet nutrient management criteria for rate, timing, or method, fewer acres meet criteria for all three:
    - 33 percent of cropped acres meet all criteria for nitrogen applications;
    - 29 percent of cropped acres meet all criteria for phosphorus applications; and
    - 25 percent of cropped acres meet criteria for *both* phosphorus and nitrogen.

About 31 percent of cropped acres are gaining soil organic carbon (that is, the average annual change in soil organic carbon is greater than zero).

Land in long-term conserving cover, as represented by enrollment in the Conservation Reserve Program (CRP) General Signup, consists of about 6 million acres—17 percent of the cultivated cropland acres in the region. About 49 percent of the land in long-term conserving cover is highly erodible.

Conservation Accomplishments at the Field Level

Compared to a model scenario without conservation practices, field-level model simulations showed that conservation practice use during the period 2003–06 has—

- reduced wind erosion by 31 percent;
- reduced waterborne sediment loss from fields by 61 percent;
- reduced nitrogen lost with windborne sediment by 27 percent;
- reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 51 percent;
- reduced nitrogen loss in subsurface flows by 57 percent;
- reduced phosphorus lost with windborne sediment by 40 percent;
- reduced total phosphorus loss (all loss pathways) from fields by 47 percent; and
- reduced pesticide loss from fields to surface water, resulting in a 38-percent reduction in edge-of-field pesticide risk (all pesticides combined) for humans and a 35-percent reduction for aquatic ecosystems.

Use of improved irrigation systems in the Arkansas-White-Red Basin has increased irrigation efficiency from 54 percent in the no-practice scenario to 69 percent in the baseline scenario. This change in efficiency represents an annual decreased need for irrigation water of 6.7 inches per year where irrigation is used.

At 6 million acres, land in long-term conserving cover (CRP) is an important part of the agricultural landscape in the Arkansas-White-Red Basin. The benefits of this conservation practice were estimated by simulating crop production on these acres without use of conservation practices. Model simulation results show that wind erosion and sediment loss have been almost completely eliminated for land in long-term conserving cover. Total nitrogen loss has been reduced by 79 percent, and total phosphorus loss has been reduced by 98 percent.

Conservation Accomplishments at the Watershed Level

Reductions in field-level losses due to conservation practices are expected to improve water quality in streams and rivers in the region. Transport of sediment, nutrients, and pesticides from farm fields to streams and rivers involves a variety of processes and time-lags, and not all of the potential pollutants leaving fields contribute to instream loads. Edge-of-field losses of sediment, nitrogen, phosphorus, and the pesticide atrazine were incorporated into a national water quality model to estimate the extent to which conservation practices have reduced amounts of these contaminants delivered to rivers and streams throughout the region. Of the total loads delivered to rivers and streams from all sources, cultivated cropland is the source for 30 percent of the sediment, 43 percent of the nitrogen, and 20 percent of the phosphorus.

The model simulations showed that conservation practices in use during the period 2003–06, including land in long-term conserving cover, have reduced average annual loads delivered to rivers and streams within the basin, compared to a no-practice scenario, by 64 percent for sediment, 59 percent for nitrogen, and 59 percent for phosphorus. The national water quality model also provided estimates of reductions in ***instream loads*** due to conservation practice use. *When considered along with loads from all other sources*, conservation practices in use on cultivated cropland in 2003–06 have reduced total instream loads delivered from this region to the Lower Mississippi River Basin by 5 percent for sediment, 27 percent for nitrogen, and 17 percent for phosphorus. The percent reduction for sediment loads delivered to the Lower Mississippi River Basin is low because of the system of reservoirs along the Arkansas and Red River systems. Major reservoirs trap significant amounts of sediment, nitrogen, and phosphorus delivered to rivers and streams from all sources, including cultivated cropland.

Opportunities Exist to Further Reduce Soil Erosion and Nutrient Losses from Cultivated Cropland

The assessment of conservation treatment needs presented in this study identifies significant opportunities to further reduce contaminant losses from farm fields. The study found that 10.4 million acres (34 percent of cropped acres) have a **high** or **moderate** level of need for additional conservation treatment. Acres with a **high** level of need (1.3 million acres) consist of the most vulnerable acres with the least conservation treatment and the highest losses of sediment or nutrients. Acres with a **moderate** level of need (9.1 million acres) consist of under-treated acres that generally have lower levels of vulnerability or have more conservation practice use than acres with a **high** level of need but still have unacceptable levels of soil erosion or nutrient loss at the field level. Nearly two-thirds of cropped acres—20.1 million acres—have a **low** level of need for additional conservation treatment.

Model simulations show that adoption of additional erosion control and nutrient management practices on the 10.4 million under-treated acres would, compared to the 2003–06 baseline, further reduce field losses in the region by—

- 36 percent for sediment loss due to water erosion,
- 26 percent for wind erosion,
- 21 percent for nitrogen lost with surface runoff,
- 21 percent for nitrogen loss in subsurface flows, and
- 21 percent for phosphorus lost to surface water (sediment-attached and soluble).

These field-level reductions would, in turn, further reduce loads delivered to rivers and streams from cultivated cropland. Relative to the 2003–06 baseline, this level of additional conservation treatment would reduce total ***instream loads*** *delivered from the region to the Lower Mississippi River Basin from all sources* by 1 percent for sediment, 5 percent for nitrogen, and 2 percent for phosphorus. These reductions in instream loads from further conservation treatment are relatively modest because the bulk of the remaining loads originate from sources other than cultivated cropland in this region.

Emerging technologies not evaluated in this study promise to provide additional conservation benefits once their use becomes more widespread. These include—

- Innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies and improved manure application equipment;
- Enhanced-efficiency nutrient application products such as slow or controlled release fertilizers, polymer coated products, nitrogen stabilizers, urease inhibitors, and nitrification inhibitors;
- Drainage water management that controls discharge of drainage water and treats contaminants, thereby reducing the levels of nitrogen loss and even some soluble phosphorus loss;
- Constructed wetlands receiving surface water runoff and drainage water from farm fields prior to discharge to streams and rivers; and
- Improved crop genetics that increase yields without increasing nutrient inputs.

Comprehensive Conservation Planning and Implementation Are Essential

The most pervasive conservation concern in the region is excessive wind erosion during dry periods, including windborne losses of nitrogen and phosphorus. Wind erosion and windborne sediment adversely impact the soil, water, and air quality, and can cause human health issues.

Wind erosion accounts for most of the soil and nutrient losses from farm fields in this region. While conservation practices in use during 2003–06 have been effective in reducing wind erosion, model simulations show that rates can exceed 4 tons per acre in at least some years for up to 23 percent of the acres in the region, and exceed 2 tons per acre in some years for up to 35 percent of the acres. About 63 percent of total phosphorus and 23 percent of total nitrogen lost from fields is with windborne sediment.

Wind erosion is much higher in the western portion of the basin, averaging 2.82 tons per acre per year. About 82 percent of total phosphorus loss and 32 percent of total nitrogen loss in the western portion of the basin result from wind erosion. Wind erosion in the eastern portion of the region averages 0.94 ton per acre per year, which is still high enough to be of concern in some years; 39 percent of total phosphorus loss and 10 percent of total nitrogen loss in this portion of the basin result from wind erosion.

Loss of sediment, nutrients, and pesticides with water is also important for some acres in the eastern portion of the basin. About 35 percent of the under-treated acres are in the eastern portion. The principal resource concern in the eastern portion is nitrogen loss in subsurface flows.

A ***comprehensive conservation planning process*** is required to identify the appropriate combination of soil erosion control practices and nutrient management techniques needed to simultaneously address soil erosion and nutrient and pesticide loss through the various loss pathways. A field with adequate conservation practice use will have a suite of practices that address all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses through the dominant loss pathways.

Targeting Enhances Effectiveness and Efficiency

Targeting program funding and technical assistance for accelerated treatment of acres with the most critical need for additional treatment is the most efficient way to reduce agricultural sources of contaminants from farm fields.

Not all acres provide the same benefit from conservation treatment. The more vulnerable acres, such as highly erodible land and soils prone to leaching or wind erosion, inherently lose more sediment or nutrients; therefore greater benefit can be attained with additional conservation treatment. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff or wind erosion are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways.

The least treated acres also provide a potential for greater benefits from treatment, especially if they are also inherently vulnerable to runoff, leaching, or wind erosion. The farmer survey showed that, while most acres benefit from use of conservation practices, environmentally "risky" management is still used on some acres (such as fall application of commercial fertilizers and manure for spring-planted crops, surface broadcast applications of commercial fertilizers and manure, and conventional tillage).

The practices in use in 2003–06 have already achieved 64 percent of potential reductions in sediment loss, 72 percent of potential reductions in nitrogen loss, and 63 percent of potential reductions in phosphorus loss. By treating all 10.4 million under-treated acres in the region with additional erosion control and nutrient management practices, an additional 15-percent reduction in potential sediment loss, an additional 14-percent reduction in potential nitrogen loss, and an additional 17-percent reduction in potential phosphorus loss could be achieved. To achieve 100 percent of potential savings (i.e., an additional 22 percent for sediment, 19 percent for phosphorus, and 14 percent for nitrogen), additional conservation treatment for the 20.1 million low-treatment-need acres would be required.

Targeting is especially important in this region because of the low proportion of cropped acres that need additional treatment. Treating the 20.1 million acres that have a low need for additional treatment would provide very small per-acre reductions in field-level loss—an inefficient way to reduce loads delivered to rivers and streams. But significant per-acre reductions could be attained for the 10.4 million under-treated acres that need additional treatment. Finding and treating these acres is an important challenge for program managers in this region.

**Effects of Conservation Practices on Ecological Conditions
Are Beyond the Scope of This Study**

Ecological outcomes are not addressed in this report, nor were the estimates of conservation treatment needs specifically derived to attain Federal, State, or local water quality goals within the region.

Ecosystem impacts related to water quality are specific to each water body. Water quality goals also depend on the designated uses for each water body. In order to understand the effects of conservation practices on water quality in streams and lakes, it is first necessary to understand what is happening in the receiving waters and then evaluate whether the practices are having the desired effect on the current state of that aquatic ecosystem.

The regional scale and statistical design of this study precludes these kinds of assessments.

The primary focus of this report is on losses of potential pollutants from farm fields and prospects for attaining further loss reductions with additional soil erosion control and nutrient management practices. Conservation treatment needs were estimated to achieve "full treatment" from the field-level perspective, rather than to reduce instream loads to levels adequate for designated water uses. The simulated treatment levels were designed to minimally affect crop yields and maintain regional production capacity for food, fiber, forage, and fuel.

From this perspective, a field with adequate conservation treatment will have combinations of practices that address all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses. For purposes of this report, "full treatment" consists of a suite of practices that—

- *avoid* or limit the potential for contaminant losses by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- *control* overland flow where needed; and
- *trap* materials leaving the field using appropriate edge-of-field mitigation.

This field-based concept of "full conservation treatment" will likely be sufficient to protect water quality for some environmental settings. For more sensitive environmental settings, however, it may be necessary to adopt even stricter management criteria and techniques such as widespread use of cover crops, drainage water management, conservation rotations, or emerging production and conservation technologies. In some cases, attainment of water quality goals may even require watershed-scale solutions, such as sedimentation basins, wetland construction, streambank restoration, or an increased proportion of acres in long-term conserving cover.

Chapter 1
Land Use and Agriculture in the Arkansas-White-Red Basin

Land Use

The Arkansas-White-Red Basin covers about 248,000 square miles (158 million acres) and includes all of Oklahoma and parts of Arkansas, Colorado, Kansas, Louisiana, Missouri, New Mexico, and Texas. The basin lies just south of the Missouri River Basin and discharges into the Lower Mississippi River Basin at three points: 1) the outlet of the Upper White River Basin in the north near Newport, AR, 2) the outlet of the Lower Arkansas River Basin near Pine Bluff, AR, and 3) the outlet of the Red River Basin in the south near Alexandria, LA.

The dominant land cover in the basin is rangeland (39 percent of the area), most of which is grass rangeland located in the western and central parts of the basin (table 1, fig. 1). Cultivated cropland accounts for about 22 percent of the area, the bulk of which is located in the central part of the basin in Kansas, Oklahoma, and northern Texas. (Cultivated cropland includes land in long-term conserving cover, which is represented by acres enrolled in the General Sign-up of the Conservation Reserve Program [CRP].)

Forestland accounts for 21 percent of the area, most of which is located in the eastern parts of the region (Missouri, Arkansas, and Louisiana) and along the western edge of the region.

Table 1. Distribution of land cover in the Arkansas-White-Red Basin

Land use	Acres*	Percent including water	Percent excluding water
Cultivated cropland and land enrolled in the CRP General Signup**	35,342,653	22	23
Hayland not in rotation with crops	5,431,823	3	3
Pastureland not in rotation with crops	9,454,735	6	6
Rangeland—grass	49,562,698	31	32
Rangeland—brush	13,167,757	8	8
Horticulture	168,339	<1	<1
Forestland			
Deciduous	20,921,088	13	13
Evergreen	9,833,614	6	6
Mixed	2,545,778	2	2
Urban	7,420,233	5	5
Wetlands			
Forested	2,024,598	1	1
Non-Forested	273,137	<1	<1
Barren	399,688	<1	<1
Subtotal	156,546,141	99	100
Water	2,130,884	1	
Total	158,677,025	100	

Source: 2001 National Land Cover Database for the Conterminous United States (Homer et al. 2007).
*Acreage estimates for cultivated cropland differ slightly from those based on the NRI-CEAP sample because of differences in data sources and estimation procedures. Acres enrolled in the CRP General Signup are used to represent land in long-term conserving cover.
**Includes hayland and pastureland in rotation with crops.

Permanent pasture and hayland represent only 9 percent of the area, and water, wetlands, horticulture, and barren land account for about 4 percent.

The remaining 5 percent of the area consists of urban land. Major metropolitan areas center around Oklahoma City and Tulsa, OK, and Wichita, KS. Urban land is also concentrated around Little Rock, AR, Shreveport, LA, and Colorado Springs, CO.

Agriculture

The 2007 Census of Agriculture reported 216,085 farms in the Arkansas-White-Red Basin, about 10 percent of the total number of farms in the United States (table 2). Land on farms was nearly 116.5 million acres, representing about 73 percent of the total area. Farms in the Arkansas-White-Red Basin make up about 13 percent of all land on farms in the nation. According to the 2007 Census of Agriculture, the value of Arkansas-White-Red Basin agricultural sales in 2007 was about $30 billion—about 21 percent from crops and 79 percent from livestock.

About 44 percent of Arkansas-White-Red Basin farms primarily raise crops, about 49 percent are primarily livestock operations, and the remaining 7 percent produce a mix of livestock and crops (table 3).

The average farm in this region is larger than in most areas of the country—539 acres compared to an average farm size of 418 acres for the Nation (table 2). Five percent of the farms have more than 2,000 acres and 14 percent have 500–2,000 acres (table 3). As in other regions, however, most of the farms are small in terms of gross sales; in 2007, 79 percent had less than $50,000 in total farm sales and 12 percent had $50,000–$250,000 in total farm sales (table 3). Farms with total agricultural sales greater than $250,000 (table 3) accounted for only 9 percent of the farms in the region.

Crop production

The Arkansas-White-Red Basin accounted for about 4 percent of all U.S. crop sales in 2007, totaling $6 billion (table 2). Wheat, hay, corn, and sorghum are the principal crops grown. About 22 percent of the nation's wheat acres and 34 percent of the Nation's sorghum-for-grain acres are in this region. About 8 million acres of hay, most of which is grass hay, are grown for use as livestock feed. Soybeans, cotton and rice are also important crops in some parts of the region.

Irrigation is important for crop production in some parts of the region. About 5 million acres of harvested cropland were irrigated in 2007 (table 2), representing 19 percent of cropland harvested in the region and 10 percent of all irrigated harvested land in the nation.

Commercial fertilizers and pesticides are widely used on agricultural land in the region (table 2). In 2007, 22 million acres of cropland were fertilized, 20 million acres of cropland and pasture were treated with chemicals for weed control, and 6 million acres of hay and cropland were treated for insect control. About 1.8 million acres had manure applied in 2007.

Livestock operations
The Arkansas-White-Red Basin accounted for about 16 percent of all U.S. livestock sales in 2007, totaling $24 billion (table 2). Livestock sales in the region are dominated by cattle sales, which totaled $16.6 billion in 2007 and represented 27 percent of all cattle sales nationally (table 2). Poultry and egg sales were also important, totaling $5.1 billion in sales in 2007 and representing 14 percent of the Nation's poultry and egg sales.

In terms of animal units, livestock populations in the region are dominated by cattle, horses, sheep, and goats. An animal unit is 1,000 pounds of live animal weight calculated as a yearly average for each farm using information reported in the 2007 Census of Agriculture. Of the 16 million livestock animal units in the region, 13.6 million animal units are cattle, horses, sheep, and goats, including fattened cattle but excluding dairy cows (table 2). Fattened cattle animal units total about 4.1 million, representing 32 percent of fattened cattle animal units in the Nation. Poultry animal units total 1.1 million, representing 14 percent of the poultry animal units in the Nation. Dairy cows, swine, and other livestock make up only 8 percent of the livestock population in this region.

About 13,700 of the farms in the region (6 percent) could be defined as animal feeding operations (AFOs) (table 3). AFOs are livestock operations typically with confined poultry, swine, dairy cattle, or beef cattle. An additional 80,700 farms have significant numbers of pastured livestock (37 percent of farms). About 3,800 of the livestock operations (28 percent of the AFOs) are relatively large, with livestock numbers in 2007 above the EPA minimum threshold for a medium concentrated animal feeding operation (CAFO). Of these, about 1,100 meet livestock population criteria for a large CAFO.

> Statistics for the Arkansas-White-Red Basin reported in table 2 are for the year 2007 as reported in the Census of Agriculture. For some characteristics, different acre estimates are reported in subsequent sections based on the NRI-CEAP sample. Estimates based on the NRI-CEAP sample are for the time period 2003–06. See chapter 2 for additional aspects of estimates based on the NRI-CEAP sample.

Watersheds
A hydrologic accounting system consisting of water resource regions, major subregions, and smaller watersheds has been defined by the U.S. Geological Survey (USGS) (1980). Each water resource region is designated with a 2-digit Hydrologic Unit Code (HUC), which is further divided into 4-digit subregions and then into 8-digit cataloging units, or watersheds. The Arkansas-White-Red drainage is represented by 14 subregions.

The concentration of cultivated cropland within each subregion is an important indicator of the extent to which sediment and nutrient loads in rivers and streams are influenced by farming operations. Cultivated cropland makes up more than 30 percent of the land base in six of the 14 subregions (table 4 and fig. 2)—
- Middle Arkansas River Basin (code 1103), with 67 percent,
- Upper Cimarron River Basin (code 1104), with 52 percent,
- Arkansas River-Keystone including Salt Fork River Basin (code 1106), with 42 percent,
- Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112), with 40 percent,
- Lower Cimarron River Basin (code 1105), with 35 percent, and
- North Canadian including Beaver River Basin (code 1110), with 32 percent.

These six subregions have two-thirds of the cultivated cropland in the region. Cultivated cropland makes up 25 percent or less of the land base in each of the other subregions (table 4).

Cultivated cropland is a minor land use in four subregions, where it accounts for only a small percentage of the total area within each subregion—
- Upper White River Basin (code 1101), with 6 percent,
- Red-Little-Saline-Sulphur Creek River Basin (code 1114), with 4 percent,
- Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111), with 3 percent, and
- Upper Canadian River Basin (code 1108), with 1 percent.

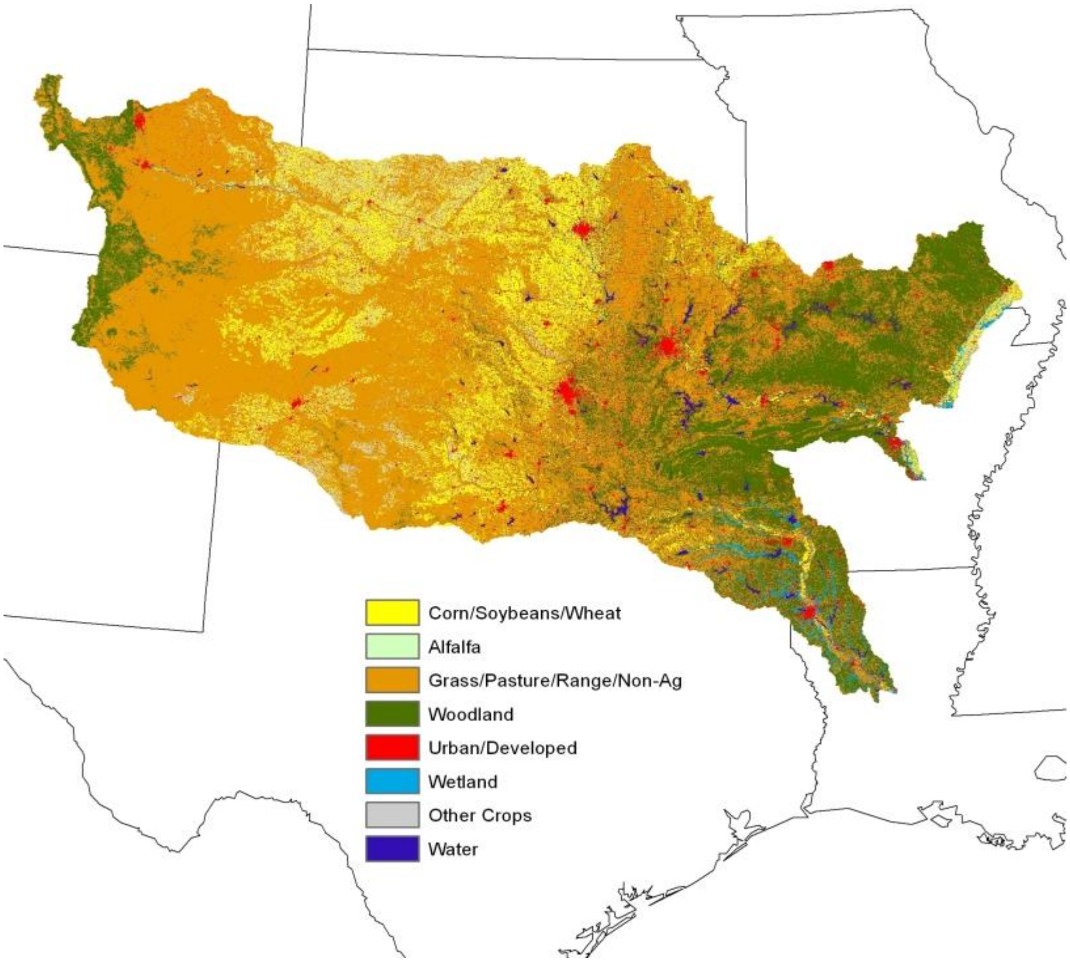
Cultivated cropland includes land in long-term conserving cover, which represents about 17 percent of the cultivated cropland acres in this region (table 4). Subregions where land in long-term conserving cover is 20 percent or more of cultivated cropland acres are—
- Upper Arkansas River Basin (code 1102), with 37 percent,
- Upper Canadian River Basin (code 1108), with 32 percent,
- Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112), with 30 percent,
- North Canadian including Beaver River Basin (code 1110), with 26 percent, and
- Upper Cimarron River Basin (code 1104), with 22 percent.

Table 2. Profile of farms and land in farms in the Arkansas-White-Red Basin, 2007

Characteristic	Value	Percent of national total
Number of farms	216,085	10
Acres on farms	116,547,987	13
Average acres per farm	539	
Cropland harvested, acres	27,703,515	9
Cropland used for pasture, acres	6,581,821	18
Cropland on which all crops failed, acres	2,557,087	35
Cropland in summer fallow, acres	3,359,656	21
Cropland idle or used for cover crops, acres	5,221,710	14
Woodland pastured, acres	3,933,401	14
Woodland not pastured, acres	3,455,331	7
Permanent pasture and rangeland, acres	61,033,415	15
Other land on farms, acres	2,702,051	9
Principal crops grown		
Wheat harvested, all types, acres	11,327,942	22
Tame and wild hay harvested, acres	5,840,021	17
Field corn for grain harvested, acres	3,257,613	4
Sorghum for grain harvested, acres	2,299,057	34
Soybeans harvested, acres	1,919,729	3
Alfalfa hay harvested, acres	1,123,049	6
Small grain hay harvested, acres	851,211	22
Cotton, acres	763,400	7
Rice, acres	266,265	10
Irrigated harvested land, acres	5,138,650	10
Irrigated pastureland or rangeland, acres	305,024	6
Cropland fertilized, acres	22,146,135	9
Pastureland fertilized, acres	5,475,300	22
Land treated for insects on hay or other crops, acres	6,302,460	7
Land treated for nematodes in crops, acres	150,645	2
Land treated for diseases in crops and orchards, acres	1,685,740	7
Land treated for weeds in crops and pasture, acres	20,295,770	9
Crops on which chemicals for defoliation applied, acres	528,102	4
Acres on which manure was applied	1,810,221	8
Total grains and oilseeds sales, million dollars	4,839	6
Total nursery, greenhouse, and floriculture sales, million dollars	334	2
Total cotton and cottonseed sales, million dollars	323	7
Total hay and other crop sales, million dollars	801	2
Total crop sales, million dollars	6,296	4
Total cattle sales, million dollars	16,596	27
Total poultry and eggs sales, million dollars	5,125	14
Total hog and pigs sales, million dollars	1,242	7
Total dairy sales, million dollars	1,032	3
Total horses, ponies, and mules sales, million dollars	79	4
Total sheep, goats, and their products sales, million dollars	32	4
Total other livestock sales, million dollars	53	2
Total livestock sales, million dollars	24,158	16
Animal units on farms		
All livestock types	16,115,752	16
Swine	838,093	8
Dairy cows	472,184	4
Fattened cattle	4,131,556	32
Other cattle, horses, sheep, goats	9,505,305	16
Chickens, turkeys, and ducks	1,127,988	14
Other livestock	40,625	10

Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA
Note: Information in the Census of Agriculture was used to estimate animal units using methods and assumptions described in USDA/NRCS (2003).

Figure 1. Land cover in the Arkansas-White-Red Basin



Source: National Agricultural Statistics Service (NASS 2007).

Table 3. Characteristics of farms in the Arkansas-White-Red Basin, 2007

	Number of farms	Percent of farms in Arkansas-White-Red Basin
Farming primary occupation	92,706	43
Farm size:		
<50 acres	61,337	28
50–500 acres	112,863	52
500–2,000 acres	30,428	14
>2,000 acres	11,457	5
Farm sales:		
<$10,000	119,343	55
$10,000–50,000	51,062	24
$50,000–250,000	26,277	12
$250,000–500,000	7,484	3
>$500,000	11,919	6
Farm type:		
Crop sales make up more than 75 percent of farm sales	95,332	44
Livestock sales make up more than 75 percent of farm sales	106,371	49
Mixed crop and livestock sales	14,382	7
Farms with no livestock sales	60,070	28
Farms with few livestock or specialty livestock types	61,553	28
Farms with pastured livestock and few other livestock types	80,705	37
Farms with animal feeding operations (AFOs)*	13,757	6

Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA

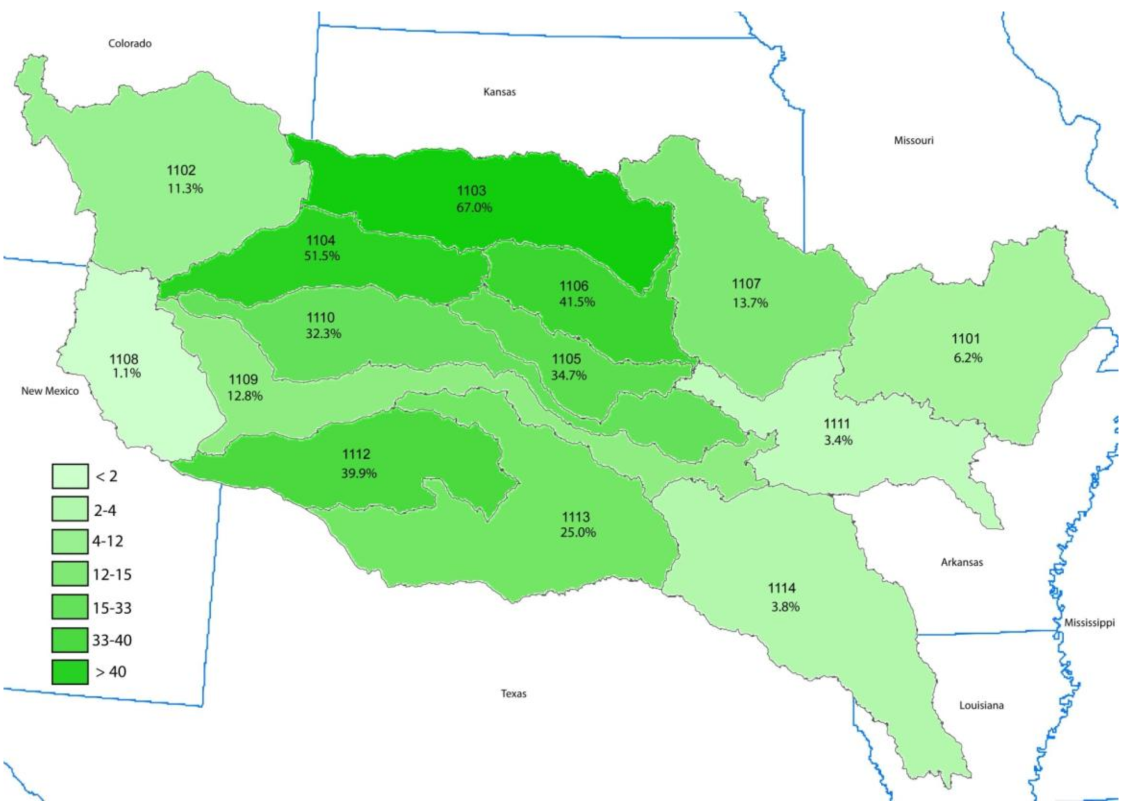
* AFOs, as defined here, typically have a total of more than 12 animal units consisting of fattened cattle, dairy cows, hogs and pigs, chickens, ducks, and turkeys.

Table 4. Cultivated cropland use in the 14 subregions in the Arkansas-White-Red Basin*

Subregion	Total area (acres)	Cultivated cropland (acres)*	Percent cultivated cropland in subregion	Percent of cultivated cropland in Arkansas-White-Red Basin	Percent of cultivated cropland acres in long-term conserving cover
Upper White River Basin (code 1101)	14,301,685	882,586	6.2	2.5	7.5
Upper Arkansas River Basin (code 1102)	15,962,027	1,802,116	11.3	5.1	36.8
Middle Arkansas River Basin (code 1103)	13,087,630	8,772,889	67.0	24.8	12.1
Upper Cimarron River Basin (code 1104)	7,743,902	3,986,576	51.5	11.3	22.3
Lower Cimarron River Basin (code 1105)	4,519,282	1,566,785	34.7	4.4	5.3
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	6,296,099	2,615,440	41.5	7.4	5.2
Neosho-Verdigris River Basin (code 1107)	13,306,203	1,828,068	13.7	5.2	7.9
Upper Canadian River Basin (code 1108)	8,076,215	87,480	1.1	0.2	31.5
Lower Canadian River Basin (code 1109)	10,886,084	1,389,240	12.8	3.9	16.5
North Canadian including Beaver River Basin (code 1110)	11,334,417	3,665,400	32.3	10.4	25.6
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	10,130,681	339,530	3.4	1.0	8.9
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	9,452,407	3,770,088	39.9	10.7	29.5
Red-Washita-Pease-Lake Texoma Basin (code 1113)	15,876,724	3,961,403	25.0	11.2	14.0
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	17,702,816	675,053	3.8	1.9	10.8
Total	158,676,173	35,342,653	22.3	100.0	17.0

Source: 2001 National Land Cover Database for the Conterminous United States (Homer et al. 2007) and the 1997 National Resources Inventory (USDA/NRCS 2002).
* Acres of cultivated cropland include land in long-term conserving cover. Estimates of cultivated cropland were obtained from HUMUS databases on land use, differing slightly from acreage estimates obtained with the NRI-CEAP sample.

Figure 2. Percent cultivated cropland, including land in long-term conserving cover, for the 14 subregions in the Arkansas-White-Red Basin



Chapter 2
Overview of Sampling and Modeling Approach

Scope of Study

This study was designed to evaluate the effects of conservation practices at the regional scale to provide a better understanding of how conservation practices are benefiting the environment and to determine what challenges remain. The report does the following.

- Evaluates the extent of conservation practice use in the region in 2003–06;
- Estimates the environmental benefits and effects of conservation practices in use;
- Estimates conservation treatment needs for the region; and
- Estimates potential gains that could be attained with additional conservation treatment.

The study was designed to quantify the effects of commonly used conservation practices on cultivated cropland, regardless of how or why the practices came to be in use. This assessment is not an evaluation of Federal conservation programs, because it is not restricted to only those practices associated with Federal conservation programs.

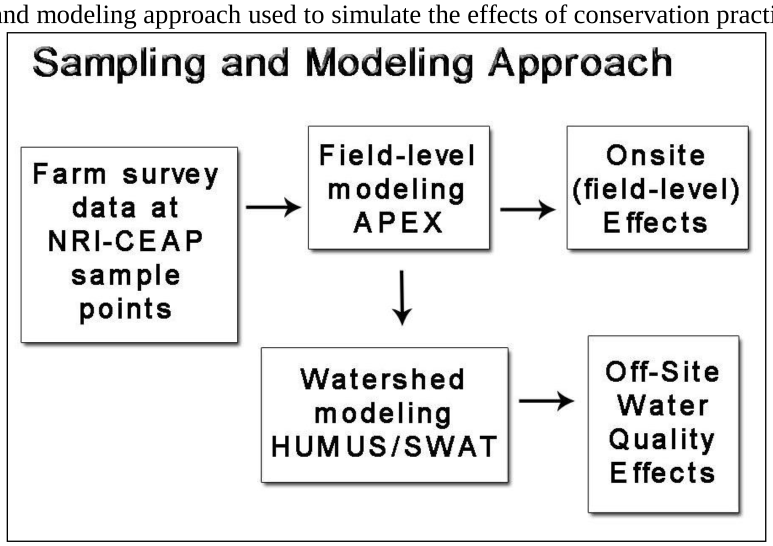
For purposes of this report, cultivated cropland includes land in row crops or close-grown crops (such as wheat and other small grain crops), hay and pasture in rotation with row crops and close-grown crops, and land in long-term conserving cover. Cultivated cropland does not include agricultural land that has been in hay, pasture, or horticulture for 4 or more consecutive years. Acres enrolled in the General Signup of the Conservation Reserve Program (CRP) were used to represent cultivated cropland currently in long-term conserving cover.

Sampling and Modeling Approach

The assessment uses a statistical sampling and modeling approach to estimate the environmental effects and benefits of conservation practices (fig. 3).

- A subset of 1,280 National Resources Inventory (NRI) sample points provides a statistical sample that represents the diversity of soils and other conditions for cropped acres in the Arkansas-White-Red Basin. The sample also includes 1,871 additional NRI sample points designated as CRP acres to represent 6 million acres of land in long-term conserving cover. NRI sample points are linked to NRCS Soil Survey databases and were linked spatially to climate databases for this study.
- A farmer survey—the NRI-CEAP Cropland Survey—was conducted at each of the 1,280 cropped sample points during the period 2003–06 to determine what conservation practices were in use and to collect information on farming practices.
- The field-level effects of the conservation practices were assessed using a field-scale physical process model—the Agricultural Policy Environmental Extender (APEX)—which simulates the day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of soil, nutrients, and pesticides.
- A watershed model and system of databases—the Hydrologic Unit Model for the United States (HUMUS)—was used to simulate how reductions of field losses have reduced instream concentrations and loadings of sediment, nutrients, and pesticides within the Arkansas-White-Red Basin. The SWAT model (Soil and Water Assessment Tool) was used to simulate nonpoint source loadings from land uses other than cropland and to route instream loads from one watershed to another.

Figure 3. Statistical sampling and modeling approach used to simulate the effects of conservation practices



The modeling strategy for estimating the effects of conservation practices consists of two model scenarios that are produced for each sample point.

1. A baseline scenario, the "baseline conservation condition" scenario, provides model simulations that account for cropping patterns, farming activities, and conservation practices as reported in the NRI-CEAP Cropland Survey and other sources.
2. An alternative scenario, the "no-practice" scenario, simulates model results as if no conservation practices were in use but holds all other model inputs and parameters the same as in the baseline conservation condition scenario.

The effects of conservation practices are obtained by taking the difference in model results between the two scenarios (fig. 4)[1] For example, to simulate "no practices" for sample points where some type of residue management is used, model simulations were conducted as if continuous conventional tillage had been used. Similarly, for sample points with structural conservation practices (buffers, terraces, grassed waterways, etc.), the no-practice scenario was simulated as if the practices were not present. The no-practice representation for land in long-term conserving cover was derived from model results for cropped acres as simulated in the no-practice scenario, representing how the land would have been managed had crops been grown without the use of conservation practices.

The approach captures the diversity of land use, soils, climate, and topography from the NRI; accounts for site-specific farming activities; estimates the loss of materials at the field scale where the science is most developed; and provides a statistical basis for aggregating results to the national and regional levels. Previous studies have used this NRI micro-simulation modeling approach to estimate soil loss, nutrient loss, and change in soil organic carbon (Potter et al. 2006), to estimate pesticide loss from cropland (Kellogg et al. 1992, 1994, 2002; Goss et al. 1998), and to identify priority watersheds for water quality protection from nonpoint sources related to agriculture (Kellogg 2000, Kellogg et al. 1997, Goebel and Kellogg 2002).

The NRI and the CEAP Sample

The approach is an extension of the NRI, a longitudinal, scientifically based survey designed to gauge natural resource status, conditions, and trends on the Nation's non-Federal land (Goebel 1998; USDA/NRCS 2002).

The NRI sampling design implemented in 1982 provided a stratified, two-stage, unequal probability area sample of the entire country (Goebel and Baker 1987; Nusser and Goebel 1997). Nominally square areas/segments were selected within geographical strata on a county-by-county basis; specific point locations were selected within each selected segment. The segments ranged in size from 40 to 640 acres but were typically half-mile square areas, and most segments contained three sample points.

At each sample point, information is collected on nearly 200 attributes; some items are also collected for the entire segment. The sampling rates for the segments were variable, typically from 2 to 6 percent in agricultural strata and much lower in remote nonagricultural areas. The 1997 NRI Foundation Sample contained about 300,000 sample segments and about 800,000 sample points.

Figure 4. Modeling strategy used to assess effects of conservation practices

[1] This modeling strategy is analogous to how the NRI produces estimates of soil erosion and the intrinsic erosion rate used to identify highly erodible land. The NRI uses the Universal Soil Loss Equation (USLE) to estimate sheet and rill erosion at each sample point on the basis of site-specific factors. Soil loss per unit area is equal to R*K*L*S*C*P. The first four factors—R, K, L, S—represent the conditions of climate, soil, and topography existing at a site. (USDA 1989). The last two factors—C and P—represent the degree to which management influences the erosion rate. The product of the first four factors is sometimes called the intrinsic, or potential, erosion rate. The intrinsic erosion rate divided by T, the soil loss tolerance factor, produces estimates of EI, the erodibility index. The intrinsic erosion rate is thus a representation of a "no-practice" scenario where C=1 represents smooth-tilled continuous fallow and P=1 represents no supporting practices.

NRCS made several significant changes to the NRI program over the past 10 years, including transitioning from a 5-year periodic survey to an annual survey. The NRI's annual design is a *supplemented panel design.* [2] A *core panel* of 41,000 segments is sampled each year, and *rotation (supplemental) panels* of 31,000 segments each vary by inventory year and allow an inventory to focus on an emerging issue. The core panel and the various supplemental panels are unequal probability subsamples from the 1997 NRI Foundation Sample.

The CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA/NRCS 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample.[3] The sample is statistically representative of cultivated cropland and formerly cultivated land currently in long-term conserving cover.

Nationally, there were over 30,000 samples in the original sample draw. A completed farmer survey was required to include the sample point in the CEAP sample. Some farmers declined to participate in the survey, others could not be located during the time period scheduled for implementing the survey, and other sample points were excluded for administrative reasons such as overlap with other USDA surveys. Some sample points were excluded because the surveys were incomplete or contained inconsistent information, land use found at the sample point had recently changed and was no longer cultivated cropland, or the crops grown were uncommon and model parameters for crop growth were not available. The national NRI-CEAP usable sample consists of about 18,700 NRI points representing cropped acres, and about 13,000 NRI points representing land enrolled in the General Signup of the CRP.

The NRI-CEAP Cropland Survey

A farmer survey—the NRI-CEAP Cropland Survey—was conducted to obtain the additional information needed for modeling the 1,280 sample points with crops.[4] The USDA National Agricultural Statistics Service (NASS) administered the survey. Farmer participation was voluntary, and the information gathered is confidential. The survey content was specifically designed to provide information on farming activities for use with a physical process model to estimate field-level effects of conservation practices.

The survey obtained information on—

- crops grown for the previous 3 years, including double crops and cover crops;
- field characteristics, such as proximity to a water body or wetland and presence of tile or surface drainage systems;
- conservation practices associated with the field;
- crop rotation plan;
- application of commercial fertilizers (rate, timing, method, and form) for crops grown the previous 3 years;
- application of manure (source and type, consistency, application rate, method, and timing) on the field over the previous 3 years;
- application of pesticides (chemical, rate, timing, and method) for the previous 3 years;
- pest management practices;
- irrigation practices (system type, amount, and frequency);
- timing and equipment used for all field operations (tillage, planting, cultivation, harvesting) over the previous 3 years, and;
- general characteristics of the operator and the operation.

In a separate data collection effort, NRCS field offices provided information on the practices specified in conservation plans for the CEAP sample points.

Because of the large size of the sample, it was necessary to spread the data collection process over a 4-year period, from 2003 through 2006. In each year, surveys were obtained for a separate set of sample points. The final CEAP sample was constructed by pooling the set of usable, completed surveys from all 4 years.

Simulating the Effects of Weather

Weather is the predominant factor determining the loss of soil, nitrogen, phosphorus, and pesticides from farm fields, and has a big influence on the effectiveness of conservation practices. To capture the effects of weather, each scenario was simulated using 47 years of actual daily weather data for the time period 1960 through 2006. The 47-year record is a serially complete daily data set of weather station data from weather station records available from the NCDC (National Climatic Data Center) for the period 1960 to 2006, including precipitation, temperature maximum, and temperature minimum (Eischeid et al. 2000). These data were combined with the respective PRISM (Parameter–Elevation Regressions on Independent Slopes Model; Daly et al. 1994) monthly map estimates to construct daily estimates of precipitation and temperature (Di Luzio et al. 2008). The same 47-year weather data were used in the HUMUS/SWAT simulations and in the APEX model simulations.

Annual precipitation over the 47-year simulation averaged about 27 inches for cropped acres in this region. However, annual precipitation varied substantially in the model simulations, both within the region and from year to year, as shown in figure 5. Each curve in figure 5 shows how annual precipitation varied over the region in one of the 47 years. The family of curves shows the variability from year to year. In general, annual precipitation ranges from lows of 10–15 inches per year to highs of 45–60 inches per year. The top curve shown is for the year 1973, the wettest year in this region during the 47 years. The curve for 1973 shows that precipitation exceeded the long-term annual average of 27 inches for 70 percent of the cropped acres in the Arkansas-White-Red Basin. The bottom curves are drought years for most of the region—1963, 1966, and 1970—when 90 percent

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[2] For more information on the NRI sample design, see www.nrcs.usda.gov/technical/NRI/.

[3] Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap.

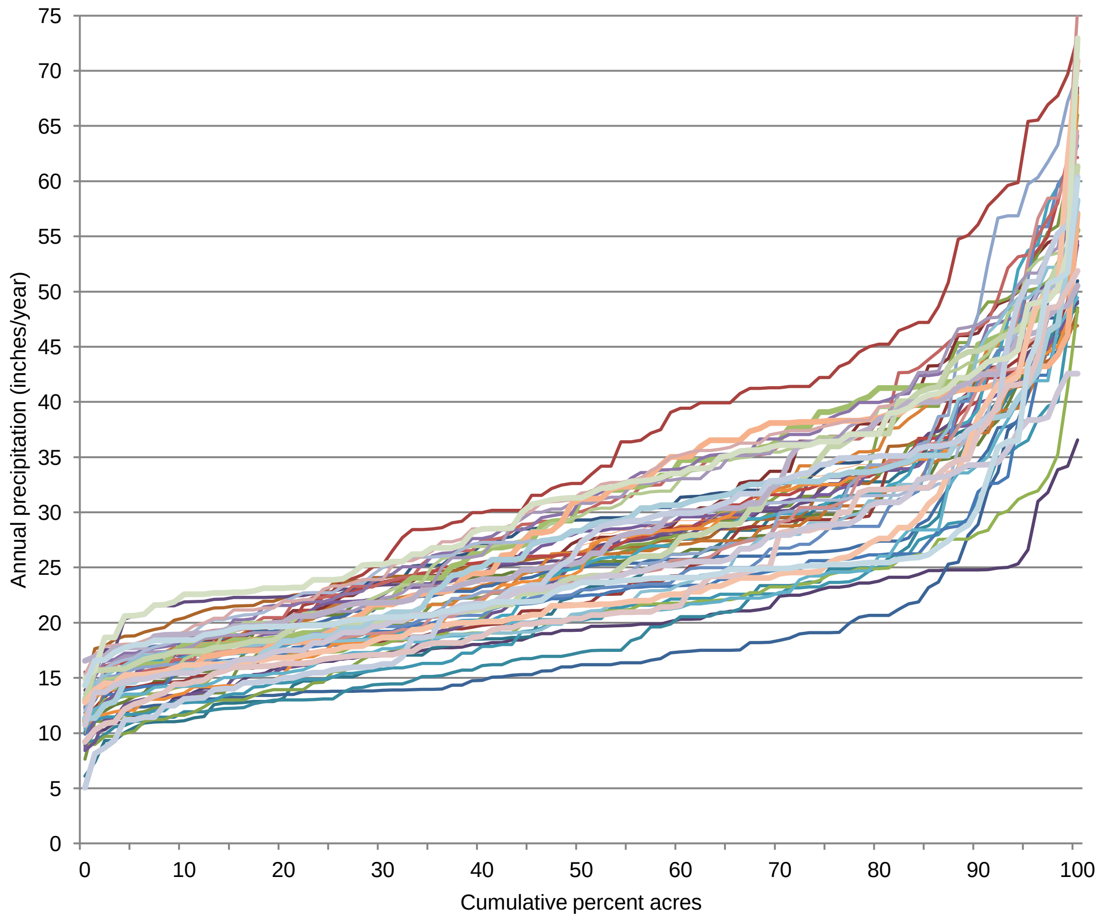
[4] The surveys, the enumerator instructions, and other documentation can be found at www.nrcs.usda.gov/technical/nri/ceap.

or more of the cropped acres had less precipitation than the long-term annual average.

The western portion of the basin gets less precipitation than the eastern portion. To show this, the region was split into two parts, as shown in figure 6, and annual precipitation contrasted in figures 7 and 8. Annual precipitation over the 47-year simulation averaged about 35 inches for cropped acres in the eastern portion and about 21 inches for cropped acres in the western portion. Year-to-year variability was also more pronounced in the eastern portion.

Throughout most of this report model results are presented in terms of the 47-year averages where weather is the only input variable that changes year to year. Since we used the cropping patterns and practices for the 2003–06 period, we did not simulate *actual* loses for each of these years. Rather, we provide estimates of what model outputs would *average* over the long-term if weather varied as it has over the past 47 years. Similarly, estimates of the average effects of conservation practices include effectiveness in extreme weather years, such as floods and prolonged droughts, as represented in the 47-year weather record shown in figures 5, 7, and 8.

Figure 5. Cumulative distributions of annual precipitation used in the model simulations for cropped acres in the Arkansas-White-Red Basin



Note:. Each of the 47 curves shown above represents a single year of data and shows how annual precipitation varies over the region in that year, starting with the acres with the lowest precipitation within the region and increasing to the acres with the highest precipitation. The family of curves shows how annual precipitation varies from year to year. Annual precipitation over the 47-year simulation averaged about 27 inches for cropped acres throughout the region.

Figure 6. Split between the eastern portion (green) and the western portion (brown) for the Arkansas-White-Red Basin

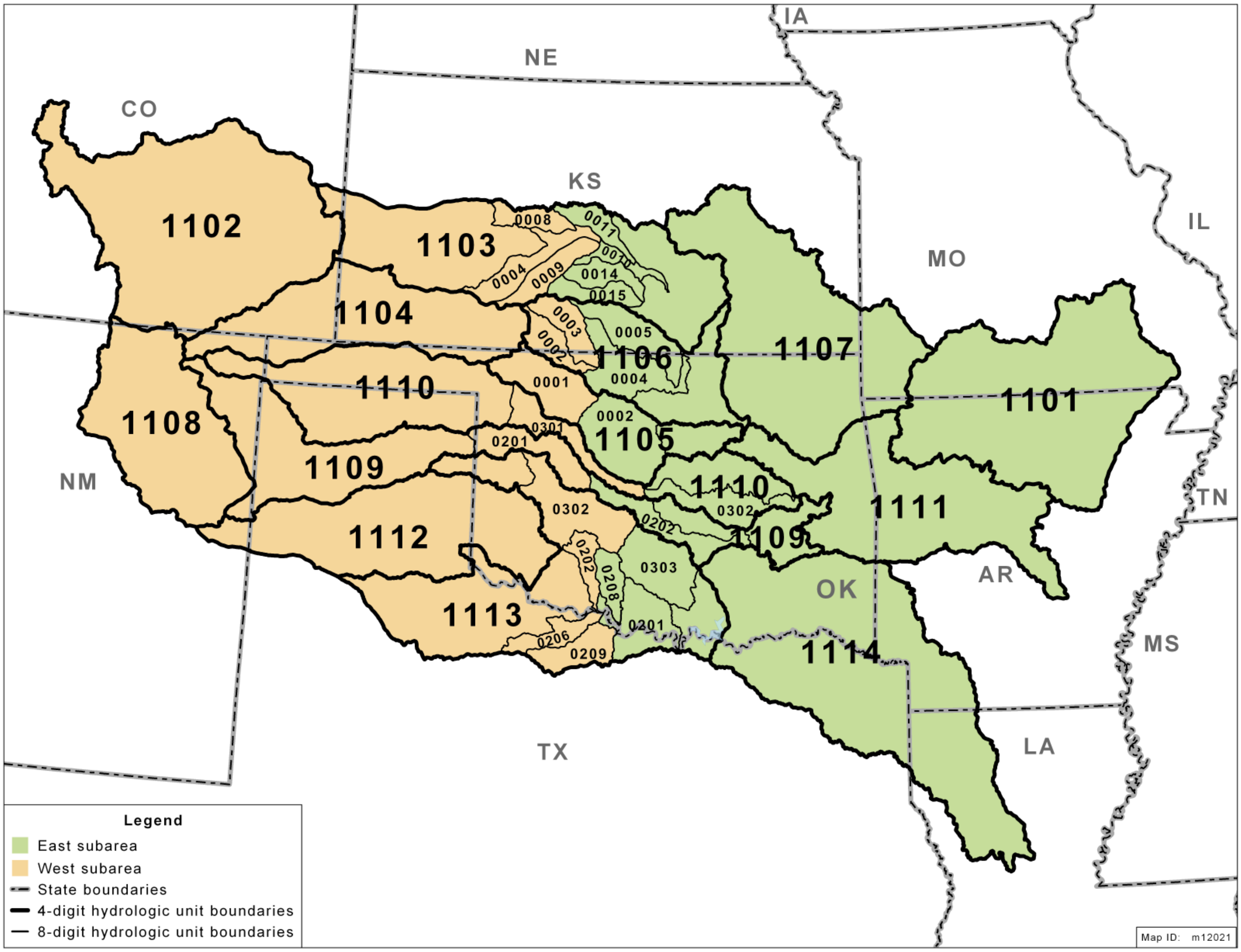


Figure 7. Mean, minimum, and maximum levels of annual precipitation used in the model simulations for cropped acres in the ***eastern portion*** of the Arkansas-White-Red Basin

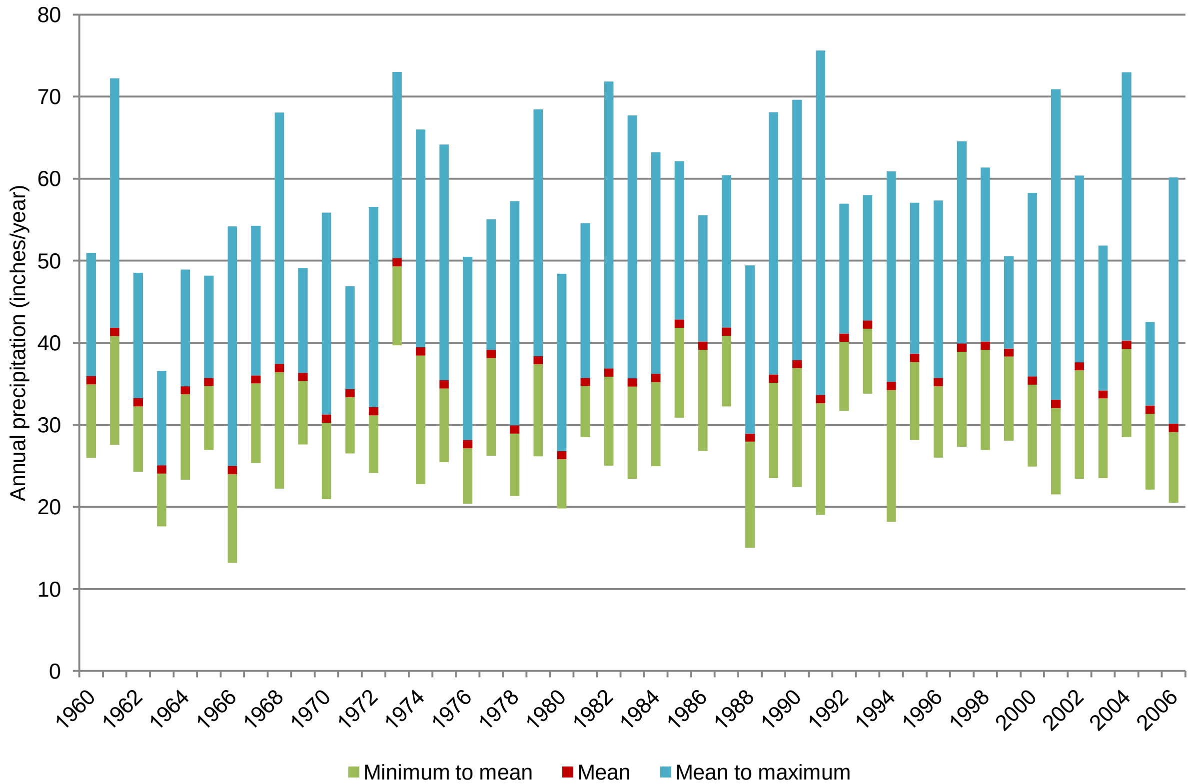
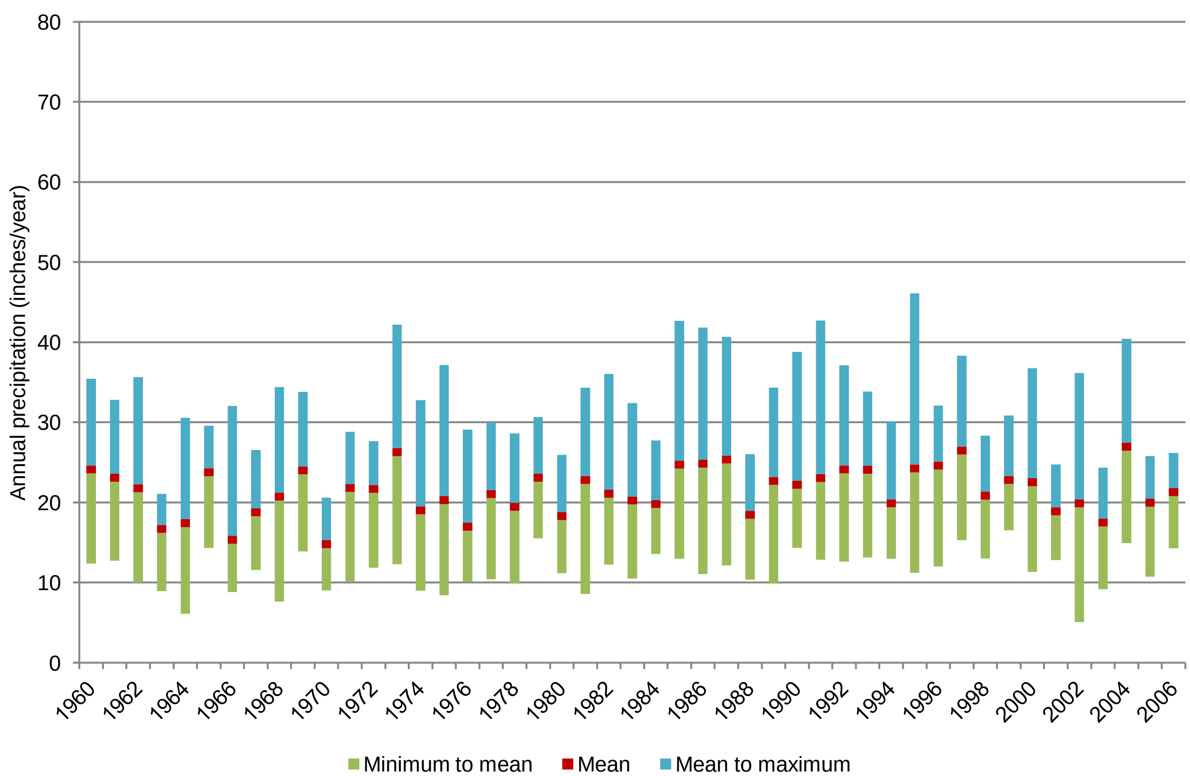


Figure 8. Mean, minimum, and maximum levels of annual precipitation used in the model simulations for cropped acres in the ***western portion*** of the Arkansas-White-Red Basin



Estimated Acres

Acres reported using the CEAP sample are “estimates” of cropped acres because of the uncertainty associated with the statistical sample. For example, the 95-percent confidence interval for the estimate of 30,476,700 cropped acres in the region has a lower bound of 29,301,000 acres and an upper bound of 31,652,400 acres. (The lower bound is the estimate minus the margin of error and the upper bound is the estimate plus the margin of error.)

(Since the CEAP sample frame only included cropped acres, the estimate does not include land in long-term conserving cover. Acres in long-term conserving cover are estimated using the full NRI sample frame for the year 2003, which also has uncertainty associated with the statistical sample.)

The CEAP sample was designed to allow reporting of results at the subregion (4-digit HUC) level in most cases. The acreage weights were derived so as to approximate total cropped acres by subregion as estimated by the full 2003 NRI.

The sample size is too small, in most cases, for reliable and defensible reporting of results for areas below the subregion level. In the Arkansas-White-Red Basin, the sample size for the Upper Canadian River Basin (code 1108) was too small to reliably report cropped acres. This subregion was combined with the Lower Canadian River Basin (code 1109) for reporting.

NRI-CEAP estimates of cropped acres for the 14 subregions within the Arkansas-White-Red Basin are presented in table 5 along with the 95-percent confidence intervals. These estimates of cropped acres differ from cultivated cropland estimates presented in tables 1 and 4 primarily because those tables also include 6 million acres of land in long-term conserving cover but also because of differences in data sources and estimation procedures. Margins of error for a selection of other estimated cropped acres used in this report are presented in appendix A.

Table 5. Estimated cropped acres based on the NRI-CEAP sample for subregions in the Arkansas-White-Red Basin

Subregion	Number of CEAP samples	Estimated acres (acres)	95-percent confidence interval: Lower bound (acres)	95-percent confidence interval: Upper bound (acres)
Eastern portion of the region				
Upper White River Basin (code 1101)	46	916,800	648,561	1,185,039
Middle Arkansas River Basin, eastern portion (codes 11030010 through 11030018)	118	3,377,854	2,815,193	3,940,515
Lower Cimarron River Basin, eastern portion (codes 11050002 and 11050003)	44	1,107,601	743,232	1,471,970
Arkansas River-Keystone including Salt Fork River Basin, eastern portion (excludes codes 11060002 and 11060003)	68	2,066,108	1,771,912	2,360,304
Neosho-Verdigris River Basin (code 1107)	122	2,080,200	1,811,441	2,348,959
Lower Canadian River Basin, including only the 8-digit watershed 11090202, and North Canadian and Beaver River Basin, including only the 8-digit watersheds 11100302 and 11100303	8	134,316	19,145	249,487
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	16	471,800	281,595	662,005
Red-Washita-Pease-Lake Texoma Basin, eastern portion (codes 11130201, 11130208, 11130210, and 11130303)	11	209,844	62,718	356,970
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	29	852,100	616,566	1,087,634
Subtotal	462	11,216,624	10,230,315	12,202,933
Western portion of the region				
Upper Arkansas River Basin (code 1102)	38	1,024,800	639,964	1,409,636
Middle Arkansas River Basin, western portion (codes 11030001 through 11030009)	140	4,530,646	3,949,504	5,111,788
Upper Cimarron River Basin (code 1104)	120	2,862,500	2,252,205	3,472,795
Lower Cimarron River Basin, western portion (code 11050001)	27	398,899	216,819	580,979
Arkansas River-Keystone including Salt Fork River Basin, eastern portion (codes 11060002 and 11060003)	17	387,492	196,103	578,881
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109), excluding the 8-digit watershed 11090202	57	1,204,975	896,235	1,513,715
North Canadian including Beaver River Basin (code 1110), excluding the 8-digit watersheds 11100302 and 11100303	139	3,045,809	2,588,610	3,503,008
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	135	2,714,600	2,405,284	3,023,916
Red-Washita-Pease-Lake Texoma Basin, western portion (codes 111301, 11130202 through 11130207, 11130209, 11130301, and 11130302)	145	3,090,356	2,642,090	3,538,622
Subtotal	818	19,260,076	18,075,570	20,444,582
Total	1,280	30,476,700	29,301,000	31,652,400

Note: Estimates are from the NRI-CEAP Cropland Survey. Subregions 1108 and 1109 are combined for reporting. Subregions 1109 and 1110 are combined for reporting in the eastern portion of the region.

Cropping Systems in the Arkansas-White-Red Basin

Cropping systems were defined on the basis of the crops grown at CEAP sample points over the 3 years that information was obtained on farming activities at each sample point. Statistical sample weights for each sample point were derived from the NRI crop history at each sample point so as to approximate acres reported in the 2003 NRI for similar cropping systems at the 4-digit HUC level. (Cropping system acres were only one of several factors taken into account in deriving the acreage weights for each sample point.)

The dominant cropping systems are the same in both the eastern portion and the western portion of the region—wheat only and sorghum with or without wheat (table 6). Half of the cropped acres in the region are wheat only (43 percent in the eastern portion and 54 percent in the western portion). Thirteen percent of the cropped acres in the region are sorghum with or without wheat (9 percent in the eastern portion and 15 percent in the western portion). These two cropping systems make up nearly two-thirds of the cropped acres in this region.

Other cropping systems important in parts of the eastern portion of the region include soybeans in rotation with wheat or sorghum, corn-soybean rotations, and rotations that include rice.

Other cropping systems important in parts of the western portion of the region include corn only or corn in rotation with close grown crops, which together represent 10 percent of the cropped acres in the western portion of the region, and cotton.

Table 6. Estimated crop acres for cropping systems in the Arkansas-White-Red Basin

	Eastern portion of region		**Western portion of region**		**Entire region**	
	Estimated acres (1,000 acres)	Percent of total	Estimated acres (1,000 acres)	Percent of total	Estimated acres (1,000 acres)	Percent of total
Wheat only	4,793	43	10,396	54	15,188	50
Sorghum-wheat and sorghum only	1,051	9	2,945	15	3,996	13
Hay-crop mix	502	4	1,140	6	1,642	5
Corn and close grown crops	435	4	1,177	6	1,612	5
Soybean with or without wheat	1,343	12	162	1	1,506	5
Corn-soybean with or without close grown crops	883	8	288	1	1,171	4
Corn only	108	1	839	4	947	3
Soybean and sorghum with or without other crops	698	6	46	<1	745	2
Rice with other crops	656	6	0	<1	656	2
Cotton only	10	<1	523	3	533	2
Remaining mix of row crops	143	1	418	2	561	2
Remaining mix of close-grown crops	102	1	84	<10	186	1
Remaining mix of row and close-grown crops	491	4	1,243	6	1,734	6
Total	11,217	100	19,260	100	30,477	100

Chapter 3
Evaluation of Conservation Practice Use—the Baseline Conservation Condition

This study assesses the use and effectiveness of conservation practices in the Arkansas-White-Red Basin for the period 2003 to 2006 to determine the baseline conservation condition for the region. The baseline conservation condition provides a benchmark for estimating the effects of existing conservation practices as well as projecting the likely effects of alternative conservation treatment. Conservation practices that were evaluated include structural practices, annual practices, and long-term conserving cover.

Structural conservation practices, once implemented, are usually kept in place for several years. Designed primarily for erosion control, they also mitigate edge-of-field nutrient and pesticide loss. Structural practices evaluated include—

- in-field practices for water erosion control, divided into two groups:
  - practices that control overland flow (terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping), and
  - practices that control concentrated flow (grassed waterways, grade stabilization structures, diversions, and other structures for water control);
- edge-of-field practices for buffering and filtering surface runoff before it leaves the field (riparian forest buffers, riparian herbaceous cover, filter strips, field borders); and
- wind erosion control practices (windbreaks/shelterbelts, cross wind trap strips, herbaceous wind barriers, hedgerow planting).

*Annual conservation practic*es are management practices conducted as part of the crop production system each year. These practices are designed primarily to promote soil quality, reduce in-field erosion, and reduce the availability of sediment, nutrients, and pesticides for transport by wind or water. They include—

- residue and tillage management;
- nutrient management practices;
- pesticide management practices; and
- cover crops.

Long-term conservation cover establishment consists of planting suitable native or domestic grasses, forbs, or trees on environmentally sensitive cultivated cropland.

Historical Context for Conservation Practice Use

The Arkansas-White-Red Basin encompasses much of the Shortgrass Plains, a windswept region with a semiarid climate. In the early 1900's homesteading was prevalent, increased global demand for American wheat and beef was elevating prices, and improved agricultural mechanization enabled extensive sodbusting of the Plains. Then, an unfortunate confluence of the Great Depression, falling global demand for U.S. agricultural goods, and prolonged drought left large areas of the Arkansas-White-Red Basin vulnerable to erosion. The Oklahoma panhandle was the epicenter of the Dust Bowl, with significant erosion in most of the western portion of the Basin.

The use of conservation practices in the Arkansas-White-Red Basin closely reflects the history of Federal conservation programs and technical assistance. In the beginning the focus was almost entirely on reducing soil erosion and preserving the soil's productive capacity. In the 1930s and 1940s, Hugh Hammond Bennett, the founder and first chief of the Soil Conservation Service (now Natural Resources Conservation Service) instilled in the national ethic the need to treat every acre to its potential by controlling soil erosion and water runoff. Land shaping structural practices (such as terraces, contour farming, and stripcropping) and sediment control structures were widely adopted.

Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. Conservation tillage, along with use of crop rotations and cover crops, was used either alone or in combination with structural practices. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres, tying farm commodity payments to conservation treatment of highly erodible land. The Conservation Reserve Program was established to enroll the most erodible cropland acres in multi-year contracts to plant acres in long-term conserving cover.

During the 1990s, the focus of conservation efforts began to shift from soil conservation and sustainability to reducing pollution impacts associated with agricultural production. Prominent among new concerns were the environmental effects of nutrient export from farm fields. Traditional conservation practices used to control surface water runoff and erosion control were mitigating a significant portion of these nutrient losses. Additional gains were being achieved using nutrient management practices—application of nutrients (appropriate timing, rate, method, and form) to minimize losses to the environment and maximize the availability of nutrients for crop growth.

Summary of Practice Use

Given the long history of conservation in the Arkansas-White-Red Basin, it is not surprising to find that nearly all cropped acres in the region have evidence of some kind of conservation practice, especially erosion control practices. The conservation practice information collected during the study was used to assess the extent of conservation practice use. Key findings are the following.

- Structural practices for controlling water erosion are in use on 46 percent of cropped acres, distributed equally among highly erodible and non-highly erodible acres. Structural practice use is more prevalent in the eastern portion of the basin, where 59 percent of cropped acres, including 66 percent of highly erodible land, have one or more structural conservation practice in use.

- Fifty-eight percent of the cropped acres meet criteria for either no-till (14 percent) or mulch till (44 percent). Two-thirds of cropped acres had evidence of some kind of reduced tillage on at least one crop.
- About 31 percent of cropped acres are gaining soil organic carbon, including 29 percent of cropped acres in the eastern portion of the region and 32 percent in the western portion.
- Producers use either residue and tillage management practices or structural practices, or both, on 87 percent of the acres.
- Nutrient management practices are widely used on cropped acres in the Arkansas-White-Red Basin.
  - 78 percent of cropped acres meet criteria for timing of nitrogen applications on all crops and 65 percent of cropped acres meet criteria for timing of phosphorus applications on all crops.
  - 62 percent of cropped acres meet criteria for method of nitrogen application on all crops and 59 percent meet criteria for method of phosphorus application on all crops.
  - 59 percent of cropped acres meet criteria for nitrogen application rate on all crops and 40 percent meet criteria for phosphorus application rates for the full crop rotation.
- Although most cropped acres meet nutrient management criteria for rate, timing, or method, fewer acres meet criteria for all three:
  - 33 percent of cropped acres meet all criteria for nitrogen applications, including acres with no nitrogen applied,
  - 29 percent of cropped acres meet all criteria for phosphorus applications, including acres with no phosphorus applied, and
  - 25 percent of cropped acres meet criteria for *both* phosphorus and nitrogen.
- During the 2003–06 period of data collection cover crops were used on less than 1 percent of the acres in the region.
- An Integrated Pest Management (IPM) indicator showed that only about 5 percent of the acres were being managed at a relatively high level of IPM.
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of about 6 million acres in the region, of which 49 percent is highly erodible land.

Structural Conservation Practices

Data on structural practices for the farm field associated with each sample point were obtained from four sources:

1. **The NRI-CEAP Cropland Survey** included questions about the presence of 12 types of structural practices: terraces, grassed waterways, vegetative buffers (in-field), hedgerow plantings, riparian forest buffers, riparian herbaceous buffers, windbreaks or herbaceous wind barriers, contour buffers (in-field), field borders, filter strips, critical area planting, and grade stabilization structures.
2. For fields with conservation plans, **NRCS field offices** provided data on all structural practices included in the plans.
3. **The USDA Farm Service Agency** (FSA) provided practice information for fields that were enrolled in the Continuous CRP for these structural practices: contour grass strips, filter strips, grassed waterways, riparian buffers (trees), and field windbreaks (Alex Barbarika, USDA/FSA, personal communication).
4. **The 2003 NRI** provided additional information for practices that could be reliably identified from aerial photography as part of the NRI data collection process. These practices include contour buffer strips, contour farming, contour stripcropping, field stripcropping, terraces, cross wind stripcropping, cross wind trap strips, diversions, field borders, filter strips, grassed waterways or outlets, hedgerow planting, herbaceous wind barriers, riparian forest buffers, and windbreak or shelterbelt establishment.

Overland flow control practices are designed to slow the movement of water across the soil surface to reduce surface water runoff and sheet and rill erosion. NRCS practice standards for overland flow control include terraces, contour farming, stripcropping, in-field vegetative barriers, and field borders. These practices are found on about 42 percent of the cropped acres in the region. Highly erodible acres have a slightly higher percentage with these practices in use—45 percent (table 7). Overland flow control practices are more prevalent in the eastern portion of the region, where 54 percent of cropped acres have these practices in use, compared to 36 percent in the western portion.

Concentrated flow control practices are designed to prevent the development of gullies along flow paths within the field. NRCS practice standards for concentrated flow control practices include grassed waterways, grade stabilization structures, diversions, and water and sediment control basins. About 23 percent of the cropped acres have one or more of these practices, including 35 percent in the eastern portion of the region and 15 percent in the western portion (table 7).

Edge-of-field buffering and filtering practices, consisting of grasses, shrubs, and/or trees, are designed to capture the surface runoff losses that were not avoided or mitigated by the in-field practices. NRCS practice standards for edge-of-field mitigation practices include edge-of-field filter strips, riparian herbaceous buffers, and riparian forest buffers. CRP's buffer practices are included in this category. Edge-of-field buffering and filtering practices are in use on only about 2 percent of all cropped acres in the region (table 7), with more use in the eastern portion of the basin than in the western portion.

Overall, about 46 percent of the cropped acres in the Arkansas-White-Red Basin are treated with one or more of these water erosion control structural practices, distributed about equally among highly erodible and non-highly erodible acres. Water erosion control structural practices are in use on 59 percent of cropped acres in the eastern portion, including

66 percent of HEL acres. In the western portion, 39 percent of cropped acres are treated with one or more of these practices.

About 54 percent of the acres in this region do not have structural practices for water erosion control. Many of these acres may not need structural practices. Of the acres without structural practices, about 91 percent have slopes less than 2 percent. Overall, about 85 percent of cropped acres in the region have slopes less than 2 percent, with about the same proportion in both the eastern and western portions.

To evaluate the overall use of structural practices for water erosion control, practice use was classified as high, moderately high, moderate, or low for each sample point according to criteria presented in figure 9. About 1 in 5 of cropped acres in the region has a high or moderately high level of treatment within the region. This percentage is 33.2 percent in the eastern portion compared to 13.4 percent in the western portion.

These structural practice treatment levels were combined with use of residue and tillage management practices to estimate conservation treatment levels for water erosion control in chapter 5, where criteria for points with slopes less than 2 percent did not include structural practice use.

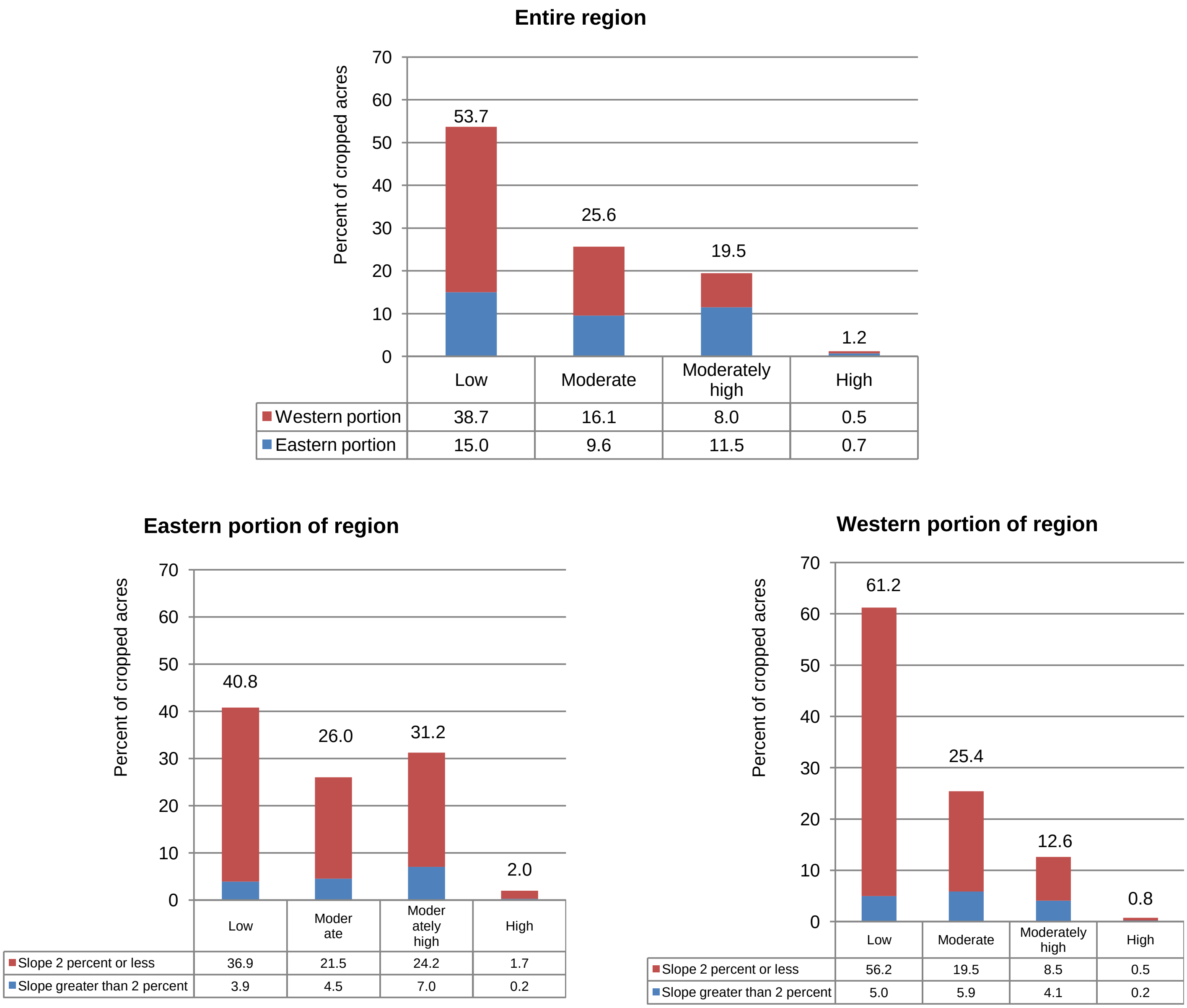
Wind erosion control practices are designed to reduce the force of the wind on the field. NRCS structural practices for wind erosion control include cross wind ridges, cross wind trap strips, herbaceous wind barriers, and windbreak or shelterbelt establishment. Wind erosion is a significant resource concern for this region. About 7 percent of the cropped acres in the region are treated for wind erosion using structural practices (table 7).

Table 7. Structural conservation practices in use for cropped acres, baseline conservation condition, Arkansas-White-Red Basin

Structural conservation practice in use	Eastern portion	Western portion	Entire region
	Percent of non-HEL cropped acres		
Overland flow control practices:Terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, in-field vegetative barriers	51	35	41
Concentrated flow control practices: Grassed waterways, grade stabilization structures, diversions, other structures for water control	34	17	24
Edge-of-field buffering and filtering practices: Riparian forest buffers, riparian herbaceous buffers, filter strips	3	1	2
Overland flow, concentrated flow, or edge-of-field practice	57	39	46
Wind erosion control practices: Windbreaks/shelterbelts, cross wind trap strips, herbaceous windbreak, hedgerow planting	11	3	6
	Percent of HEL cropped acres		
Overland flow control practices:Terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, in-field vegetative barriers	61	38	45
Concentrated flow control practices: Grassed waterways, grade stabilization structures, diversions, other structures for water control	39	12	20
Edge-of-field buffering and filtering practices: Riparian forest buffers, riparian herbaceous buffers, filter strips	3	1	1
Overland flow, concentrated flow, or edge-of-field practice	66	39	47
Wind erosion control practices: Windbreaks/shelterbelts, cross wind trap strips, herbaceous windbreak, hedgerow planting	11	6	7
	Percent of all cropped acres		
Overland flow control practices:Terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, in-field vegetative barriers	54	36	42
Concentrated flow control practices: Grassed waterways, grade stabilization structures, diversions, other structures for water control	35	15	23
Edge-of-field buffering and filtering practices: Riparian forest buffers, riparian herbaceous buffers, filter strips	3	1	2
Overland flow, concentrated flow, or edge-of-field practice	59	39	46
Wind erosion control practices: Windbreaks/shelterbelts, cross wind trap strips, herbaceous windbreak, hedgerow planting	11	4	7

Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.
Note: About 32 percent of cropped acres in the Arkansas-White-Red Basin are highly erodible land (HEL), 25 percent in the eastern portion and 36 percent in the western portion. Soils are classified as HEL if they have an erodibility index (EI) score of 8 or higher. A numerical expression of the potential of a soil to erode, EI considers the physical and chemical properties of the soil and climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped.

Figure 9. Percent of cropped acres at four conservation treatment levels for structural practices, baseline conservation condition, Arkansas-White-Red Basin



Entire region

	Low	Moderate	Moderately high	High
Western portion	38.7	16.1	8.0	0.5
Eastern portion	15.0	9.6	11.5	0.7

Eastern portion of region

	Low	Moderate	Moderately high	High
Slope 2 percent or less	36.9	21.5	24.2	1.7
Slope greater than 2 percent	3.9	4.5	7.0	0.2

Western portion of region

	Low	Moderate	Moderately high	High
Slope 2 percent or less	56.2	19.5	8.5	0.5
Slope greater than 2 percent	5.0	5.9	4.1	0.2

Criteria for four levels of treatment with structural conservation practices are:

- **High treatment**: Edge-of-field mitigation *and* at least one in-field structural practice (concentrated flow or overland flow practice) required.
- **Moderately high treatment**: Either edge-of-field mitigation required or both concentrated flow and overland flow practices required.
- **Moderate treatment**: No edge-of-field mitigation, either concentrated flow or overland flow practices required.
- **Low treatment**: No edge-of-field or in-field structural practices.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.
Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.

Residue and Tillage Management Practices

Simulations of the use of residue and tillage management practices were based on the field operations and machinery types reported in the NRI-CEAP Cropland Survey for each sample point. The survey obtained information on the timing, type, and frequency of each tillage implement used during the previous 3 years, including the crop to which the tillage operation applied. Model outcomes affected by tillage practices, such as erosion and runoff, were determined based on APEX processes of the daily tillage activities as reported in the survey.

To evaluate the level of residue and tillage management, the Soil Tillage Intensity Rating (STIR) (USDA/NRCS 2007) was used for tillage intensity and gains or losses in soil organic carbon (based on model simulation results) were used as an indicator of residue management.

STIR values represent the soil disturbance intensity, which was estimated for each crop at each sample point.[5] The soil disturbance intensity is a function of the kinds of tillage, the frequency of tillage, and the depth of tillage. STIR values were calculated for each crop and for each of the 3 years covered by the NRI-CEAP Cropland Survey (accounting for multiple crops or cover crops). STIR values greater than 100 are generally considered conventionally tilled. STIR values less than 30 are considered to be no-till when there is a positive trend with soil organic carbon. By combining the STIR values for each crop year with model output on the long-term trend in soil organic carbon gain or loss, eight categories of residue and tillage management were identified.[6]

Overall, 58 percent of cropped acres in the Arkansas-White-Red Basin meet the tillage intensity rating for either no-till or mulch till (table 8)—about 14 percent for no-till and 44 percent for mulch till. No-till use was about the same in both the eastern and western portions of the basin. Mulch till use, however, was higher in the western portion—51 percent of cropped acres compared to 33 percent in the eastern portion.

About 8 percent of cropped acres did not meet criteria for mulch till or no-till but had reduced tillage on some crops in the rotation (table 8). The use of reduced tillage is about the same in both the eastern and western portions of the region.

Nearly 1 in 3 acres are conventionally tilled in the Arkansas-White-Red Basin, with a higher occurrence in the eastern portion of the region (44 percent of cropped acres) than in the western portion (28 percent) (table 8).

[5] Percent residue cover was not used to evaluate no-till or mulch till because this criterion is not included in the current NRCS practice standard for Residue and Tillage Management. Residue is, however, factored into erosion and runoff estimates in APEX.

[6] STIR values in combination with carbon trends are in line with the use of the Soil Conditioning Index (SCI), which approximates the primary criteria for NRCS residue management standards. The NRCS practice standard, as applied in the field, may include other considerations to meet site specific resource concerns that are not considered in this evaluation.

Use of no-till in this region is lower than in other regions within the Mississippi River drainage area. The percentage of cropped acres that meet the tillage intensity rating for no-till ranges from 28 percent in the Upper Mississippi River Basin to 52 percent in the Ohio-Tennessee River Basin, compared to 14 percent for cropped acres in the Arkansas-White-Red Basin. The lower adoption rates for no till are attributable to two primary differences in this region as compared to the previous reported regions. First is the increase of cotton acres in crop rotations for this region. The average STIR rating for cotton in this region is approximately 140, as compared to corn and soybean average tillage intensities of 81and 55, respectively. The other major driver behind low adoption is soil related. Loamy textured or medium textured soils lend themselves more readily to tillage reductions without adverse production impacts. Coarser textures have a tendency to compact and heavier textured soils tend to encounter seedbed preparation problems. Medium textured soils comprise about 52 percent of the acres in the Arkansas-White-Red Basin. The Upper Mississippi and Missouri basins have about 62 percent and the Ohio-Tennessee River Basin has 77 percent. An additional difference in this basin is the increase in gravity irrigation or furrow irrigation which *requires* additional tillage.

Structural practices and residue and tillage management practices influence losses of sediment, nutrients, and pesticides due to water erosion. Most of the cropped acres (87 percent) in the Arkansas-White-Red Basin have one or both of these types of water erosion control practices (table 9). About 21 percent meet tillage intensity for no-till or mulch till *and* have structural practices. About 38 percent of cropped acres meet tillage criteria without structural practices in use. About 21 percent have structural practices without any kind of residue or tillage management.

To evaluate the use of residue and tillage management practices, practice use was classified as high, moderately high, moderate, or low for each sample point according to criteria presented in figure 10. The high and moderately high treatment levels represent the 22.4 percent of cropped acres that meet tillage intensity criteria for either no-till or mulch till with gains in soil organic carbon.

The high treatment level (18 percent of the acres) includes only those acres where the tillage intensity criteria are met for *each* crop in the rotation. Criteria for the high treatment level were met for 18 percent of cropped acres in both the eastern portion of the basin and the western portion.

The majority of cropped acres—51 percent—have a moderate level of treatment in this region. Most of these acres are losing soil organic carbon. Some are gaining soil organic carbon but tillage intensity exceeds criteria for mulch till (fig. 10).

About 27 percent of the acres have a low treatment level, consisting of continuous conventional tillage for all crops in the rotation and loss of soil organic carbon.

These residue and tillage management treatment levels were combined with the use of structural practices to estimate conservation treatment levels for water erosion control in chapter 5.

Table 8. Residue and tillage management practices for the baseline conservation condition based on STIR ratings for tillage intensity, Arkansas-White-Red Basin

Residue and tillage management practice in use	Percent of cropped acres in eastern portion	Percent of cropped acres in western portion	Percent of all cropped acres
All acres			
Average annual tillage intensity for crop rotation meets criteria for no-till*	13	15	14
Average annual tillage intensity for crop rotation meets criteria for mulch till**	33	51	44
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	11	7	8
Continuous conventional tillage in every year of crop rotation***	44	28	34
Total	100	100	100

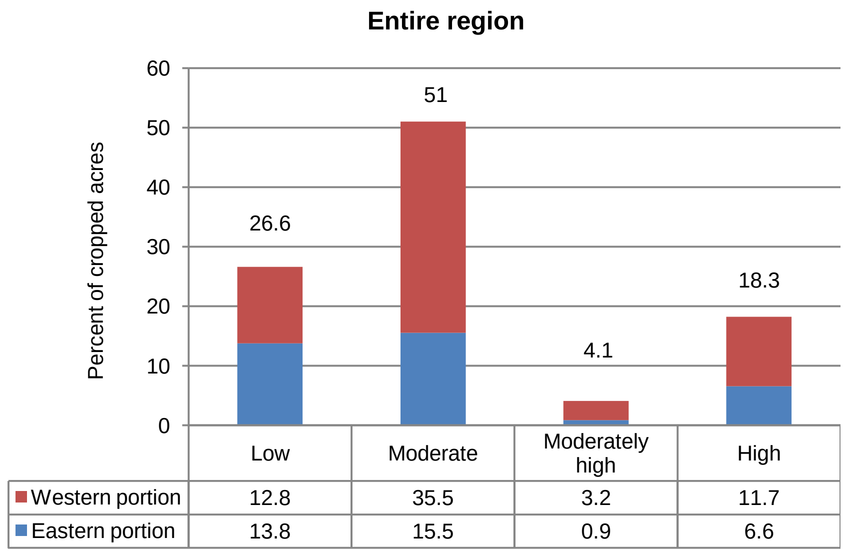
* Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is less than 30.
** Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is between 30 and 100.
*** Soil Tillage Intensity Rating (STIR) for every crop year in the rotation is more than 100.
Note: A description of the Soil Tillage Intensity Rating (STIR) can be found at http://stir.nrcs.usda.gov/.
Note: Percents may not add to totals because of rounding.
Note: Percent residue cover was not used to determine no-till or mulch till.
Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.

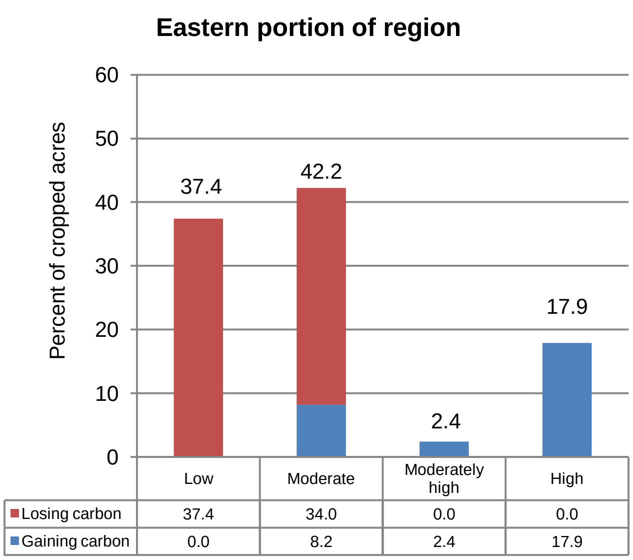
Table 9. Percent of cropped acres with water erosion control practices for the baseline conservation condition, Arkansas-White-Red Basin

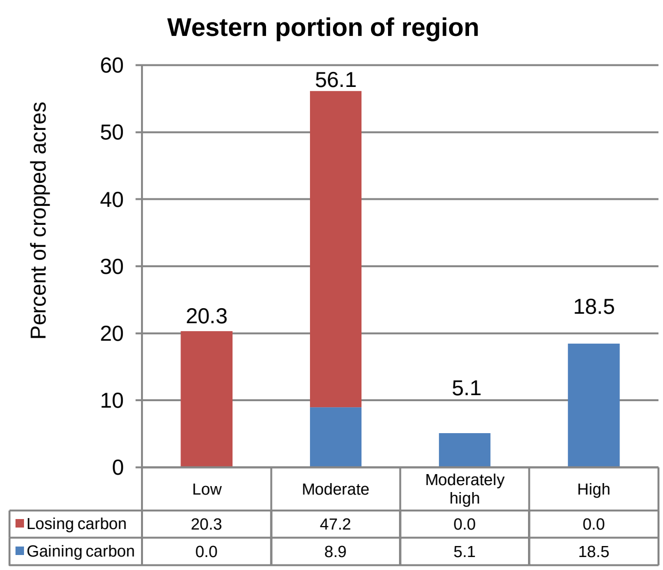
Conservation treatment	Percent of cropped acres in eastern portion	Percent of cropped acres in western portion	Percent of all cropped acres
No-till or mulch till with carbon gain, no structural practices	10	19	16
No-till or mulch till with carbon loss, no structural practices	12	27	22
Some crops with reduced tillage, no structural practices	5	3	4
Structural practices and no-till or mulch till with carbon gain	10	5	7
Structural practices and no-till or mulch till with carbon loss	14	15	14
Structural practices and some crops with reduced tillage	5	4	4
Structural practices only	31	16	21
No water erosion control treatment	14	12	13
All acres	100	100	100

Note: Percents may not add to totals because of rounding.
Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.

Figure 10. Percent of cropped acres at four conservation treatment levels for residue and tillage management, baseline conservation condition, Arkansas-White-Red Basin







Criteria for four levels of treatment with residue and tillage management are:

- **High treatment**: *All crops* meet tillage intensity criteria for either no-till or mulch till and crop rotation is gaining soil organic carbon.
- **Moderately high treatment**: *Average annual* tillage intensity meets criteria for mulch till or no-till and crop rotation is gaining soil organic carbon; some crops in rotation exceed tillage intensity criteria for mulch till.
- **Moderate treatment**: Some crops have reduced tillage but tillage intensity exceeds criteria for mulch till or crop rotation is gaining soil organic carbon and tillage intensity exceeds criteria for mulch till; most acres in this treatment level are losing soil organic carbon.
- **Low treatment**: Continuous conventional tillage and crop rotation is losing soil organic carbon.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.
Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.

Conservation Crop Rotation

In the Arkansas-White-Red Basin, crop rotations that meet NRCS criteria (NRCS practice code 328) occur on about 90 percent of the cropped acres. This practice consists of growing different crops in a planned rotation to manage nutrient and pesticide inputs, enhance soil quality, or reduce soil erosion. Including hay or a close grown crop in rotations with row crops can have a pronounced effect on long-term average field losses of sediment and nutrients, as well as enhancement of soil quality.

The model outputs reported in chapter 4 reflect the effects of conservation crop rotations. However, the benefits of conservation crop rotation practices could not be assessed quantitatively in this study for two reasons. First, it was not possible to differentiate conservation crop rotations from crop rotations for other purposes, such as the control of pests or in response to changing markets. Second, the "no-practice scenario" would require simulation of mono-cropping systems. Not only was there inadequate information on chemical use and other farming practices for widespread mono-crop production, but arbitrary decisions about which crops to simulate at each sample point would be required to preserve the level of regional production.

Cover Crops

Cover crops are planted when the principal crops are not growing. The two most important functions of cover crops from a water quality perspective are (1) to provide soil surface cover and reduce soil erosion, and (2) to utilize and convert excess nutrients remaining in the soil from the preceding crop into plant biomass, thereby reducing nutrient leaching and minimizing the amount of soluble nutrients in runoff during the non-crop growing season. From a soil quality perspective, cover crops help capture atmospheric carbon in plant tissue, provide habitat for the soil food web, and stabilize or enhance soil aggregate strength.

The presence or absence of cover crops was determined from farmer responses in the NRI-CEAP Cropland Survey. The following criteria were used to identify a cover crop.

- A cover crop must be a close-grown crop that is not harvested as a principal crop, or if it is harvested, must have been specifically identified in the NRI-CEAP Cropland Survey as a cover crop to indicate that the harvest was for an acceptable purpose (such as biomass removal or use as mulch or forage material).
- Spring-planted cover crops are inter-seeded into a growing crop or are followed by the seeding of a summer or late fall crop that may be harvested during that same year or early the next year.
- Late-summer-planted cover crops are followed by the harvest of another crop in the same crop year or the next spring.
- Fall-planted cover crops are followed by the spring planting of a crop for harvest the next year.

Some cover crops are planted for soil protection during establishment of spring crops such as sugar beets and potatoes. Early spring vegetation protects young crop seedlings.

In the Arkansas-White-Red Basin, cover crops were not commonly used as a conservation practice during the period covered by the farmer survey (2003–06). Less than 1 percent of the acres (10 sample points) met the above criteria for cover crop use in this region.

Irrigation Management Practices

Irrigation in the United States has its roots in the arid West where precipitation is insufficient to meet the needs of growing crops. In other parts of the United States, rainfall totals are sufficient in most years to produce satisfactory yields. The distribution of the rainfall during the crop growing season, however, is sometimes problematic, especially in years when precipitation is below average. In these cases, irrigation applications are sometimes used to supplement natural rainfall. This supplemental irrigation water can overcome soil moisture deficiencies during drought stress periods and improve yields. Natural rainfall in the Arkansas-White-Red Basin varies from a few inches to more than 40 inches, generally increasing from the west to east across the Basin, so irrigation is essential for crop growth in some areas and is used as a supplemental supply in other areas.

Irrigation applications are made with either a pressure or a gravity system. Gravity systems, as the name implies, utilize gravitational energy to move water from higher elevations to lower elevations, such as moving water from a ditch at the head of a field, across the field to the lower end. Pumps are most often used to create the pressure in pressure systems, and the water is applied under pressure through pipes and nozzles of one form or another. There are also variations such as where water is diverted at higher elevations and the pressure head created by gravity is substituted for the energy of a pump.

Proper irrigation involves applying appropriate amounts of water to the soil profile to reduce any plant stress while at the same time minimizing water losses through evaporation, deep percolation, and runoff. Conversion of much of the gravity irrigated area to pressure systems and the advent of pressure systems in rain-fed agricultural areas has reduced the volumes of irrigation water lost to deep percolation and end-of-field runoff, but has greatly increased the volume of water lost to evaporation in the pressurized sprinkling process. Modern sprinklers utilize improved nozzle technology to increase droplet size as well as reduce the travel time from the nozzle to the ground. Irrigation specialists consider the center pivot or linear move sprinkler with low pressure spray and low flow systems such as drip and trickle systems as the current state of the art.

According to the NRI-CEAP cropland survey, about 20 percent of cropped acres—6 million acres—receive irrigation water in the Arkansas-White-Red Basin for one or more crops. About 11 percent of cropped acres in the eastern portion of the basin are irrigated and 25 percent in the western portion.

To evaluate the efficiency of irrigation systems, a single measure of over-all irrigation efficiency was developed—Virtual Irrigation System Efficiency (VISE). VISE consists of three variables with values unique to each of 19 types of irrigation systems. The first of the three variables is an application efficiency, which accounts for some losses from the on-farm conveyance system, the field conveyance mechanism, and as the water is applied to the field. In sprinkler systems this loss could be high due to evaporation. Application efficiency could also be reduced by leaky pipelines or ditches in more porous soils. The second factor is a coefficient that accounts for the loss of water below the root-zone, or deep percolation, during the irrigation process. In gravity systems deep percolation is normally much higher at the upper end of the field and lessens toward the lower end of the field. The deep percolation coefficient ensures that enough water is applied so that the profile is at least filled all across the field, even if that requires excess applications to some parts of the field. The third factor accounts for the percent of water running off the edge of the field. The CEAP surveys reported few fields with runoff, even with gravity systems. While there is likely more runoff than reported, the survey values were used to define the baseline system.

Approximately 70 percent of the irrigation in the Arkansas-White-Red Basin is by pressure systems and 30 percent is irrigated with gravity systems. Most common pressure systems are center-pivot or linear-move systems with low pressure spray (43.8 percent of irrigated acres) followed by center-pivot or linear-move systems with impact sprinkler heads (13 percent of irrigated acres). There are lesser numbers of center pivots or linear move systems with near ground emitters, side roll or wheel lines, solid set, and hand move sprinkler systems. Other pressure systems include a small number of acres with the highly efficient low flow irrigation which includes drip and trickle systems. Common gravity irrigation systems include open discharges (15.5 percent of irrigated acres), polypipe (7 percent of irrigated acres), gated pipe (4.3 percent of irrigated acres), and improved gated pipe systems (1.8 percent of irrigated acres), and numerous other gravity systems. The open discharge category can include little controlled direct discharge from a well, discharge from large irrigation structures, or discharge from alfalfa valves. The improved gated pipe systems include the popular surge technique. Approximately 44 percent of the irrigation systems in the Arkansas-White-Red Basin are capable of irrigation efficiencies that would be considered appropriate for state-of-the-art irrigation.

Nutrient Management Practices

Nitrogen and phosphorus are essential inputs to profitable crop production. Farmers apply these nutrients to the land as commercial fertilizers and manure to promote plant growth and increase crop yields. Not all of the nutrients applied to the land, however, are taken up by crops; some are lost to the environment, which can contribute to offsite water quality problems.

Sound nutrient management systems can minimize nutrient losses from the agricultural management zone while providing adequate soil fertility and nutrient availability to ensure realistic yields. (The agricultural management zone is defined as the zone surrounding a field that is bounded by the bottom of the root zone, edge of the field, and top of the crop canopy.) Such systems are tailored to address the specific cropping system, nutrient sources available, and site characteristics of each field. Nutrient management systems have four basic criteria for application of commercial fertilizers and manure.[7]

1. Apply nutrients at the **appropriate rate** based on soil and plant tissue analyses and realistic yield goals.
2. Apply the **appropriate form** of fertilizer and organic material with compositions and characteristics that resist nutrient losses from the agricultural management zone.
3. Apply at the **appropriate time** to supply nutrients to the crop when the plants have the most active uptake and biomass production, and avoid times when adverse weather conditions can result in large losses of nutrients from the agricultural management zone.
4. Apply using the **appropriate application method** that provides nutrients to the plants for rapid, efficient uptake and reduces the exposure of nutrient material to forces of wind and water.

Depending on the field characteristics, these nutrient management techniques can be coupled with other conservation practices such as conservation crop rotations, cover crops, residue management practices, and structural practices to minimize the potential for nutrient losses from the agricultural management zone. Even though nutrient transport and losses from agricultural fields cannot be completely eliminated, they can be minimized by careful management and kept within an acceptable level.

The presence or absence of nutrient management practices was based on information on the timing, rate, and method of application for manure and commercial fertilizer as reported by the producer in the NRI-CEAP Cropland Survey. The appropriate form of nutrients applied was not evaluated because the survey was not sufficiently specific about the material formulations that were applied. The following criteria were used to identify the appropriate rate, time, and method of nutrient application for each crop or crop rotation.

- All commercial fertilizer and manure applications are within 3 weeks prior to plant date, at planting, or within 60 days after planting. For fall-planted winter wheat, spring applications also were considered appropriate timing.
- The method of application for commercial fertilizer or manure is some form of incorporation or banding or spot treatment or foliar applied.

[7] These criteria are also referred to as “4R nutrient stewardship—right rate, right time, right place, and right source” (Bruulsema et al. 2009).

- The rate of nitrogen application, including the sum of both commercial fertilizer and manure nitrogen available for crops in the year of application, is—
  - less than 1.4 times the amount of nitrogen removed in the crop yield at harvest for *each* crop[8], except for wheat and other small grain crops,
  - less than 1.6 times the amount of nitrogen removed in the crop yield at harvest for wheat and other small grain crops (barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale), and
  - less than 60 pounds of nitrogen per bale of cotton harvested.
- The rate of phosphorus application summed over all applications and crops in the rotation, including both commercial fertilizer and manure phosphorus, is less than 1.1 times the amount of phosphorus removed in the crop yields at harvest.

Phosphorus application rate criteria apply to the *full crop rotation* to account for infrequent applications intended to provide phosphorus for multiple crops or crop years, which is often the case with manure applications. Nitrogen application rate criteria apply to *each* crop in the rotation.

These nutrient management criteria are intended to represent practice recommendations commonly found in comprehensive nutrient management conservation plans and generally are consistent with recommended rates. While consistent with NRCS standards, they do not necessarily represent the best possible set of nutrient management practices. For example, lower application rates are possible when timing and method criteria are also met and when soil erosion and runoff are controlled.

Nutrient management practices are widely used on cropped acres in the Arkansas-White-Red Basin, as shown in table 10.

- 78 percent of cropped acres meet criteria for timing of nitrogen applications on all crops and 65 percent of cropped acres meet criteria for timing of phosphorus applications on all crops.
- 62 percent of cropped acres meet criteria for method of nitrogen application on all crops and 59 percent meet criteria for method of phosphorus application on all crops.
- 59 percent of cropped acres meet criteria for nitrogen application rate on all crops and 40 percent meet criteria for phosphorus application rates for the full crop rotation.

These percentages of cropped acres meeting nutrient management criteria were higher in the eastern portion of the basin than in the western portion with the exception of the percent of acres meeting the nitrogen method of application criteria, which was higher in the western portion (table 10).

[8] The 1.4 ratio of application rate to yield represents 70-percent use efficiency for applied nitrogen, which has traditionally been accepted as good nitrogen management practice. The 30 percent "lost" includes plant biomass left in the field, volatilization during and following application, immobilization by soil and soil microbes, and surface runoff and leaching losses. A slightly higher ratio is used for small grain crops to maintain yields at current levels.

Only 4 percent of cropped acres have no nitrogen applied in the model simulations. No phosphorus was applied for 21 percent of cropped acres, including 30 percent in the western portion of the region and 6.5 percent in the eastern portion.

Fall applications still occur on some acres. Nutrients applied in the fall for spring-planted crops are generally more susceptible to environmental losses than spring applications. Based on the survey, about 5 percent of the cropped acres in the Arkansas-White-Red Basin receive fall applications of either commercial nitrogen fertilizer or manure on at least one crop in the rotation, excluding cases where a fall crop was planted. About 3 percent of cropped acres receive fall applications of either commercial phosphorus fertilizer or manure on at least one crop in the rotation, excluding cases where a fall crop was planted.

According to the NRI-CEAP cropland survey, only about 4 percent of cropped acres (1.3 million acres) have manure applied in this region. Seventy-five percent of the land application of manure is in the western portion of the basin, where 5 percent of cropped acres receive manure. The highest percentages of cropped acres with manure applied are in two subregions: Upper White River Basin (code 1101) with 12 percent and the Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111) with 12 percent (Appendix B, table B1).

Although most cropped acres meet nutrient management criteria for rate, timing, or method, fewer acres meet criteria for all three, including acres with no nitrogen or phosphorus applied (table 10):

- 33 percent of cropped acres meet all criteria for nitrogen applications;
- 29 percent of cropped acres meet all criteria for phosphorus applications; and
- 25 percent of cropped acres meet criteria for *both* phosphorus and nitrogen applications.

Lower nitrogen rate criteria are appropriate for acres that meet application timing and method criteria and also are fully treated for soil erosion control because more of the nitrogen applied is retained on the field and is therefore available for crop growth. In the simulation of additional soil erosion control and nutrient management (full treatment) in chapter 6, the rates of nitrogen application, including both commercial fertilizer and manure nitrogen, were proportionately reduced to the following levels—

- 1.2 times the amount of nitrogen removed in the crop yield at harvest for *each* crop, except for wheat and small grain crops, and
- 1.5 times the amount of nitrogen removed in the crop yield at harvest for wheat and small grain crops.
- 50 pounds of nitrogen per bale of cotton harvested.

About 23 percent of cropped acres in the region meet *all* nutrient management criteria including these lower nitrogen rate criteria consistent with full treatment and including acres not receiving nutrient applications (table 10). This percentage was slightly higher for the western portion of the basin (25 percent) than for the eastern portion (20 percent).

Using the evaluation criteria presented in table 10, four levels of treatment for nitrogen and phosphorus management were derived for use in evaluating the adequacy of nitrogen and phosphorus management. These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated in chapter 5. Criteria for each of the four treatment levels are presented in figures 11 and 12.

The high treatment level represents consistent use of appropriate rate, timing, and method for all crops, including the lower nitrogen application rate criteria appropriate for full conservation treatment conditions. Based on these treatment levels, about 34 percent of the acres in the Arkansas-White-Red Basin have a high level of nitrogen management and about 50 percent have a high level of phosphorus management (figs. 11 and 12). This high level of treatment is more prevalent in the western portion of the basin than in the eastern portion.

Criteria for the moderately high level of treatment are based only on the rate of application, which are:

- All crops have nitrogen application rates less than 1.6 times the nitrogen in the crop yield for wheat and other small grain crops and less than 60 pounds of nitrogen applied per cotton bale and less than 1.4 times the nitrogen in the crop yield for all other crops.
- The phosphorus application rates are less than 1.1 times the phosphorus in the crop yield for the crop rotation.

About 29 percent of cropped acres in the Arkansas-White-Red basin have a moderately high treatment level for nitrogen and about 12 percent have a moderately high treatment level for phosphorus (figs. 11 and 12).

The moderate treatment level is where either the timing or method criteria are met (but not both) and the rate criteria are not met. In the Arkansas-White-Red basin, 32 percent of cropped acres have a moderate level of nitrogen management and 22 percent of cropped acres have a moderate level of phosphorus management.

The low treatment level includes all acres that do not meet the criteria for the higher levels of management. About 5 percent of cropped acres in the Arkansas-White-Red basin have a low treatment level for nitrogen and about 17 percent have a low treatment level for phosphorus.

The evaluation of conservation practices and associated estimates of conservation treatment needs are based on practice use derived from a farmer survey conducted during the years 2003–06. Use of conservation practices can vary year to year depending on economic and environmental factors, including changes in crop rotations in response to market conditions, year-to-year changes in weather-related factors affecting tillage, irrigation, and nutrient management, and conservation program funding levels and program rules.

Since the 2003–06 survey, States in the Arkansas-White-Red Basin have continued to work with farmers to enhance conservation practice adoption in an ongoing effort to reduce nonpoint source pollution contributing to water quality concerns. As a result, some practices may currently be in wider use within the watershed than the CEAP survey shows for 2003–06. Changes in land use and cropping system in response to market conditions could also result in less use of some conservation practices.

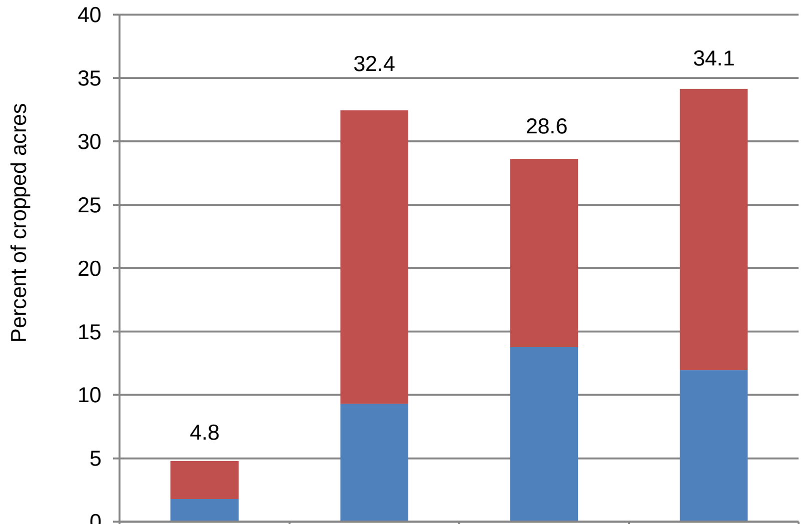
Table 10. Nutrient management practices for the baseline conservation condition, Arkansas-White-Red Basin

	Percent of acres in eastern portion	Percent of acres in western portion	Percent of all cropped acres
Nitrogen*			
No N applied to any crop in rotation	3	4	4
For samples where N is applied:			
Time of application			
All crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	85	74	78
Some but not all crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	3	6	5
No crops in rotation have application of N (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	8	15	13
Method of application			
All crops in rotation have N applied with incorporation or banding/foliar/spot treatment	49	69	62
Some but not all crops in rotation have N applied with incorporation or banding/foliar/spot treatment	25	16	20
No crops in rotation have N applied with incorporation or banding/foliar/spot treatment	23	11	15
Rate of application			
All crops in rotation meet the nitrogen rate criteria described in text	67	54	59
Some but not all crops in rotation meet the nitrogen rate criteria described in text	26	34	31
No crops in rotation meet the nitrogen rate criteria described in text	4	8	6
Timing and method and rate of application			
All crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	35	32	33
Some but not all crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	36	42	40
No crops meet the nitrogen rate , timing criteria, and method criteria described above	26	22	23
Phosphorus*			
No P applied to any crop in rotation	6.5	29.9	21.3
For samples where P is applied:			
Time of application			
All crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	85	54	65
Some but not all crops have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	2	4	3
No crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	6	12	10
Method of application			
All crops in rotation have P applied with incorporation or banding/foliar/spot treatment	69	52	59
Some but not all crops in rotation have P applied with incorporation or banding/foliar/spot treatment	15	11	13
No crops in rotation have P applied with incorporation or banding/foliar/spot treatment	9	7	8
Rate of application			
Crop rotation has P applied at a rate less than 1.1 times the removal of P in the yield at harvest for the crop rotation	51	34	40
Crop rotation has P applied at a rate more than 1.1 times the removal of P in the yield at harvest for the crop rotation	42	36	39
Timing and method and rate of application			
Crop rotation has P rate less than 1.1 times removal at harvest and meet timing and method criteria described above	38	23	29
Crop rotation has P rate less than 1.1 times removal at harvest and some but not all crops meet timing and method criteria described above	11	8	9
Crop rotation has P rate more than 1.1 times removal at harvest and may or may not meet timing and method criteria described above	45	39	41
Nitrogen and Phosphorus			
Crop rotation P rate less than 1.1 and N rate criteria described in text and all applications within 3 weeks before planting or within 60 days after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied	22	26	25
Crop rotation P rate less than 1.1 and N rate criteria appropriate for full conservation treatment (see text) and all applications within 3 weeks before planting or within 60 days after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied	20	25	23
All sample points	100	100	100

Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion. Percents may not add to 100 because of rounding.

* These estimates include adjustments made to the reported data on nitrogen and phosphorus application rates from the survey because of missing data and data-entry errors. In the case of phosphorus, the 3-year data period for which information was reported was too short to pick up phosphorus applications made at 4- and 5-year intervals between applications, which is a common practice for producers adhering to sound phosphorus management techniques. Since crop growth, and thus canopy development which decreases erosion, is a function of nitrogen and phosphorus, it was necessary to add additional nitrogen and phosphorus when the reported levels were insufficient to support reasonable crop yields throughout the 47 years in the model simulation. The approach taken was to first identify crop samples that have application rates recorded erroneously or were under-reported in the survey. The model was used to identify these samples by running the simulation at optimal levels of nitrogen and phosphorus for crop growth. The set of crop samples identified were treated as if they had missing data. Additional nitrogen or phosphorus was added to these crop samples so that the total nitrogen or phosphorus use was similar to that for the unadjusted set of crop samples. About 33 percent of the acres received a nitrogen adjustment for one or more crops. About 28 percent of the acres received a phosphorus adjustment for one or more crops. Nitrogen and phosphorus were added by increasing the existing applications (thus preserving the reported timing and methods), when present, or were applied at plant. (For additional information on adjustment of nutrient application rates, see "Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling," available at http://www.nrcs.usda.gov/technical/nri/ceap

Figure 11. Percent of cropped acres at four conservation treatment levels for nitrogen management, baseline conservation condition, Arkansas-White-Red Basin



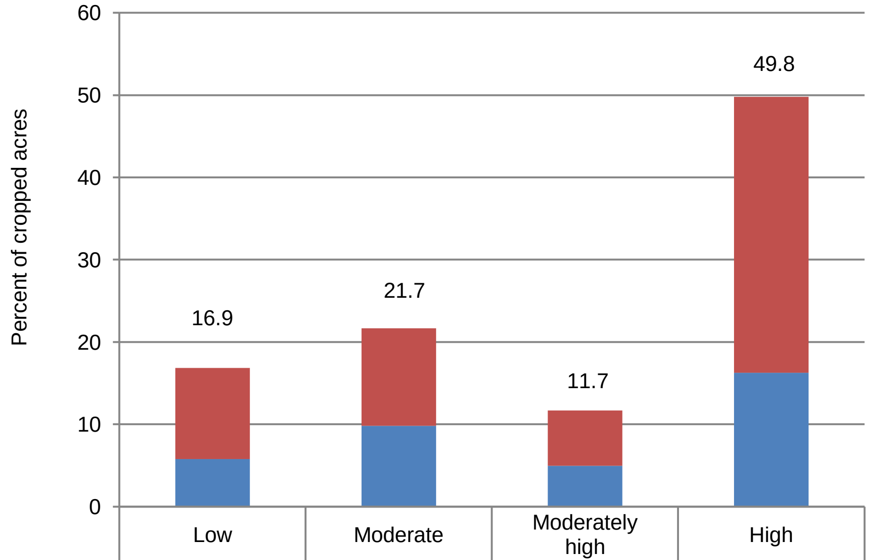
	Low	Moderate	Moderately high	High
Western portion	3.0	23.1	14.8	22.2
Eastern portion	1.8	9.3	13.8	11.9

Criteria for four levels of nitrogen management are:

- **High treatment**: All crops have: (1) total nitrogen application rates (including manure) less than 1.2 times the nitrogen in the crop yield for crops other than cotton and small grains, less than 1.5 times the nitrogen in the crop yield for small grains, and less than 50 pounds of nitrogen applied per cotton bale; (2) all applications occur within 3 weeks before planting or within 60 days after planting; and (3) all applications are incorporated or banding/foliar/spot treatment is used.
- **Moderately high treatment**: All crops have total nitrogen application rates (including manure) less than 1.4 times the nitrogen in the crop yield for crops other than cotton and small grains, less than 1.6 times the nitrogen in the crop yield for small grains, and less than 60 pounds of nitrogen applied per cotton bale for all crops. Timing and method of application criteria may or may not be met.
- **Moderate treatment**: All crops do not meet criteria for rate but meet above criteria for timing *or* method.
- **Low treatment**: All crops in rotation do not meet criteria for rate, timing and method, although some crops in the rotation may meet one or more of the application criteria.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.
Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.

Figure 12. Percent of cropped acres at four conservation treatment levels for phosphorus management, baseline conservation condition, Arkansas-White-Red Basin



	Low	Moderate	Moderately high	High
Western portion	11.1	11.9	6.7	33.5
Eastern portion	5.8	9.8	5.0	16.3

Criteria for four levels of phosphorus management are:

- **High treatment**: (1) total phosphorus application rates (including manure) summed over all crops are less than 1.1 times the phosphorus in the crop yields for the crop rotation, (2) all applications occur within 3 weeks before planting or within 60 days after planting, and (3) all applications are incorporated or banding/foliar/spot treatment was used. (Note that phosphorus applications for individual crops could exceed 1.1 times the phosphorus in the crop yield but total applications for the crop rotation could not.)
- **Moderately high treatment**: Total phosphorus application rates (including manure) are less than 1.1 times the phosphorus in the crop yield for the crop rotation. No method or timing of application criteria is applied.
- **Moderate treatment**: Sample points that do not meet the high or moderately high criteria but all phosphorus applications for all crops have appropriate time *and* method of application.
- **Low treatment**: All acres have excessive application rates over the crop rotation and inadequate method or timing of application for at least one crop in the rotation.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.
Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.

Pesticide Management Practices

The presence or absence of pesticide management practices was based on an Integrated Pest Management (IPM) indicator developed using producer responses to the set of IPM-related questions in the NRI-CEAP Cropland Survey (table 11).[9]

Adoption of IPM systems can be described as occurring along a continuum from largely reliant on prophylactic control measures and pesticides to multiple-strategy, biologically intensive approaches. IPM adoption is not usually an either/or situation. The practice of IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environment scenario. Where appropriate, each site should have in place a management strategy for **Prevention, Avoidance, Monitoring,** and **Suppression** of pest populations (the **PAMS** approach) (Coble 1998). In order to qualify as IPM practitioners, growers would use tactics in all four PAMS components.

Prevention is the practice of keeping a pest population from infesting a field or site, and should be the first line of defense. It includes such tactics as using pest-free seeds and transplants, preventing weeds from reproducing, irrigation scheduling to avoid situations conducive to disease development, cleaning tillage and harvesting equipment between fields or operations, using field sanitation procedures, and eliminating alternate hosts or sites for insect pests and disease organisms.

Avoidance may be practiced when pest populations exist in a field or site but the impact of the pest on the crop can be avoided through some cultural practice. Examples of avoidance tactics include crop rotation in which the crop of choice is not a host for the pest, choosing cultivars with genetic resistance to pests, using trap crops or pheromone traps, choosing cultivars with maturity dates that may allow harvest before pest populations develop, fertilization programs to promote rapid crop development, and simply not planting certain areas of fields where pest populations are likely to cause crop failure.

Monitoring and proper identification of pests through surveys or scouting programs, including trapping, weather monitoring, and soil testing where appropriate, are performed as the basis for suppression activities. Records are kept of pest incidence and distribution for each field or site. Such records form the basis for crop rotation selection, economic thresholds, and suppressive actions.

Suppression of pest populations may be necessary to avoid economic loss if prevention and avoidance tactics are not successful. Suppressive tactics include *cultural* practices such as narrow row spacing or optimized in-row plant populations, alternative tillage approaches such as no-till or strip-till systems, cover crops or mulches, or using crops with allelopathic potential in the rotation. *Physical* suppression tactics include cultivation or mowing for weed control, baited or pheromone traps for certain insects, and temperature management or exclusion devices for insect and disease management. *Biological* controls, including mating disruption for insects, are alternatives to conventional pesticides, especially where long-term control of a troublesome pest species can be attained. Naturally occurring biological controls, where they exist, are important IPM tools. *Chemical pesticides* are applied as a last resort in suppression systems using a sound management approach, including selection of pesticides with low risk to non-target organisms.

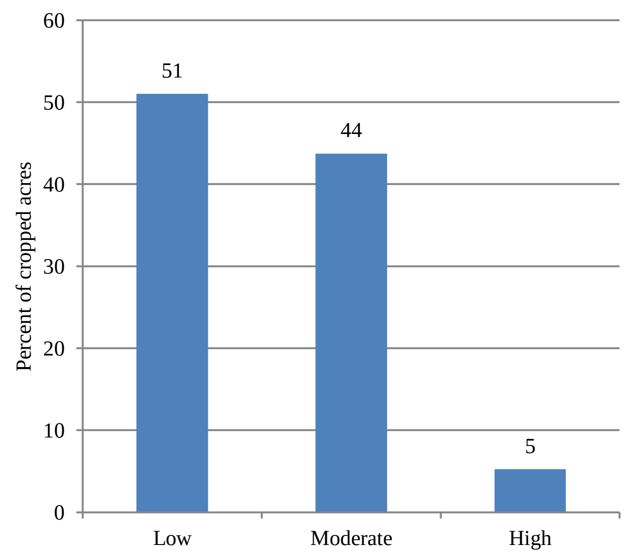
An IPM index was developed to determine the level of IPM activity for each sample point. The index was constructed as follows.

- Scores were assigned to each question by a group of IPM experts.
- Scores for each PAMS category were normalized to have a maximum score of 100.
- The four PAMS categories were also scored in terms of relative importance for an IPM index: prevention = 1/6, avoidance = 1/6, monitoring = 1/3, and suppression = 1/3.
- The IPM indicator was calculated by multiplying the normalized PAMS category by the category weight and summing over the categories.

An IPM indicator score greater than 60 defined sample points with a high level of IPM activity. Sample points with an IPM indicator score of 35 to 60 were classified as moderately high IPM treatment and sample points with an IPM score less than 35 were classified as low IPM treatment.

About 5 percent of the acres in the Arkansas-White-Red Basin have a high level of IPM activity (fig. 13). About 44 percent have a moderate level of IPM activity, and 51 percent have a low level of IPM activity. The IPM indicator scores are about the same for the eastern and western portions of the region.

Figure 13. Integrated Pesticide Management indicator for the baseline conservation condition, Arkansas-White-Red Basin



[9] For a full documentation of the derivation of the IPM indicator, see "Integrated Pest Management (IPM) Indicator Used in the CEAP Cropland Modeling," available at http://www.nrcs.usda.gov/technical/nri/ceap.

Table 11. Summary of survey responses to pest management questions, Arkansas-White-Red Basin

Survey question	Number samples with "yes" response	Percent of cropped acres
Prevention		
Pesticides with different action rotated or tank mixed to prevent resistance	156	13
Plow down crop residues	463	35
Chop, spray, mow, plow, burn field edges, etc.	463	36
Clean field implements after use	621	50
Remove crop residue from field	176	14
Water management used to manage pests (irrigated samples only)	45	3
Avoidance		
Rotate crops to manage pests	549	45
Use minimum till or no-till to manage pests	416	33
Choose crop variety that is resistant to pests	361	27
Planting locations selected to avoid pests	103	8
Plant/harvest dates adjusted to manage pests	163	13
Monitoring		
Scouting practice: general observations while performing routine tasks	572	46
Scouting practice: deliberate scouting	440	34
--Established scouting practice used	175	13
--Scouting due to pest development model	87	6
--Scouting due to pest advisory warning	126	9
Scouting done by: (only highest of the 4 scores is used)		
--Scouting by operator	277	21
--Scouting by employee	10	1
--Scouting by chemical dealer	20	2
--Scouting by crop consultant or commercial scout	141	10
Scouting records kept to track pests?	200	15
Scouting data compared to published thresholds?	218	17
Diagnostic lab identified pest?	76	6
Weather a factor in timing of pest management practice	286	21
Suppression		
Pesticides used?	887	70
Weather data used to guide pesticide application	480	38
Biological pesticides or products applied to manage pests	47	3
Pesticides with different mode of action rotated or tank mixed to prevent resistance	156	13
Pesticide application decision factor (one choice only):		
--Routine treatments or preventative scheduling	370	29
--Comparison of scouting data to published thresholds	71	6
--Comparison of scouting data to operator's thresholds	124	9
--Field mapping or GPS	4	0
--Dealer recommendations	55	4
--Crop consultant recommendations	97	7
--University extension recommendations	2	0
--Neighbor recommendations	3	0
--"Other"	63	6
Maintain ground covers, mulch, or other physical barriers	454	36
Adjust spacing, plant density, or row directions	187	14
Release beneficial organisms	12	1
Cultivate for weed control during the growing season	293	22
Number of respondents	1,280	100

Note: The scores shown in this table were used to develop an IPM indicator as discussed in the text.

Conservation Cover Establishment

Establishing long-term cover of grass, forbs, or trees on a site provides the maximum protection against soil erosion. Conservation cover establishment is often used on cropland with soils that are vulnerable to erosion or leaching. The practice is also effective for sites that are adjacent to waterways, ponds, and lakes. Because these covers do not require annual applications of fertilizer and pesticides, this long-term conserving cover practice greatly reduces the loss of nitrogen and phosphorus from the site, and nearly eliminates pesticide loss. Because conservation covers are not harvested, they generate organic material that decomposes and increases soil organic carbon. For this study, the effect of a long-term conserving cover practice was estimated using acres enrolled in the General Signup of the CRP. The CRP General Signup is a voluntary program in which producers with eligible land enter into 10- to 15-year contracts to establish long-term cover to reduce soil erosion, improve water quality, and enhance wildlife habitat.

Landowners receive annual rental payments and cost-share assistance for establishing and maintaining permanent vegetative cover. To be eligible for enrollment in the CRP General Signup, the field (or tract) must meet specified crop history criteria.

Other factors governing enrollment in the CRP include natural resource-based eligibility criteria, an Environmental Benefits Index (EBI) used to compare and rank enrollment offers, acreage limits, and upper limits on the proportion of a county's cropland that can be enrolled (USDA Farm Service Agency 2004; Wiebe and Gollehon 2006). Initially, the eligibility criteria included only soil erosion rates and inherent soil erodibility. During the 1990s and to date, the eligibility criteria have continued to evolve, with increasing emphasis placed on issues other than soil erodibility. For contract offer ranking, weight was given to proposals that also benefited wildlife, air and water quality, and other environmental concerns.

As of 2003, about 31.5 million acres were enrolled in the CRP General Signup nationally (USDA/NRCS 2007). About 20 percent of these acres (6 million acres) are in the Arkansas-White-Red Basin. The bulk of these acres (91 percent) are found in the western portion of the basin.

Approximately 49 percent of the cropland acres enrolled in the CRP in the Arkansas-White-Red Basin are classified as highly erodible land. The inclusion of non-highly erodible land is due to both the expansion of enrollment eligibility criteria beyond soil erosion issues and the fact that farmers were allowed to enroll entire fields in the CRP even if only a portion of the field met the criteria. (Enrollment rules varied by signup period and eligibility criterion.)

In the Arkansas-White-Red Basin, 74 percent of the CRP land is planted to introduced grasses, 24 percent to native grasses, 1.3 percent to wildlife habitat, and about 1.3 percent to trees. The plantings designated in the NRI database for each sample point were simulated in the APEX model. However, in all cases the simulated cover was a mix of species and all points included at least one grass and one clover species.

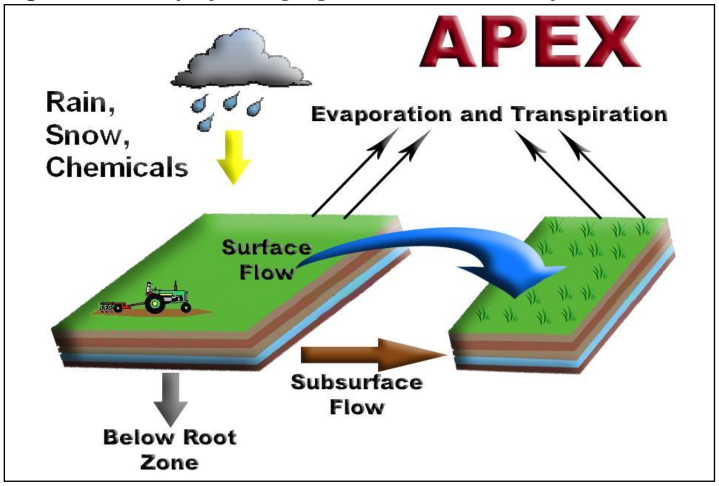
Chapter 4
Onsite (Field-Level) Effects of Conservation Practices

The Field-Level Cropland Model—APEX

A physical process model called APEX was used to simulate the effects of conservation practices at the field level (Williams et al. 2006; Williams et al. 2008; Gassman et al. 2009 and 2010).[10] The I_APEX model run management software developed at the Center for Agricultural and Rural Development, Iowa State University, was used to perform the simulations in batch mode.[11]

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides (fig. 14). The APEX model and its predecessor, EPIC (Environmental Policy Impact Calculator), have a long history of use in simulation of agricultural and environmental processes and of the effect of agricultural technology and government policy (Izaurralde et al. 2006;Williams 1990; Williams et al. 1984; Gassman et al. 2005).[12]

Figure 14. Daily hydrologic processes simulated by APEX



On a daily basis, APEX simulates the farming operations used to grow crops, such as planting, tillage before and after planting, application of nutrients and pesticides, application of manure, irrigation, and harvest. Weather events and their interaction with crop cover and soil properties are simulated; these events affect crop growth and the fate and transport of water and chemicals through the soil profile and over land to the edge of the field. Over time, the chemical makeup and physical structure of the soil may change, which in turn affect crop yields and environmental outcomes. Crop residue remaining on the field after harvest is transformed into organic matter. Organic matter may build up in the soil over time, or it may degrade, depending on climatic conditions, cropping systems, and management.

APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion, and the loss of sediment beyond the edge of the field. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field. Exchange of gaseous forms between the soil and the atmosphere is simulated, including losses of gaseous nitrogen compounds.

Irrigation, which is important for crop production in parts of the Arkansas-White-Red Basin, was simulated using an "auto-irrigation" algorithm in APEX. Availability of a full irrigation water supply was assumed. When the APEX model detected water-induced yield stress above a specified threshold for irrigated fields (so indicated in the survey), it simulated the application of irrigation to the crop root-zone. The amount of irrigation water applied at each application was determined by the amount of irrigation water required to fill the root-zone, accounting for efficiency losses associated with infield transport and application. An irrigation event was simulated when actual yield was less than 95 percent of potential yield due to water stress; the minimum application was 20 millimeters (0.8 inches); the annual maximum application was limited to 2,000 millimeters (78 inches); and at least 3 days had to elapse between each irrigation event.

The NRI-CEAP Cropland Survey was the primary source of information on all farming activities simulated using APEX. Crop data were transformed for the model into a crop rotation for each sample point, which was then repeated over the 47-year simulation. The 3 years of data reported in the survey were represented in the model simulation as 1-, 2-, 3-, 4-, or 5-year crop rotations. For example, a 2-year corn-soybean rotation was used if the operator reported that corn was grown in the first year, soybeans in the second year, and corn again in the third year. In this case, only 2 of the reported 3 years of survey data were used. If management differed significantly for the 2 years that corn was grown (manure was applied, for example, or tillage was different), the rotation was expanded to 4 years, retaining the second year of corn and repeating the year of soybeans. In addition, some rotations with alfalfa or grass seed were simulated as 5-year rotations. Specific rules and procedures were established for using survey data to simulate cover crops, double crops, complex systems such as intercropping and nurse crops, perennial hay in rotations, abandoned crops, re-planting, multiple harvests, manure applications, irrigation, and grazing of cropland before and after harvest.[13]

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[10] The full theoretical and technical documentation of APEX can be found at http://epicapex.brc.tamus.edu/downloads/user-manuals.aspx.

[11] The IAPEX software steps through the simulations one at a time, extracting the needed data from the Access input tables, executes APEX, and then stores the model output in Access output files. The Web site for that software is http://www.card.iastate.edu/environment/interactive_programs.aspx.

[12] Summaries of APEX model validation studies on how well APEX simulates measured data are presented in Gassman et al. (2009) and in "APEX Model Validation for CEAP" found at http://www.nrcs.usda.gov/technical/nri/ceap.

[13] For a detailed description of the rules and procedures, see "Transforming Survey Data to APEX Model Input Files," http://www.nrcs.usda.gov/technical/nri/ceap.

Use of conservation practices in the Arkansas-White-Red Basin was obtained from four sources, as described in chapter 3: (1) NRI-CEAP Cropland Survey, (2) NRCS field offices, (3) USDA Farm Service Agency (FSA), and (4) the 2003 NRI. For each sample point, data from these four sources were pooled and duplicate practices discarded.[14]

Simulating the No-Practice Scenario

The purpose of the no-practice scenario is to provide an estimate of sediment, nutrient, and pesticide loss from farm fields under conditions without the use of conservation practices. The benefits of conservation practices in use within the Arkansas-White-Red Basin were estimated by contrasting model output from the no-practice scenario to model output from the baseline conservation condition (2003–06). The only difference between the no-practice scenario and the baseline conservation condition is that the conservation practices are removed or their effects are reversed in the no-practice scenario simulations. There were usually several alternatives that could be used to represent "no practices." The no-practice representations derived for use in this study conformed to the following guidelines.

- **Consistency:** It is impossible to determine what an individual farmer would be doing if he or she had not adopted certain practices, so it is important to represent all practices on all sample points in a consistent manner that is based on the intended purpose of each practice.

- **Simplicity:** Complex rules for assigning "no-practice" activities lead to complex explanations that are difficult to substantiate and sometimes difficult to explain and accept. Complexity would not only complicate the modeling process but also hamper the interpretation of results.

- **Historical context avoided:** The no-practice scenario is a technological step backward for conservation, not a chronological step back to a prior era when conservation practices were not used. Although the advent of certain conservation technologies can be dated, the adoption of technology is gradual, regionally diverse, and ongoing. It is also important to retain the overall crop mix in the region, as it in part reflects today's market forces. Therefore, moving the clock back to 1950s (or any other time period) agriculture is not the goal of the no-practice scenario. Taking away the conservation ethic is the goal.

- **Moderation:** The no-practice scenario should provide a reasonable level of inadequate conservation so that a reasonable benefit can be determined, where warranted, but not so severe as to generate exaggerated conservation gains by simulating the worst-case condition. Tremendous benefits could be generated if, for example, nutrients were applied at twice the recommended rates with poor timing or application methods in the no-practice simulation. Similarly, large erosion benefits could be calculated if the no-practice representation for tillage was fall plowing with moldboard plows and heavy disking, which was once common but today would generally be considered economically inefficient.

- **Maintenance of crop yield or efficacy**. It is impossible to avoid small changes in crop yields, but care was taken to avoid no-practice representations that would significantly change crop yields and regional production capabilities. The same guideline was followed for pest control—the suite of pesticides used was not adjusted in the no-practice scenario because of the likelihood that alternative pesticides would not be as effective and would result in lower yields under actual conditions.

A deliberate effort was made to adhere to these guidelines to the same degree for all conservation practices so that the overall level of representation would be equally moderate for all practices.

Table 12 summarizes the adjustments to conservation practices used in simulation of the no-practice scenario.

No-practice representation of structural practices

The no-practice field condition for structural practices is simply the removal of the structural practices from the modeling process. In addition, the soil condition is changed from "Good" to "Poor" for the determination of the runoff curve number for erosion prediction.

Overland flow. This group includes such practices as terraces and contouring which slow the flow of water across the field. For the practices affecting overland flow of water and therefore the P factor of the USLE-based equations, the P factor was increased to 1. Slope length is also changed for practices such as terraces to reflect the absence of these slope-interrupting practices.

Concentrated flow. This group of practices is designed to address channelized flow and includes grassed waterways and grade stabilization structures. These practices are designed to prevent areas of concentrated flow from developing gullies or to stabilize gullies that have developed. The no-practice protocol for these practices removes the structure or waterway and replaces it with a "ditch" as a separate subarea. This ditch, or channel, represents a gully; however, the only sediment contributions from the gully will come from downcutting. Headcutting and sloughing of the sides are not simulated in APEX.

[14] For a detailed description of the rules and procedures for simulation of structural conservation practices, see "Modeling Structural Conservation Practices in APEX," http://www.nrcs.usda.gov/technical/nri/ceap.

Table 12. Construction of the no-practice scenario for the Arkansas-White-Red Basin

Practice adjusted	Criteria used to determine if a practice was in use	Adjustment made to create the no-practice scenario
Structural practices	1. Overland flow practices present	1. USLE P-factor changed to 1 and slope length increased for points with terraces, soil condition changed from good to poor.
	2. Concentrated flow—managed structures or waterways present	2. Structures and waterways replaced with earthen ditch, soil condition changed from good to poor.
	3. Edge-of-field mitigation practices present	3. Removed practice and width added back to field slope length.
	4. Wind erosion control practices present	4. Unsheltered distance increased to 400 meters
Residue and tillage management	STIR ≤100 for any crop within a crop year	Add two tandem diskings 1 week prior to planting
Cover crop	Cover crop planted for off-season protection	Remove cover crop simulation (field operations, fertilizer, grazing, etc.)
Irrigation (See text for details)	Pressure systems	East—Change to hand-move sprinkler system except where the existing system is less efficient West—Change to gravity systems except on sandy soils and steep slopes
	Gravity systems	Where conveyance is pipeline, change to gated pipe unless existing system is less efficient. Where conveyance is ditch, change to unlined ditch with portals
Nitrogen rate	Total of all applications of nitrogen (commercial fertilizer and manure applications) ≤1.4 times harvest removal for non-legume crops, except for cotton and small grain crops	Increase rate to 1.9 times harvest removal (proportionate increase in all reported applications, including manure)
	Total of all applications of nitrogen (commercial fertilizer and manure applications) ≤1.6 times harvest removal for small grain crops	Increase rate to 2.0 times harvest removal (proportionate increase in all reported applications, including manure)
	Total of all applications of nitrogen (commercial fertilizer and manure applications) for cotton ≤60 pounds per bale	Increase rate to 90 pounds per bale (proportionate increase in all reported applications, including manure)
Phosphorus rate	Applied total of fertilizer and manure P over all crops in the crop rotation ≤ 1.1 times total harvest P removal over all crops in rotation.	Increase commercial P fertilizer application rates to reach 2.0 times harvest removal for the crop rotation (proportionate increase in all reported applications over the rotation), accounting also for manure P associated with any increase in manure applications to meet nitrogen application criteria for the no practice scenario. Manure applications were not further increased to meet the higher P rate for the no-practice scenario.
Commercial fertilizer application method	Incorporated or banded	Change to surface broadcast
Manure application method	Incorporated, banded, or injected	Change to surface broadcast
Commercial fertilizer application timing	Within 3 weeks prior to planting, at planting, or within 60 days after planting.	Moved to 3 weeks prior to planting. Manure applications were not adjusted for timing in the no-practice scenario.
Pesticides	1. Practicing high level of IPM	1. All incorporated applications changed to surface application. For each crop, the first application event after planting and 30 days prior to harvest replicated twice, 1 week and 2 weeks later than original.
	2. Practicing moderate level of IPM	2. Same as for high level of IPM, except replication of first application only 1 time, 1 week after original
	3. Spot treatments	3. Application rates for spot treatments were adjusted upward relative to the baseline rate to represent whole-field application (see text)
	4. Partial field treatments	4. Application rates for partial field treatments were adjusted upward relative to the baseline rate to represent whole-field application (see text)

Edge of field. These practices include buffers, filters, and other practices that occur outside the primary production area and act to mitigate the losses from the field. The no-practice protocol removes these areas and their management. When the practices are removed, the slope length is also restored to the undisturbed length that it would be if the practices were not in place. (When simulating a buffer in APEX, the slope length reported in the NRI is adjusted.)

Wind control. Practices such as windbreaks or shelterbelts, cross wind ridges, stripcropping or trap strips, and hedgerows are examples of practices used for wind control. The unsheltered distance reflects the dimensions of the field as modeled, 400 meters or 1,312 feet. Any practices reducing the unsheltered distance are removed and the unsheltered distance set to 400 meters.

No-practice representation of conservation tillage

The no-practice tillage protocols are designed to remove the benefits of conservation tillage. For all crops grown with some kind of reduced tillage, including cover crops, the no-practice scenario simulates conventional tillage, based on the STIR (Soil Tillage Intensity Rating) value. Conventional tillage for the purpose of estimating conservation benefits is defined as any crop grown with a STIR value above 100. (To put this in context, no-till or direct seed systems have a STIR of less than 30, and that value is part of the technical standard for Residue Management, No-Till/Strip Till/Direct Seed [NRCS Practice Standard 329]). Those crops grown with a STIR value of less than 100 in the baseline conservation condition had tillage operations added in the no-practice scenario.

Simulating conventional tillage for crops with a STIR value of less than 100 requires the introduction of additional tillage operations in the field operations schedule. For the no-practice scenario, two consecutive tandem disk operations were added prior to planting. In addition to adding tillage, the hydrologic condition for assignment of the runoff curve number was changed from good to poor on all points receiving additional tillage. Points that are conventionally tilled for all crops in the baseline condition scenario are also modeled with a “poor“ hydrologic condition curve number.

The most common type of tillage operation in the survey was disking, and the most common disk used was a tandem disk for nearly all crops, in all parts of the region, and for both dryland and irrigated agriculture. The tandem disk has a STIR value of 39 for a single use. Two consecutive disking operations will add 78 to the existing tillage intensity, which allows for more than 90 percent of the crops to exceed a STIR of 100 and yet maintain the unique suite and timing of operations for each crop in the rotation. Although a few sample points will have STIR values in the 80s or 90s after adding the two disking operations, the consistency of an across-the-board increase of 78 is simple and provides the effect of a distinctly more intense tillage system.

These additional two tillage operations were inserted in the simulation one week prior to planting, one of the least vulnerable times for tillage operations because it is close to the time when vegetation will begin to provide cover and protection.

No-practice representation of cover crops

The no-practice protocol for this practice removes the planting of the crop and all associated management practices such as tillage and fertilization. In a few cases the cover crops were grazed; when the cover crops were removed, so were the grazing operations.

No-practice representation of irrigation practices

The no-practice irrigation protocols were designed to remove the benefits of better water management and the increased efficiencies of modern irrigation systems. Irrigation efficiencies are represented in APEX by a combination of three coefficients that recognize water losses from the water source to the field as discussed in chapter 3: evaporation losses with sprinkler systems, percolation losses below the root-zone during irrigation, and runoff at the lower end of the field. These coefficients are combined to form an overall system efficiency that varies with soil type and land slope.

The Arkansas-White-Red Basin is situated partly in what would be considered the supplemental irrigation area as well the traditional western irrigated area where irrigation is essential for crop production. The dividing line between the traditional irrigation area and the supplemental irrigated area runs north through central Oklahoma, Kansas, and Nebraska to the Canadian border. It represents the point where acres to the east could most likely expect substantial crop yields most years without irrigation.

The western area was treated differently from the eastern area in the spirit of developing a no-practice scenario with reasonableness as discussed previously. The irrigated fields in the supplemental irrigation area required less reduction in technology for the no-practice representation mostly because much of the supplemental irrigated area did not have a history of transitioning from gravity to pressure technology.

In the no-practice representation, all conservation practices, such as Irrigation Water Management and Irrigation Land Leveling, were removed. If the sample was pressure irrigated, the on-farm conveyance was left as reported because pressure systems were often developed along with conveyance technology that was compatible with the landscape. If the system was gravity-fed in the western part of the region, conveyance was assumed to be an open ditch in the no-practice scenario. In the area with supplemental irrigation and gravity systems, the conveyance remained unchanged unless the delivery system was a ditch. If the no-practice water delivery system was a ditch, gravity systems were simulated with unlined ditches and portals. Where the no-practice conveyance was pipelines, the gravity system reverted back to gated pipe. In the western part of the region, the pressure systems were replaced with gravity systems for no-practice scenario except on steep slopes and sandy soils where the pressure system was simulated with hand-move sprinklers. In the supplemental irrigation area, the pressure systems were also simulated with hand-move sprinklers. In cases where the efficiency of the baseline system was less than the efficiency of the no-practice system, no reduction in irrigation technology was made for the no-practice scenario.

After making the indicated adjustments to the irrigation technology for the no-practice scenario, 83 percent of the irrigated acres had of gravity systems and approximately 17 percent had pressure systems. Primary systems in the no-practice scenario are gated pipe (47 percent of irrigated acres). portals from unlined ditches (19 percent of irrigated acres), and open discharge (16 percent of irrigated acres).

No-practice representation of nutrient management practices

The no-practice nutrient management protocols are designed to remove the benefits of proper nutrient management techniques.

The NRCS Nutrient Management standard (590) allows a variety of methods to reduce nutrient losses while supplying a sufficient amount of nutrient to meet realistic yield goals. The standard addresses nutrient loss in two primary ways: (1) by altering rates, form, timing, and methods of application, and (2) by installing buffers, filters, or erosion or runoff control practices to reduce mechanisms of loss. The latter method is covered by the structural practices protocols for the no-practice scenario. The goals of the nutrient management no-practice protocols are to alter three of the four basic aspects of nutrient application—rate, timing, and method. The form of application was not addressed because of the inability to determine if proper form was being applied.

Commercial nitrogen fertilizer rate. For the no-practice scenario, the amount of commercial nitrogen fertilizer applied was—

- increased to 1.9 times harvest removal for non-legume crops receiving less than or equal to 1.4 times the amount of nitrogen removed at harvest in the baseline scenario, except for wheat and other small grain crops; and
- increased to 2.0 times harvest removal for wheat and other small grain crops receiving less than or equal to 1.6 times the amount of nitrogen removed at harvest in the baseline scenario.
- increased to 90 pounds per bale for cotton crops receiving less than 60 pounds of nitrogen per bale in the baseline scenario.

The ratio of 1.9 for the increased nitrogen rate was determined by the average rate-to-yield-removal ratio for crops exceeding the application-removal ratio of 1.4. Where nitrogen was applied in multiple applications, each application was increased proportionately.

The assessment was made on an average annual basis for each crop in the rotation using average annual model output on nitrogen removed with the yield at harvest in the baseline conservation condition scenario.

Commercial phosphorus fertilizer rate. The threshold for identifying proper phosphorus application rates was 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. The threshold is lower for phosphorus than for nitrogen because phosphorus is not lost through volatilization to the atmosphere and much less is lost through other pathways owing to strong bonding of phosphorus to soil particles.

For the no-practice scenario, the amount of commercial phosphorus fertilizer applied was increased to 2.0 times the harvest removal rate for the crop rotation. The ratio of 2.0 for the increased phosphorus rate was determined by the average rate-to-yield-removal ratio for crops with phosphorus applications exceeding 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. Multiple commercial phosphorus fertilizer applications were increased proportionately to meet the 2.0 threshold.

Manure application rate. For sites receiving manure, the appropriate manure application rate in tons per acre was identified on the basis of the total nitrogen application rate, including both manure and commercial nitrogen fertilizer. Thus, if the total for all applications of nitrogen (commercial fertilizer and manure) was less than or equal to 1.4 times removal at harvest for non-legume crops, the no-practice manure application rate was increased such that the combination of commercial fertilizer and manure applications resulted in a total rate of nitrogen application equal to 1.9 times harvest removal. Both commercial nitrogen fertilizer and the amount of manure were increased proportionately to reach the no-practice scenario rate. For small grain crops, the same approach was used using the criteria defined above for commercial nitrogen fertilizer. As done with commercial nitrogen fertilizer, the assessment was made separately for each crop in the rotation.

Any increase in phosphorus from manure added to meet the nitrogen criteria for the no-practice scenario was taken into account in setting the no-practice commercial phosphorus fertilizer application rate.

Thus, no adjustment was made to manure applied at rates below the P threshold of 1.1 in the no-practice scenario because the manure application rate was based on the nitrogen level in the manure.

Timing of application. Nutrients applied closest to the time when a plant needs them are the most efficiently utilized and least likely to be lost to the surrounding environment. All commercial fertilizer applications occurring within 3 weeks prior to planting, at planting, or within 60 days after planting were moved back to 3 weeks prior to planting for the no-practice scenario. For example, split applications that occur within 60 days after planting are moved to a single application 3 weeks before planting for the no-practice scenario.

Timing of manure applications was not adjusted in the no-practice scenario.

Method of application. Nutrient applications, including manure applications, that were incorporated or banded were changed to a surface broadcast application method for the no-practice scenario.

No-practice representation of pesticide management practices

Pesticide management for conservation purposes is a combination of three types of interrelated management activities:

1. A mix of soil erosion control practices that retain pesticide residues within the field boundaries.
2. Pesticide use and application practices that minimize the risk that pesticide residues pose to the surrounding environment.
3. Practice of Integrated Pest Management (IPM), including partial field applications and spot treatment.

The first activity is covered by the no-practice representation of structural practices and residue and tillage management. The second activity, for the most part, cannot be simulated in large-scale regional modeling because of the difficulty in assuring that any changes in the types of pesticides applied or in the method or timing of application would provide sufficient protection against pests to maintain crop yields.[15] Farmers, of course, have such options, and environmentally conscientious farmers make tradeoffs to reduce environmental risk. But without better information on the nature of the pest problem both at the field level and in the surrounding area, modelers have to resort to prescriptive and generalized approaches to simulate alternative pesticides and application techniques, which would inevitably be inappropriate for many, if not most, of the acres simulated.

The no-practice representation for pesticide management is therefore based on the third type of activity—IPM.

One of the choices for methods of pesticide application on the survey was "spot treatment." Typically, spot treatments apply to a small area within a field and are often treated using a hand-held sprayer. Spot treatment is an IPM practice, as it requires scouting to determine what part of the field to treat and avoids treatment of parts of the field that do not have the pest problem. The reported rate of application for spot treatments was the rate per acre treated. For the baseline simulation, it was assumed that all spot treatments covered 5 percent of the field. Since the APEX model run and associated acreage weight for the sample point represented the whole field, the application rate was adjusted downward to 5 percent of the per-acre rate reported for the baseline scenario. For the no-practice scenario, the pesticide application rate as originally reported was used, simulating treatment of the entire field rather than 5 percent of the field. In the Arkansas-White-Red Basin, there were 15 sample points with spot treatments, representing 1.3 percent of the cropped acres**.**

Partial field treatments were simulated in a manner similar to spot treatments. Partial field treatments were determined using information reported in the survey on the percentage of the field that was treated. (Spot treatments, which are also partial field treatments, were treated separately as described above.) For the baseline scenario, application rates were reduced proportionately according to how much of the field was treated. For the no-practice scenario, the rate as reported in the survey was used, simulating treatment of the entire field. However, this adjustment for the no-practice scenario was only done for partial field treatments on less than one-third of the field, as larger partial field treatments could have been for reasons unrelated to IPM. About 1.1 percent of the cropped acres in the Arkansas-White-Red Basin had partial field treatments of pesticides (15 samples).

The IPM indicator, described in the previous chapter, was used to adjust pesticide application methods and to increase the frequency of applications to represent "no IPM practice." For samples classified as having either high or moderate IPM use, all soil-incorporated pesticide applications in the baseline condition were changed to surface applications in the no-practice scenario. For high IPM cases, the first application event between planting and 30 days before harvest was replicated twice for each crop, 1 week and 2 weeks after its original application. For moderate IPM cases, the first application event was replicated one time for each crop, 1 week after its original application.

No-practice representation of land in long-term conserving cover

The no-practice representation of land in long-term conserving cover is cultivated cropping with no conservation practices in use. For each CRP sample point, a set of cropping simulations was developed to represent the probable mix of management that would be applied if it were cropped. Cropped sample points were matched to each CRP sample point on the basis of slope, soil texture, soil hydrologic group, and geographic proximity. The cropped sample points that matched most closely were used to represent the cropped condition that would be expected at each CRP sample point if the field had not been enrolled in CRP. In most cases, seven "donor" points were used to represent the crops that were grown and the various management activities to represent crops and management for the CRP sample point "as if" the acres had not been enrolled in CRP. The crops and management activities of each donor crop sample were combined with the site and soil characteristics of the CRP point for the no-practice representation of land in long-term conserving cover.

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[15] The APEX model can simulate pesticide applications, but it does not currently include a pest population model that would allow simulation of the effectiveness of pest management practices. Thus, the relative effectiveness of pesticide substitution or changes in other pest management practices cannot be evaluated.

Potential for Using Model Simulation to Assess Alternative Conservation Policy Options

The models and databases used in this study to assess the effects of conservation practices are uniquely capable of being used to simulate a variety of alternative policy options and answers "what if" questions. The simulation models incorporate a large amount of natural resource and management data and account for the physical processes that determine the fate and transport of soil, nutrients, and pesticides. What is new and innovative about the CEAP-Cropland model simulations is that the farming activities represented at each of the individual sample points are based on actual farming activities that are consistent with the specific natural resource conditions at each sample point—climate, soil properties, and field characteristics—thus accounting for the diversity of farming operation activities and natural conditions that exist in the "real world." Moreover, the field-level model results are linked to a regional water quality model that provides a direct connection between activities at the farm field level and offsite water quality outcomes.

While many of the results in this report have implications for policy questions, the primary purpose of the study was to assess the effects of conservation practices. Separate model simulations and scenarios that account for the specific goals of policy would need to be constructed to appropriately address other policy-related issues. Examples of conservation policy issues that could be further explored with the CEAP cropland modeling system include—

- simulation of additional conservation treatment required to meet specific water quality goals, including the extent to which conservation treatment can be used to meet nitrogen and phosphorus reduction goals for the region;
- assessment of the impact of climate change on the performance of existing conservation practices and additional conservation treatment required to maintain the level of water quality in future years;
- determination of the number and kind of acres that would provide the most cost-effective approach to meeting regional conservation program goals, given constraints in budget and staff;
- experimentation with alternatives for new conservation initiatives and the environmental benefits that could be attained;
- simulation of proposed rules for carbon or nutrient trading; evaluation of potential future options for Conservation Reserve Program (CRP) enrollments, including identification of the number and kind of acres that would provide the maximum water quality protection; and
- evaluation and assessment of treatment alternatives for specific environmental issues, such as treatment alternatives for tile-drained acres, treatment alternatives for acres receiving manure, or treatment alternatives to reduce soluble nutrient loss.

Effects of Practices on Fate and Transport of Water

Water is a potent force that interacts with or drives almost all environmental processes acting within an agricultural production system. The hydrologic conditions prevalent in the Arkansas-White-Red Basin are critical to understanding the estimates of sediment, nutrient, and pesticide loss presented in subsequent sections. The APEX model simulates hydrologic processes at the field scale—precipitation, irrigation, evapotranspiration, surface water runoff, infiltration, subsurface flows, and percolation beyond the bottom of the soil profile.

Baseline condition

Precipitation and irrigation are the sources of water for a field. Annual precipitation over the 47-year simulation averaged about 27 inches in this region—35 inches in the eastern portion of the basin and 21 inches in the western portion. (See figs. 7 and 8.) About 6 million cropped acres (20 percent) are irrigated in the Arkansas-White-Red Basin, about 80 percent of which are in the western portion of the basin. As simulated in the models, irrigated crop acres receive about 17 inches of irrigation water per year (table 13).

Nearly all (91 percent) of the land in long-term conserving cover is located in the western portion of the basin. Annual precipitation for these acres is about the same as other non-irrigated acres in the western portion of the region (table 13).

Most of the water that leaves the field is lost through evaporation from the soil and plant surfaces and transpiration by plants (evapotranspiration) (table 14, fig. 15). Evapotranspiration is the dominant loss pathway for all cropped acres in this region. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) On average, about 83 percent of the water loss for cropped acres in this region is through evapotranspiration—75 percent in the eastern portion of the basin and 90 percent in the western portion.

Model results indicate that evapotranspiration losses vary, however, according to soil characteristics and land cover; as shown in figure 16, evapotranspiration ranges from about 50 percent to 100 percent of the total amount of water that leaves the field.

Evapotranspiration for land in long-term conserving cover is slightly less than evapotranspiration for cropped acres in the western portion of the region. The difference is consistent with the difference in precipitation between cropped acres in the western portion and land in long-term conserving cover.

The Ogallala Aquifer—A Decreasing Resource in the High Plains

Much of the High Plains is underlain by a vast reservoir of groundwater known as the Ogallala Aquifer. The aquifer, which extends from South Dakota to Texas, spans an area of nearly 175,000 square miles—an area larger than the State of California. Formation of the aquifer dates back some 10 to 12 million years ago with deposition of sediment over the surface of the present-day High Plains.

Farmers began tapping the Ogallala for irrigation water more than a century ago and intensified withdrawals after World War II. Water from the Ogallala represents about 30 percent of all U.S. groundwater withdrawals for irrigation, and it irrigates more than 25 percent of all U.S. irrigated land. Water from the aquifer is also withdrawn for livestock use, industrial and household purposes. Withdrawals of water from the aquifer have depleted an estimated 6 percent of the water originally stored in the aquifer, according to the U.S. Geological Survey (USGS). The rate of depletion, however, varies significantly from place to place. Although withdrawals have exceeded natural recharge on average, some areas—particularly in Nebraska—have experienced increases in Ogallala groundwater levels.

The area of greatest groundwater depletion underlies the southern portion of the region, with large areas of depletion in Texas and Kansas. Much of this area is in the Arkansas-White-Red Basin. According to USGS, groundwater levels have declined by as much as 234 feet under parts of Texas. As this resource becomes more limited or more expensive to withdraw, the face of agriculture in the region could change as farmers limit irrigated acreage, adopt limited irrigation strategies, or revert to dryland farming.

Table 13. Water sources for cultivated cropland in model simulations of the Arkansas-White-Red Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Cropped acres		
Entire region (30 million acres)				
Non-irrigated acres (24 million acres)				
Average annual precipitation (inches)	27.2	27.2	0.0	0
Irrigated acres (6 million acres)				
Average annual precipitation (inches)	24.2	24.2	0.0	0
Average annual irrigation water applied (inches)	16.7	23.4	6.7	29
Eastern portion of region (11 million acres)				
Non-irrigated acres (108 million acres)				
Average annual precipitation (inches)	34.4	34.4	0.0	0
Irrigated acres (1.2 million acres)				
Average annual precipitation (inches)	43.7	43.7	0.0	0
Average annual irrigation water applied (inches)	16.6	22.7	6.1	27
Western portion of region (19 million acres)				
Non-irrigated acres (14.4 million acres)				
Average annual precipitation (inches)	22.2	22.2	0.0	0
Irrigated acres (4.8 million acres)				
Average annual precipitation (inches)	19.3	19.3	0.0	0
Average annual irrigation water applied (inches)	16.7	23.6	6.9	29
		Land in long-term conserving cover		
Entire region (6 million acres) *				
Average annual precipitation (inches)	20.7	20.7	0.0	0
Average annual irrigation water applied (inches)**	0.0	5.6	5.6	100

* About 91 percent of acres in long-term conserving cover (enrolled in CRP General Signup) are in the western portion of the basin.
**Land in long-term conserving cover was not irrigated, but some farming practices used to simulate a cropped condition to represent the no-practice scenario included irrigation. Values shown in the table for land in long-term conserving cover are averages over all acres, including non-irrigated acres.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 14 subregions.

Table 14. Water loss pathways for cultivated cropland in the Arkansas-White-Red Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Cropped acres		
Entire region (30 million acres)				
Average annual evapotranspiration (inches)	24.6	24.7	0.1	<1
Average annual surface water runoff (inches)	2.4	3.2	0.8	26
Irrigated acres (6 million acres)	2.8	6.2	3.4	55
Non-irrigated acres (24 million acres)	2.3	2.4	0.2	7
Average annual subsurface water flows (inches)	2.6	2.6	0.0	0
Irrigated acres (6 million acres)	4.1	4.7	0.6	13
Non-irrigated acres (24 million acres)	2.3	2.1	-0.2**	-7**
Eastern portion of region (11 million acres)				
Average annual evapotranspiration (inches)	28.0	27.9	-0.1	<1
Average annual surface water runoff (inches)	4.7	5.3	0.6	11
Irrigated acres (1.2 million acres)	9.7	12.3	2.6	21
Non-irrigated acres (10 million acres)	4.1	4.4	0.3	7
Average annual subsurface water flows (inches)	4.6	4.2	-0.4**	-8**
Irrigated acres (1.2 million acres)	10.6	9.4	-1.1**	-12**
Non-irrigated acres (10 million acres)	3.9	3.6	-0.3**	-7**
Western portion of region (19 million acres)				
Average annual evapotranspiration (inches)	22.6	22.8	0.2	1
Average annual surface water runoff (inches)	1.0	2.0	1.0	49
Irrigated acres (4.8 million acres)	1.1	4.7	3.6	77
Non-irrigated acres (14.4 million acres)	1.0	1.1	0.1	7
Average annual subsurface water flows (inches)	1.5	1.7	0.2	12
Irrigated acres (4.8 million acres)	2.4	3.5	1.0	30
Non-irrigated acres (14.4 million acres)	1.2	1.1	-0.1**	-7**
		Land in long-term conserving cover		
Entire region (6 million acres)				
Average annual evapotranspiration (inches)	19.4	21.7	2.3	11
Average annual surface water runoff (inches)	0.4	1.8	1.5	79
Average annual subsurface water flows (inches)*	1.1	1.9	0.8	43

* Subsurface flow pathways include: (1) deep percolation to groundwater, including groundwater return flow; (2) subsurface flow intercepted by tile drains or drainage ditches; (3) lateral subsurface outflow; and (4) quick-return subsurface flow.
** Negative reductions represent an average gain in subsurface flows due to the use of conservation practices.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 14 subregions.

Approximately equal amounts of water are lost through surface water runoff and through subsurface flow pathways in this region (table 14). Subsurface flow pathways include—

1. deep percolation to groundwater, including groundwater return flow to surface water,
2. subsurface flow that is intercepted by tile drains or drainage ditches, when present, and
3. lateral subsurface outflow or quick-return flow that emerges as surface water runoff, such as natural seeps.

Losses of water through surface water runoff and through subsurface flow pathways are much higher in the eastern portion of the region than in the western portion. Surface water runoff losses average 4.7 inches per year in the eastern portion of the region, compared to only 1.0 inch per year in the western portion. Similarly, subsurface water losses average 4.6 inches per year in the eastern portion of the region, compared to only 1.5 inches per year in the western portion (table 14).

Loss of water in subsurface flows averages about 12 percent of water loss for cropped acres in the eastern portion of the basin and 6 percent in the western portion. However, these percentages vary among the acres, as shown in figure 16.

(In figures 15 and 16, the horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same sample point on another curve.)

Surface water runoff is higher for irrigated acres than for non-irrigated acres in the eastern portion of the region, but not in the western portion (table 14).

For land in long-term conserving cover, average annual surface water runoff and losses to subsurface flows are less than but similar to losses for cropped acres in the western portion of the basin (table 14).

Figure 15. Estimates of average annual water lost through three loss pathways for cropped acres in the Arkansas-White-Red Basin, baseline conservation condition

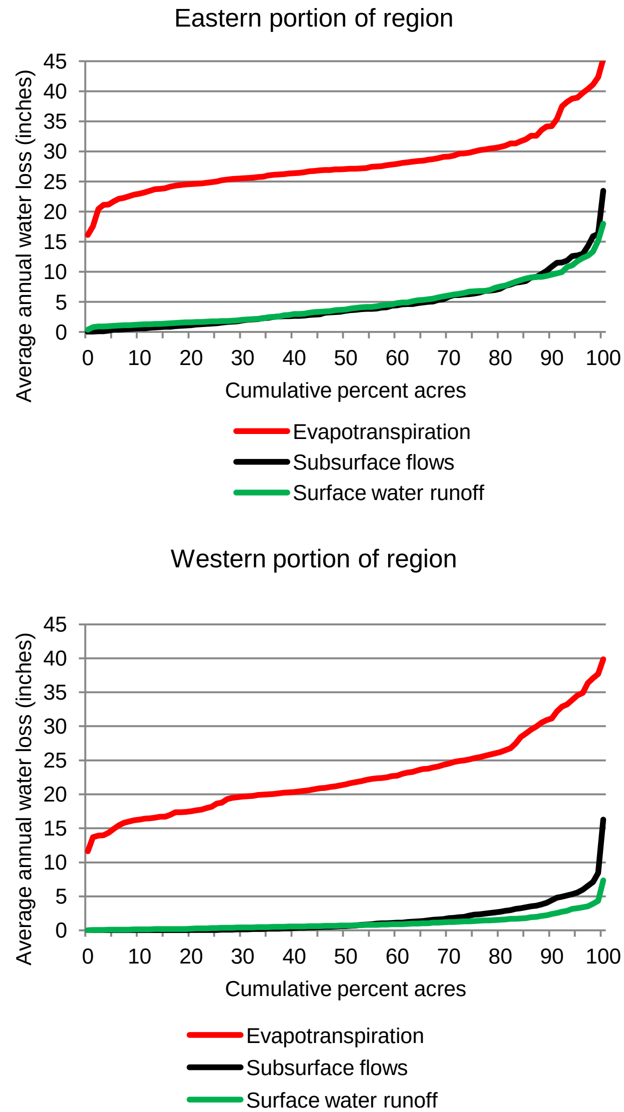
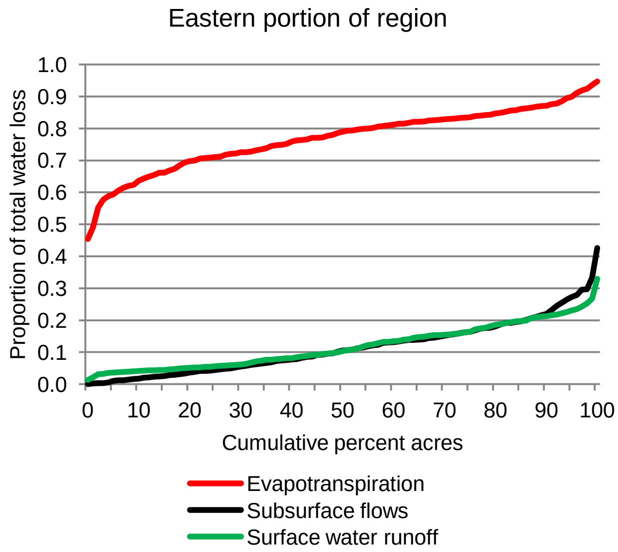
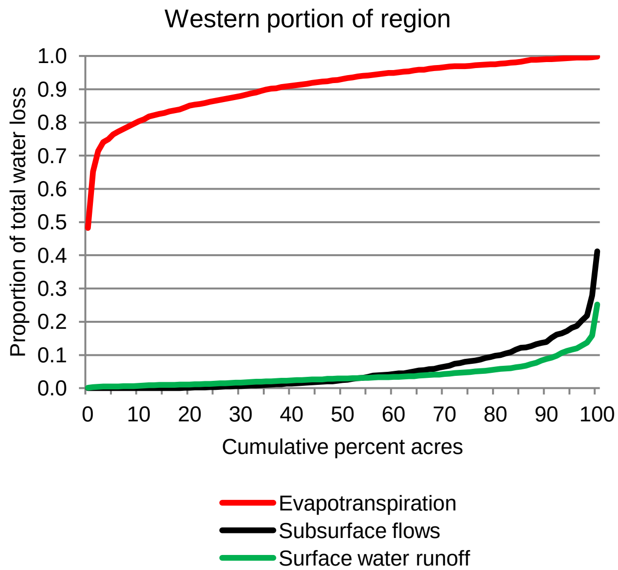


Figure 16. Proportion of water lost through three loss pathways for cropped acres in the Arkansas-White-Red Basin, baseline conservation condition





Tile Drainage

Tile drainage flow is included in the water loss category "subsurface water flows" in this report. (See table 14.) Other components of subsurface water flow include: 1) deep percolation to groundwater, including groundwater return flow to surface water, 2) lateral subsurface flows intercepted by surface drainage ditches, and 3) lateral subsurface outflow or quick-return flow that emerges as surface water runoff, such as natural seeps.

While the farmer survey provided information on whether or not the field with the CEAP sample point had tile drainage, tile drainage flow and loss of soluble nutrients in tile drainage water are not reported separately because other important information on the tile drainage characteristics were not covered in the survey. The missing information includes—

- the depth and spacing of the tile drainage field,
- the extent of the tile drainage network,
- the proportion of the field, or other fields, that benefited from the tile drainage system, and
- the extent to which overland flow and subsurface flow from surrounding areas enters through tile surface inlets.

Without this additional information, it is not possible to accurately separate out the various components of subsurface flow when tile drainage systems are present.

In the Arkansas-White-Red Basin, only about 1 percent of the cropped acres have some portion of the field that is tile drained, according to the farmer survey. In the baseline, about 80 percent of the subsurface flow—as well as the soluble nutrients carried in the subsurface flow—was allocated by the physical process model (APEX) to tile drainage flow for these acres.

Effects of conservation practices

Cropped acres. Structural water erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil.[16] In addition, the less efficient irrigation technologies used to simulate the no-practice scenario result in reductions in irrigation water use for the baseline conservation condition.

Use of improved irrigation systems in the Arkansas-White-Red Basin increases irrigation efficiency from 54 percent in the no-practice scenario to 69 percent in the baseline scenario. This change in efficiency represents an annual decreased need for irrigation water of 6.7 inches per year where irrigation is used (table 13). Irrigation water use savings were slightly higher in the western portion of the basin (6.9 inches for irrigated acres, a 29-percent reduction relative to the baseline) than in the eastern portion (6.1 inches for irrigated acres, representing a 27-percent reduction). These water savings are shown graphically for all irrigated acres in the Arkansas-White-Red Basin in figure 17.

Model simulations indicate that conservation practices have reduced surface water runoff in the region by about 0.8 inch per year averaged over all acres, representing a 26-percent reduction (table 14, fig. 18). The percent reduction was much higher in the western portion (49 percent) than in the eastern portion (11 percent). Most of these reductions in surface water

[16] Model simulations did not include increased infiltration for some structural practices—model parameter settings conservatively prevented infiltration of run-on water and its dissolved contaminants in conservation buffers including field borders, filter strips and riparian forest buffers.

runoff occur for irrigated acres (table 14, fig. 19). For the entire region, conservation practices reduce surface water runoff by 3.4 inches per year, on average, for irrigated acres, compared to only 0.2 inch per year for nonirrigated acres.

Figure 17. Estimates of average annual irrigation water use for irrigated crop acres in the Arkansas-White-Red Basin

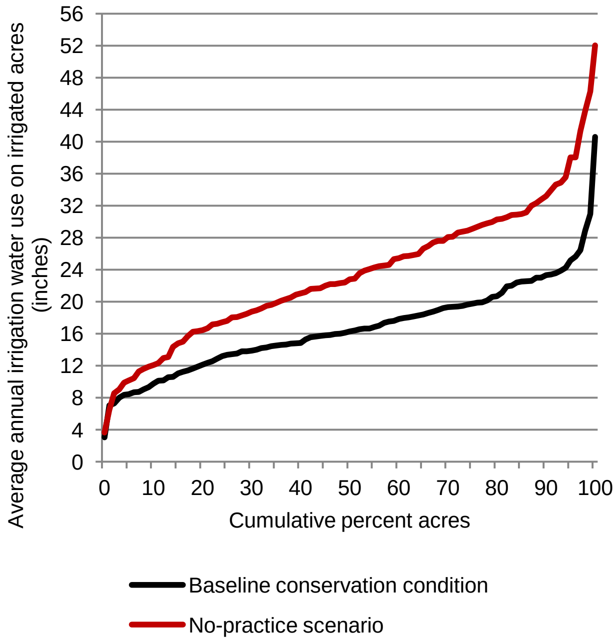
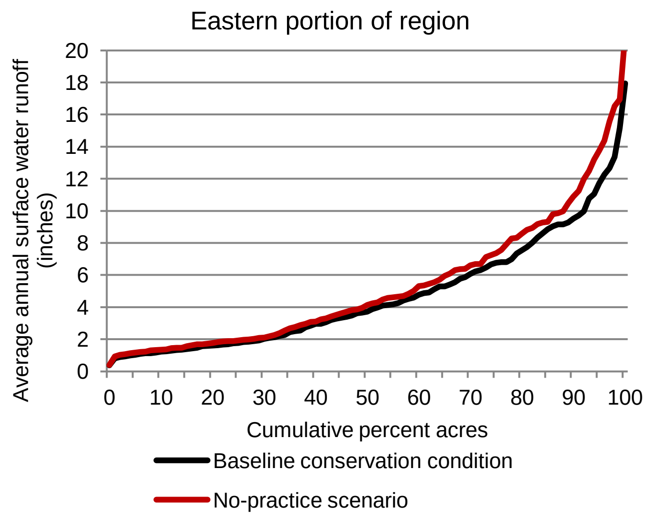


Figure 18. Estimates of average annual surface water runoff for cropped acres in the Arkansas-White-Red Basin



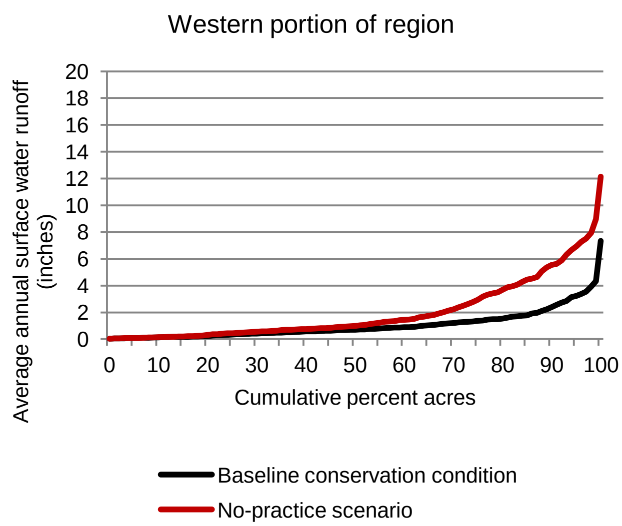
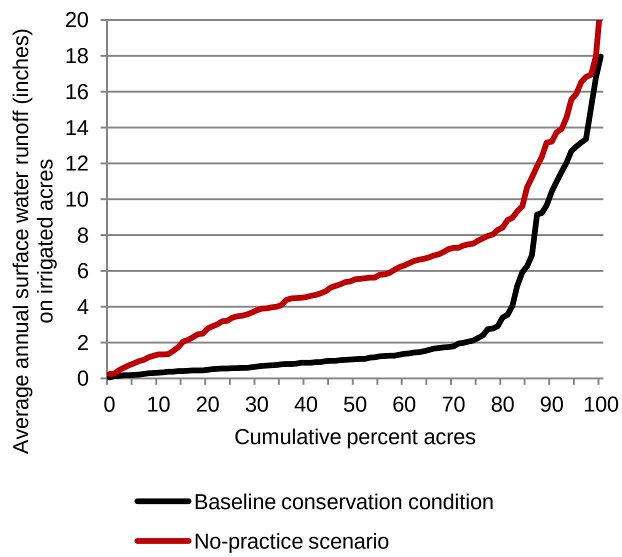


Figure 19. Estimates of average annual surface water runoff for irrigated crop acres in the Arkansas-White-Red Basin



While reductions in surface water runoff due to conservation practices average only 0.8 inch for cropped acres in the region, reductions range from less than zero[17] to about 7 inches per year (fig. 20). The majority of acres exhibit zero or near zero reductions. The larger reductions shown in figure 20 represent irrigated acres.

Subsurface flows are less affected by conservation practices for most acres in this region (fig. 21). As shown in figure 22, conservation practice use produces reductions in subsurface water flows for some acres (shown as negative gains in the figure). For other acres, subsurface water flows have negligible gains, especially in the western portion of the basin. Figure 22 shows a few acres with increases in subsurface flows and a few acres with decreases in subsurface flows, but the majority were unaffected by conservation practice use.

For the region, conservation practice use reduces the volume of subsurface flows by an average of 0.6 inch per year (13 percent reduction) for irrigated acres, but increases the volume of subsurface flows by an average of 0.2 inch per year (7 percent increase) for non-irrigated acres (table 14). In the western portion, conservation practice use reduces the volume of subsurface flows by 30 percent for irrigated acres, on average, and increases the volume for non-irrigated acres by 7 percent. In the eastern portion, conservation practice use increases the volume of subsurface flows by 12 percent for irrigated acres and 7 percent for non-irrigated acres.

Conservation practice use has little effect on average evapotranspiration for cropped acres in this region (table 14).

Figure 20. Estimates of average annual reduction in surface water runoff due to the use of conservation practices on cropped acres in the Arkansas-White-Red Basin

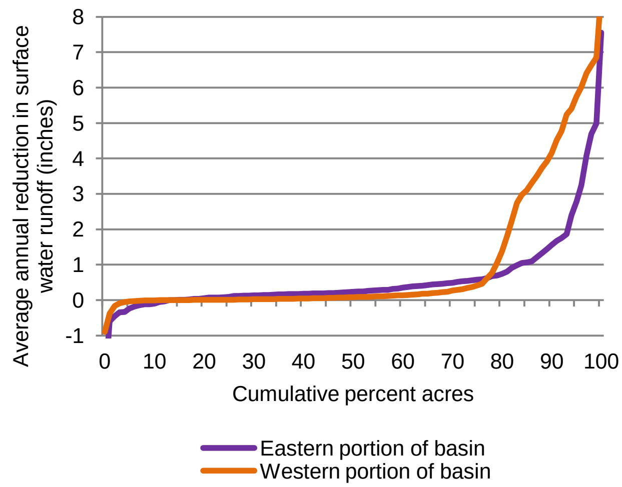


Figure 21. Estimates of average annual subsurface flows for cropped acres in the Arkansas-White-Red Basin

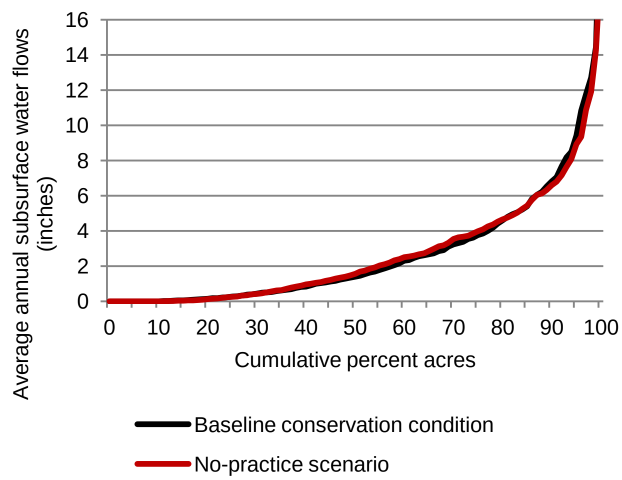
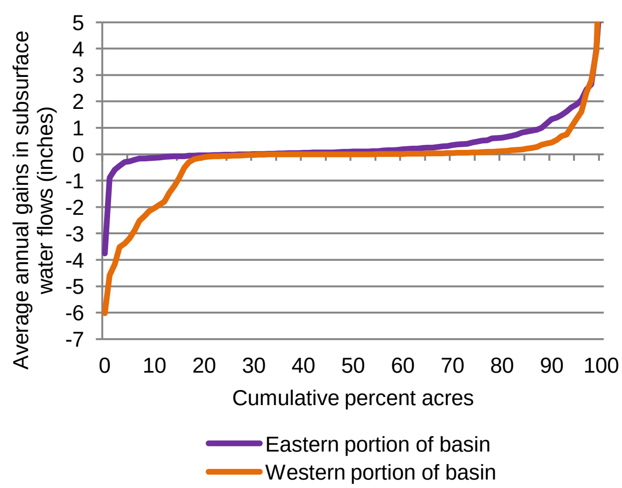


Figure 22. Estimates of average annual gain in subsurface flows due to the use of conservation practices on cropped acres in the Arkansas-White-Red Basin



[17] About 5 percent of cropped acres in the region have less surface water runoff in the no-practice scenario than the baseline, resulting in negative reductions. These gains in surface water runoff when conservation practices are applied can occur on soils with low to moderate potential for runoff when: (1) excessive nutrient application rates in the no-practice scenario produces more biomass, lowering soil moisture and thus reducing runoff, or (2) tillage of the surface soil in the no-practice scenario reduces surface compaction and crusting, producing temporary surface roughness that in turn reduces runoff.

Land in long-term conserving cover. At 6 million acres, land in long-term conserving cover is an important part of the agricultural landscape in the Arkansas-White-Red Basin. The benefits of this conservation "practice" were estimated by simulating crop production (without use of conservation practices) on each sample point from the NRI that represented acres enrolled in the Conservation Reserve Program General Sign-up. The soil characteristics and weather used in the simulation were taken from the NRI sample points and combined with farming activities, including crops grown, from similar acres in the CEAP dataset for cropped acres, as described earlier in this chapter.

Reductions in surface water runoff due to conversion to long-term conserving cover average 1.5 inches per year in this region, representing an average annual reduction of 79 percent for these acres (table 14). As shown in figure 23, however, per-acre reductions vary from very small amounts in the drier parts of the basin to reductions of 8 inches or more on other acres.

Reductions in subsurface water flows due to conversion to long-term conserving cover average 0.8 inch per year, representing an average annual reduction of 43 percent (table 14). However, long-term conserving cover reduces the volume of water lost from the field in subsurface flow pathways for only about half of the acres, as indicated in figure 24 by negative gains. Conversion of cultivated cropland to long-term conserving cover has no effect on subsurface flows for another 40 percent of the acres, and results in gains in subsurface flows for about 10 percent of the acres.

Figure 23. Estimates of average annual reduction in surface water runoff due to conversion to long-term conserving cover in the Arkansas-White-Red Basin

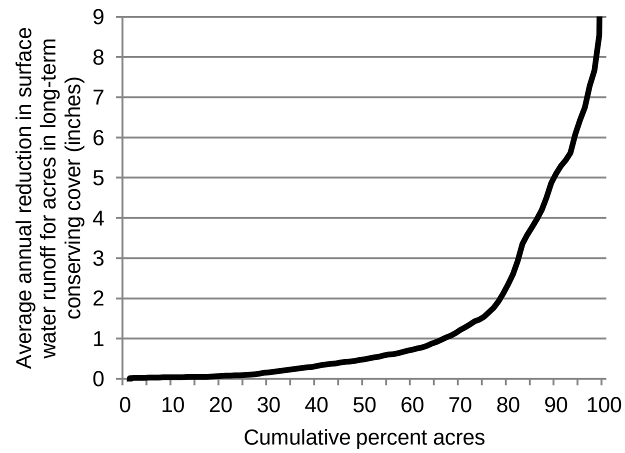
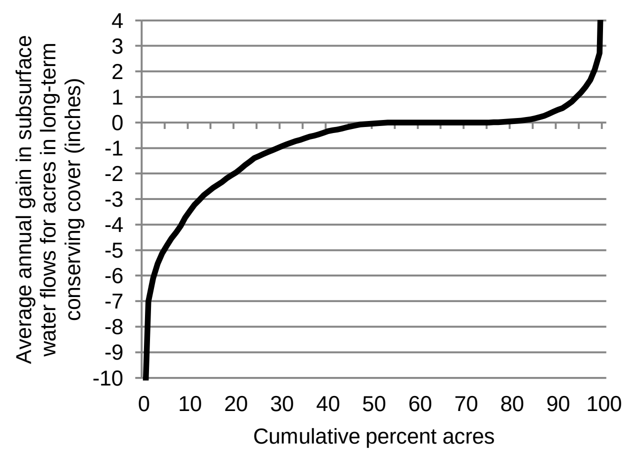


Figure 24. Estimates of average annual gain in subsurface flows due to conversion to long-term conserving cover in the Arkansas-White-Red Basin



Cumulative Distributions Show How Effects of Conservation Practices Vary Throughout the Region

The design of this study provides the opportunity to examine not only the overall mean value for a given outcome, but also the entire distribution of outcomes. This is possible because outcomes are estimated for each of the 1,280 sample points used to represent cropped acres in the Arkansas-White-Red Basin and for each of the 1,871 sample points used to represent land in long-term conserving cover. Cumulative distributions show the full set of estimates and thus demonstrate how conditions and the effects of conservation practices vary throughout the region.

Cumulative distributions shown in this report are plots of the value for each percentile. In figure 18, for example, the curve for average annual surface water runoff for the baseline conservation condition, eastern portion of the basin, consists of each of the percentiles of the distribution of 462 surface water runoff estimates for the eastern portion of the basin, weighted by the acres associated with each sample point. The 10^{th} percentile for the baseline conservation condition is 1.2 inches per year, indicating that 10 percent of the acres have 1.2 inches or less of surface water runoff, on average. Similarly, the same curve shows that 25 percent of the acres have surface water runoff less than 1.8 inches per year. The 50^{th} percentile—the median—is 3.7 inches per year, compared to the mean value of 4.7 inches per year from table 14. At the high end of the distribution, 90 percent of the acres in this region have surface water runoff less than 9.5 inches per year; and conversely, 10 percent of the acres have surface water runoff greater than 9.5 inches per year.

Thus, the distributions show the full range of outcomes for cultivated cropland acres in the Arkansas-White-Red Basin. The full range of outcomes for the baseline condition is compared to that for the no-practice scenario in figure 18 to illustrate the extent to which conservation practices reduce surface water runoff throughout the region.

Figure 20 shows the effects of conservation practices on surface water runoff using the distribution of the *reduction* in surface water runoff, calculated as the outcome for the no-practice scenario minus the outcome for the baseline conservation condition at each of the sample point. The distribution for the eastern portion of the basin shows that, while the mean reduction is 0.6 inch per year (table 14), 16 percent of the acres have reductions due to conservation practices greater than one inch per year and about 10 percent of the acres actually have small increases in surface water runoff (i.e., negative reductions) as a result of conservation practice use.

Effects of Practices on Wind Erosion

Wind velocity, tillage, vegetative cover, and the texture and structure of the soil are primary determinants of wind erosion. Wind erosion removes the most fertile parts of the soil such as the lighter, less dense soil constituents including organic matter, clays, and silts. Wind erosion occurs when the soil is unprotected and wind velocity exceeds about 13 miles per hour near the surface. Wind erosion is estimated in APEX using the Wind Erosion Continuous Simulation (WECS) model. The estimated wind erosion rate is the amount of eroded material leaving the downwind edge of the field.

Wind erosion is a significant resource concern for some cropped acres in the Arkansas-White-Red Basin. A concern of crop producers with wind erosion is crop damage to young seedlings exposed to windblown material. Wind erosion rates as low as 0.5 ton per acre have caused physical damage to young seedlings. Wind erosion can also deposit sediment rich in nutrients into adjacent ditches and surface drainage systems, where it is then transported to water bodies with runoff. Wind erosion rates greater than 2 tons per acre per year can result in significant losses of soil and associated contaminants over time. Wind erosion rates greater than 4 tons per acre can result in excessive soil loss annually and can also have adverse effects on human health.

Baseline condition

For all cropped acres, model simulations show that the average annual rate of wind erosion is 2.17 tons per acre (table 15). Wind erosion is higher in the western portion of the basin, averaging 2.82 tons per acre. Wind erosion in the eastern portion of the region averages 1.05 tons per acre, which is still high enough to be of concern.

Figure 25 shows the annual variability in wind erosion for the region. During some years and for some acres, wind erosion rates can be very high. Wind erosion rates exceed 4 tons per acre in at least some years for up to 23 percent of the acres in the region, and exceed 2 tons per acre in some years for up to 35 percent of the acres. Figure 25 also shows, however, that the majority of acres in the region do not have excessive wind erosion; about 50 percent of cropped acres have wind erosion rates less than 1 ton per acre in all years.

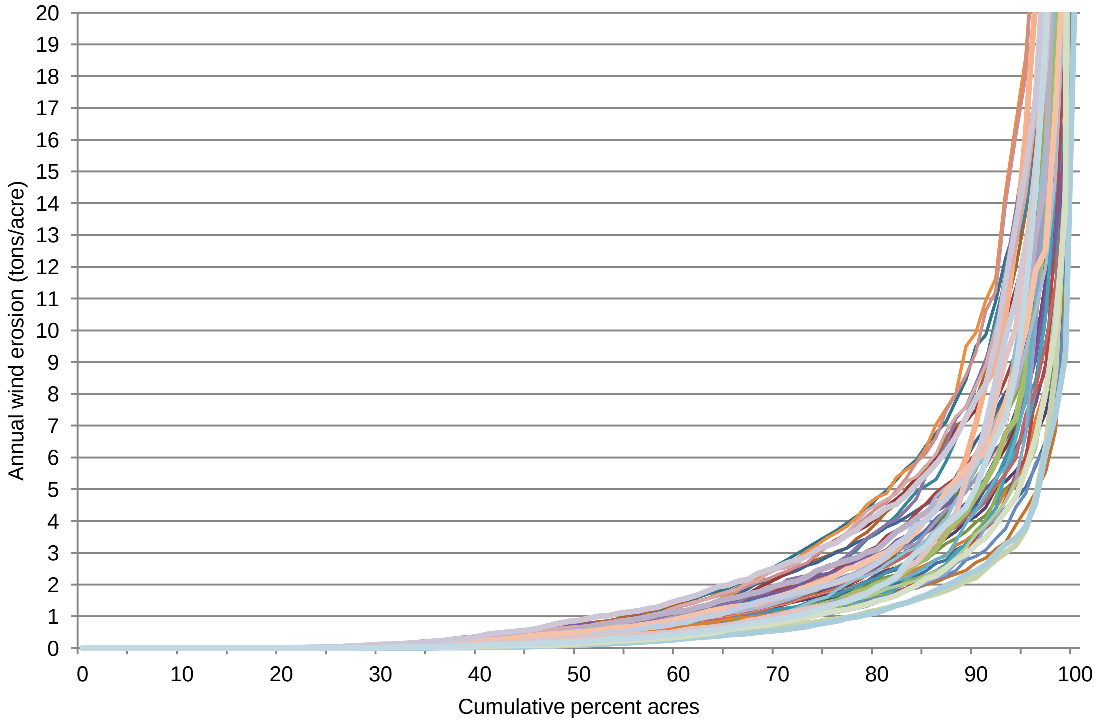
Wind erosion on land in long-term conserving cover is negligible (table 15).

Table 15. Average annual wind erosion (tons/acre) for cultivated cropland in the Arkansas-White-Red Basin

	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres				
Entire region (30 million acres)	2.17	3.13	0.96	31
Eastern portion of region (11million acres)	1.05	1.33	0.27	21
Western portion of region (19 million acres)	2.82	4.18	1.37	33
Land in long-term conserving cover				
Entire region (6 million acres)	<0.01	0.52	0.52	100

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 14 subregions.

Figure 25. Distribution of annual wind erosion rate for each year of the 47-year model simulation, Arkansas-White-Red Basin



Note: This figure shows how annual wind erosion (tons per acre per year) varies within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual wind erosion varies over the region in that year, starting with the acres with the lowest rates and increasing to the acres with the highest rates. The family of curves shows how annual wind erosion rates vary from year to year.

Costs of Excessive Wind Erosion

Wind erosion represents a major natural resource problem in the western United States. Of the estimated annual 2 billion tons of cropland soil loss by wind, approximately 88 percent occurs in the Western States. During a windstorm, the very fine windblown soil material becomes suspended in the atmosphere and may travel many miles before being deposited back to the surface. Windblown sediment is often deposited in drainage ditches, where it is then easily transported into rivers and streams with surface water runoff. Windblown material originating from cropland is generally rich in nutrients and can contain pesticides and other contaminants.

Programs and mitigating practices are traditionally designed and paid for on the basis of losses in soil productivity, crop quality and yield, and other on-farm economic impacts. But the full costs of wind erosion also include offsite damages. The two most obvious offsite impacts relate to maintenance of roadside ditches and reduced visibility on highways, sometimes resulting in accidents and fatalities. Other impacts include human health issues associated with impaired air quality and costs related to clean up and repair and replacement of equipment and facilities (Huszar 1989). In a study of offsite costs of wind erosion in New Mexico, offsite costs were estimated to average over $400 million per year, dwarfing the $10 million per year onsite damages estimated by other studies (Davis 1989). The annual offsite wind erosion costs for all the western states are estimated at between $3.76 and $12.08 billion (Huszar 1989).

Effects of conservation practices

Farmers address wind erosion using conservation practices designed to enhance the soil's ability to resist and reduce the wind velocity near the soil surface. Properly planned and applied residue management reduces wind erosion by leaving more organic material on the soil surface, which in turn helps preserve soil aggregate stability and promotes further aggregation. Physical barriers such as windbreaks or shelterbelts, herbaceous wind barriers or windbreaks, cross wind trap strips, or ridges constructed perpendicular to the prevailing wind direction also reduce the intensity of wind energy at the surface. Row direction or arrangement, surface roughening, and stripcropping also lessen the wind's energy.

Structural practices for wind erosion control are in use on 6 percent of the cropped acres in the Arkansas-White-Red Basin. Other practices common in the region, such as residue and tillage management, reduced tillage, and various water erosion control practices, are also effective in reducing wind erosion.

Model simulations indicate that conservation practices have reduced the average wind erosion rate for the region by 31 percent (table 15, fig. 26). Reductions in wind erosion on cropped acres are much higher in the western portion of the basin than in the eastern portion, as shown in figure 27. On average, conservation practices have reduced wind erosion by 1.37 tons per acre in the western portion of the basin (33 percent reduction) and by 0.27 ton per acre in the eastern portion (21 percent reduction). Figure 27 shows, however, that reductions in wind erosion due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil.[18]

Wind erosion on land in long-term conserving cover has essentially been eliminated, representing per-acre reductions averaging 0.5 ton per acre per year compared to a cropped condition for those acres (table 15).

Figure 26. Estimates of average annual wind erosion for cropped acres in the Arkansas-White-Red Basin

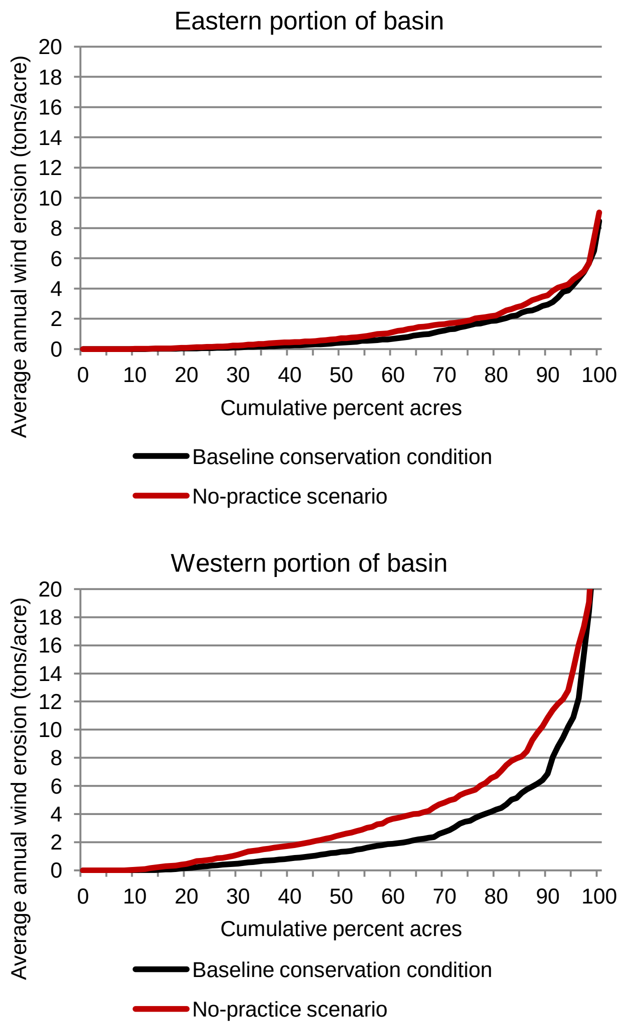
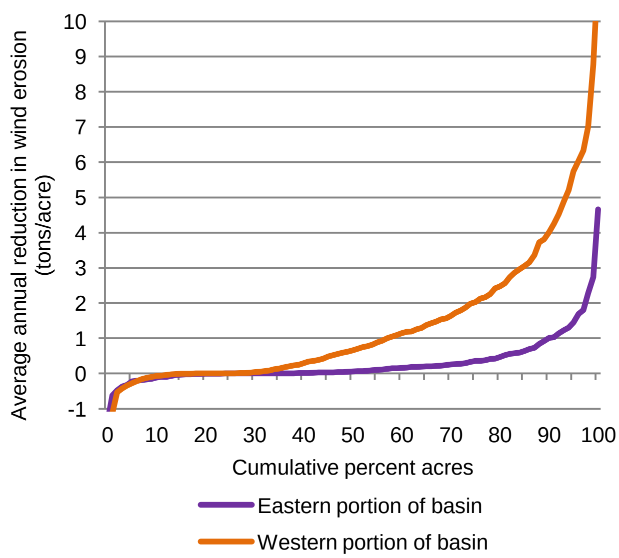


Figure 27. Estimates of average annual reduction in wind erosion due to the use of conservation practices on cropped acres in the Arkansas-White-Red Basin



[18] For a small number of acres (10 percent of cropped acres in both the eastern and western portions), wind erosion was slightly higher in the baseline condition than in the no-practice scenario, resulting in small negative reductions shown in figure 27. This condition can occur on some acres because of the higher fertilization rates used to simulate the no-practice scenario, which can result in more vegetative cover protecting the soil from the forces of the wind.

Effects of Practices on Water Erosion and Sediment Loss

Sheet and rill erosion

Forms of water erosion include sheet and rill, ephemeral gully, classical gully, and streambank. Each type is associated with the progressive concentration of runoff water into channels leading downslope. The first stage is sheet and rill erosion, which can be modeled using the Universal Soil Loss Equation (USLE). Sheet and rill erosion is the detachment and movement of soil particles within the field that occurs during rainfall events. Controlling sheet and rill erosion is important for sustaining soil productivity and preventing soil from leaving the field.

Model simulations show that sheet and rill erosion on cropped acres in the Arkansas-White-Red Basin averages about 0.52 ton per acre per year (table 16). Sheet and rill erosion rates are higher in the eastern portion of the basin, averaging 0.94 ton per acre per year, than in the western portion, averaging only 0.28 ton per acre.

Model simulation results also show that conservation practices have reduced sheet and rill erosion on cropped acres in the Arkansas-White-Red Basin by an average of 0.29 ton per acre per year, representing a 35-percent reduction on average (table 16). Percent reductions were about the same in the eastern and western portions of the basin, but the magnitude of the reduction in sheet and rill erosion is much higher in the eastern portion.

For land in long-term conserving cover, sheet and rill erosion has been reduced from 0.51 ton per acre per year if cropped without conservation practices to 0.02 ton per acre (table 16), on average.

Sediment loss from water erosion

Soil erosion and sedimentation are separate but interrelated resource concerns. Sedimentation is that portion of the eroded material that settles out in areas onsite or offsite. Sediment loss, as estimated in this study, includes the portion of the sheet and rill eroded material that is transported beyond the edge of the field and settles offsite as well as some sediment that originates from gully erosion processes. Sediment is composed of detached and transported soil minerals, organic matter, plant and animal residues, and associated chemical and biological compounds. Edge-of-field conservation practices are designed to filter out a portion of the material and reduce sediment loss.

For this study, the APEX model was set up to estimate sediment loss using a modified version of MUSLE, called MUST (not MUSS, as was mistakenly reported in the CEAP reports on the Chesapeake Bay, the Great Lakes, and the Ohio-Tennessee River Basins).[19] The model variant called MUST uses an internal sediment delivery ratio to estimate the amount of eroded soil that actually leaves the boundaries of the field. A large percentage of the eroded material is redistributed and deposited within the field or trapped by buffers and other conservation practices and does not leave the boundary of the field, which is taken into account in the sediment delivery calculation. *The estimate also includes some gully erosion and some ephemeral gully erosion. For this reason, sediment loss rates can exceed sheet and rill erosion rates.*

Estimates of sediment loss from water erosion do not include wind-eroded material that is subsequently deposited along field borders or in ditches and transported as sediment with rainfall and runoff events. The current state of water erosion modeling does not include sediment displaced from the field by wind. (Wind eroded material incorporated into the soil with tillage or biological activity prior to a runoff event would be included, however.) Wind-eroded material can be an important source of sediment delivered to rivers and streams in this region.

Baseline condition for cropped acres. The average annual sediment loss for cropped acres in the Arkansas-White-Red Basin is relatively low compared to other regions of the country, averaging only 0.34 ton per acre per year for the entire region, according to the model simulation (table 16). Sediment loss is highest in the eastern portion of the basin, averaging 0.70 ton per acre, compared to an average of 0.13 ton per acre in the western portion.

On an annual basis, however, sediment loss can be high for some acres. Figure 28 shows that, with the conservation practices currently in use in the Arkansas-White-Red Basin, annual sediment loss can exceed 2 tons per acre for about 10 percent of the acres in one or more years. Figure 28 also shows that nearly 80 percent of cropped acres would have low levels of sediment loss (less than 1 ton per acre) under all conditions, including years with high precipitation.

Soil loss due to water erosion is much lower than soil loss due to wind erosion in this region, as can be seen by comparing figure 28 to figure 25. (Both figures are drawn to the same scale for comparison.) The comparison also shows that, for both wind erosion and water erosion, erosion concerns are low or negligible for the majority of cropped acres in the region, even during years with high or low precipitation. Acres with high soil loss are restricted to a minority of acres within the region that have the highest inherent vulnerability for erosion and have inadequate soil erosion control practices in place.

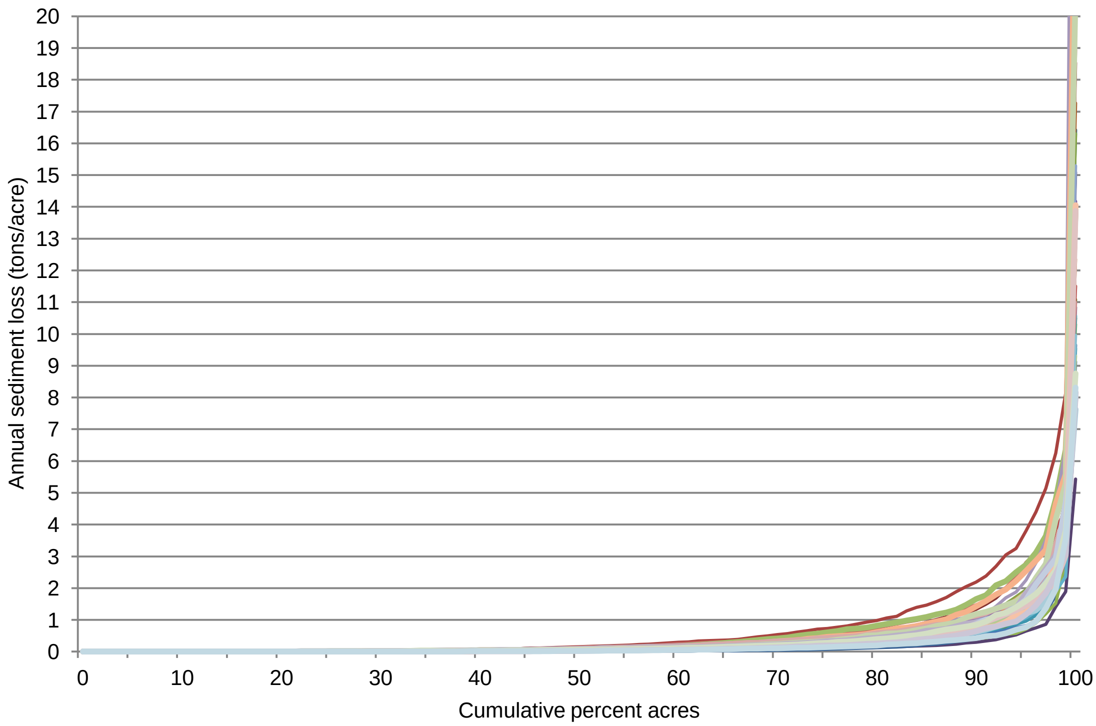
[19] APEX provides a variety of options for modeling erosion and sedimentation, including USLE, RUSLE, MUSS, MUSLE, and MUST. MUST is the most appropriate choice for simulation of sediment loss for small areas (less than 1 hectare, for example).

Table 16. Field-level effects of conservation practices on erosion and sediment loss for cultivated cropland in the Arkansas-White-Red Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Cropped acres		
Entire region (30 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.52	0.81	0.29	35
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.34	0.87	0.53	61
Eastern portion of region (11 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.94	1.47	0.53	36
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.70	1.43	0.73	51
Western portion of region (19 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.28	0.42	0.14	34
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.13	0.55	0.42	76
		Land in long-term conserving cover		
Entire region (6 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.02	0.51	0.49	96
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.01	0.58	0.58	99

* Estimated using the Revised Universal Soil Loss Equation.
**Estimated using MUST, which includes some sediment from gully erosion. See text.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 14 subregions.

Figure 28. Distribution of annual sediment loss for each year of the 47-year model simulation, Arkansas-White-Red Basin



Note: This figure shows how annual sediment loss (tons per acre per year) varies within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual sediment loss varies over the region in that year, starting with the acres with the lowest sediment loss and increasing to the acres with the highest sediment loss. The family of curves shows how annual sediment loss varies from year to year.

Figure 29. Estimates of average annual sediment loss for cropped acres in the Arkansas-White-Red Basin

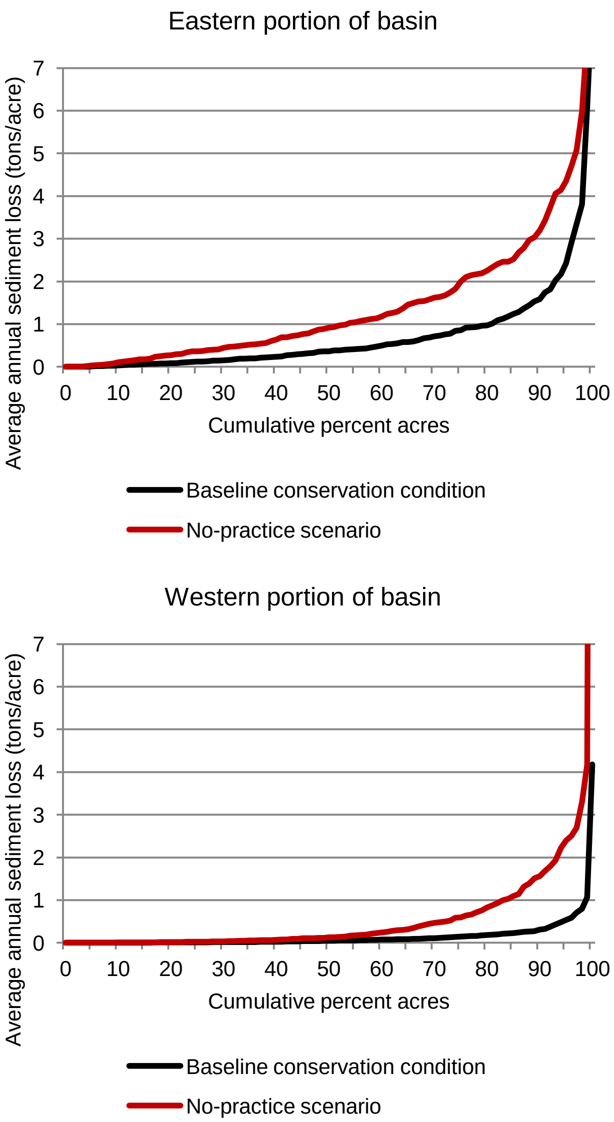
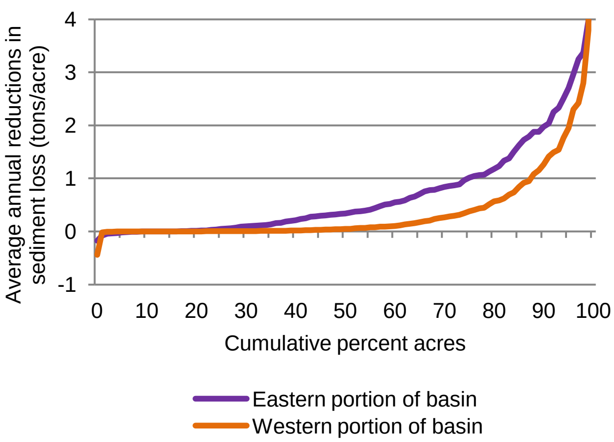


Figure 30. Estimates of average annual reduction in sediment loss due to the use of conservation practices on cropped acres in the Arkansas-White-Red Basin



Note: About 1 percent of the acres had less sediment loss in the no-practice scenario than the baseline conservation condition, resulting from the increase is surface water runoff on some acres due to conservation practices. (See figure 20.)

Effects of conservation practices on cropped acres. Without conservation practices, sediment loss would be a significant issue in some parts of the basin, as shown in figure 29. Model simulations indicate that the use of conservation practices in the Arkansas-White-Red Basin has reduced average annual sediment loss from water erosion in the eastern portion of the basin by an average of 0.73 ton per acre per year, representing a 51-percent reduction. Conservation practices were also effective in reducing sediment loss in the western portion of the basin, where sediment loss was reduced 76 percent, on average, even though loss levels were much lower for most acres (table 16).

Reductions in sediment loss due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil. Figure 30 shows that reductions greater than 1 ton per acre per year in the western portion of the basin are restricted to the 12 percent of cropped acres with the highest vulnerability to sediment loss. In the eastern portion, reductions in sediment loss were greater than 1 ton per acre for about 25 percent of cropped acres (figure 30).

Land in long-term conserving cover. Acres in long-term conserving cover have very little erosion or sediment loss, and thus show nearly 100-percent reductions when compared to a cropped condition (table 16). If these 6 million acres were still being cropped without any conservation practices, sediment loss would average about 0.58 ton per acre per year for these acres (table 16).

Effects of Practices on Soil Organic Carbon

The landscape and climate in the Arkansas-White-Red Basin is more conducive to maintaining and enhancing soil organic carbon in the eastern portion of the basin but less so in the western portion.

Soils are more fertile and precipitation is higher in the eastern portion of the basin than in the western portion. Soil organic carbon levels in the eastern portion of the basin are somewhat higher than those of the west due to this increased rainfall but tend to be much less than those in the Upper Mississippi and Missouri River Basins. The warmer climate and increased occurrence of low residue crops such as cotton decrease the ability of these soils to maintain or enhance carbon stores. Additionally, the hotter summer temperatures, especially at night contribute to reduce the production potential of the higher residue crops like corn, thereby further reducing the carbon sequestration in these soils.

The western portion of the basin occurs primarily in the Central and Western Great Plains Land Resource regions and is dominated by wheat and other small grain production along with dryland and irrigated cotton. It receives 14 inches per year less rainfall than the eastern portion, on average. These dry conditions strongly influence the amount of biomass production potential. The soils in the western portion developed under short and mid-grass prairies and are generally shallower than in the eastern portion. The drier climate and lower biomass production potential makes it more difficult for the residue management cropping systems in the western portion to accumulate carbon. The drier climate also slows biological degradation, however, and soil organic carbon can accumulate in soils when disturbance by tillage is minimal.

In this study, estimation of soil organic carbon change is based on beginning soil characteristics that reflect the effects of years of traditional conventional tillage practices and older, lower yielding crop varieties. These effects generally resulted in soils with organic carbon levels at or near their low steady state. Modern high-yielding crop varieties with and without the adoption of conservation tillage tend to readily improve the status of carbon in many soils, especially those with beginning stocks far less than the steady state representation of the present management. Beginning the simulations at a lower steady state for carbon allows for a more equitable comparison of conservation practices, particularly conservation tillage. Because of this, model estimates of soil organic carbon change may be somewhat larger than shown in other studies. Nevertheless, model estimates obtained in this study fall within the expected range for the continuum of adoption of new crop genetics and tillage practices.

Baseline condition for cropped acres

Model simulation shows that average soil organic carbon change for cropped acres is small and negative; the average loss for the region is 48 pounds per acre per year for the baseline conservation condition (table 17). Only about 29 percent of cropped acres in the eastern portion of the basin are gaining soil organic carbon (fig. 31), and only about 32 percent of cropped acres in the western portion of the basin are gaining soil organic carbon. For the region as a whole, 31 percent of cropped acres are gaining soil organic carbon.

These estimates account for losses of carbon with sediment removed from the field by wind and water erosion. Loss of soil organic carbon due to wind and water erosion averages about 116 pounds per acre per year for the baseline conservation condition in the eastern portion of the basin and 127 per acre per year in the western portion (table 17).

Cropped acres that are gaining soil organic carbon every year provide soil quality benefits that enhance production and reduce the potential for sediment, nutrient, and pesticide losses. Soil organic carbon improves the soil's ability to function with respect to nutrient cycling, improves water holding capacity, and reduces erodibility through enhanced soil aggregate stability.

Given the challenging nature of the inherent conditions in some parts of this region, maintenance of soil organic carbon is also an important benchmark. Cropping systems can be considered to be maintaining soil organic carbon if average annual losses do not exceed 100 pounds per acre per year; this rate of change is typically too small to detect via typical soil sampling over a 20-year period. Applying this criterion, about 37 percent of the acres in the western portion of the basin and 38 percent in the eastern portion would be considered to be maintaining (but not enhancing) soil organic carbon. A total of 69 percent of the acres in the western portion of the basin and 67 percent in the eastern portion would be either maintaining or enhancing soil organic carbon (fig. 31).

Effects of conservation practices on cropped acres

Without conservation practices, the annual change in soil organic carbon would be an average loss of 54 pounds per acre per year for the entire region, compared to an average loss of 48 pounds per acre for the baseline (table 17). Thus, conservation practices in the region have resulted in an average annual gain in soil organic carbon of 6 pounds per acre per year on cropped acres. The average gain in the western portion of the basin due to conservation practices is somewhat higher—14 pounds per acre per year. However, in the eastern portion of the basin conservation practices have resulted in a small *reduction* in soil organic carbon of about 8 pounds per acre, on average. The difference in trends is quite small and well within margins of error, but the slight decreases in carbon in the eastern portion when conservation practices are added are likely a result of reduced nitrogen application with proper nutrient management.

The effects of conservation practices on the long-term average annual change in soil organic carbon varies considerably among acres in the region, as shown in figure 32. Some acres have gains of over 100 pounds per acre per year due to practices, while other acres have losses in excess of 100 pounds per acre. The extent to which residue and nutrient management is used as well as the soil's potential to sequester carbon and the extent and kind of other conservation practice use are responsible for these differences.

For the entire region, the 31 percent of acres gaining soil organic carbon have an average annual gain of 91 pounds per acre per year in the baseline conservation condition. If conservation practices were not in use, slightly more (34 percent) of the acres would be gaining soil organic carbon but the annual rate of gain would be slightly less (88 pounds per acre per year) on those acres.

Some of the increased gain in soil organic carbon due to conservation practices is the result of soil erosion control—keeping soil organic carbon on the field promotes soil quality. Residues are not only key in increasing soil organic carbon, they are also vital as physical protection against erosion losses. If conservation practices were not in use, loss of soil organic carbon due to wind and water erosion would average 162 pounds per acre per year over the entire region, compared to 123 pounds per acre per year with conservation practices (table 17). This represents an average reduction due to practices of 24 percent—19 percent in the eastern portion of the basin and 27 percent in the western portion.

For air quality concerns, the analysis centers on the decrease in carbon dioxide emissions. Soils gaining carbon are obviously diminishing emissions, but so are soils that continue to lose carbon but at a slower rate. For all cropped acres, the gain in soil organic carbon of 6 pounds per acre per year due to conservation practice use is equivalent to a carbon dioxide emission reduction of 0.3 million U.S. tons of carbon dioxide for the Arkansas-White-Red Basin.

Table 17. Field-level effects of conservation practices on soil organic carbon for cultivated cropland in the Arkansas-White-Red Basin

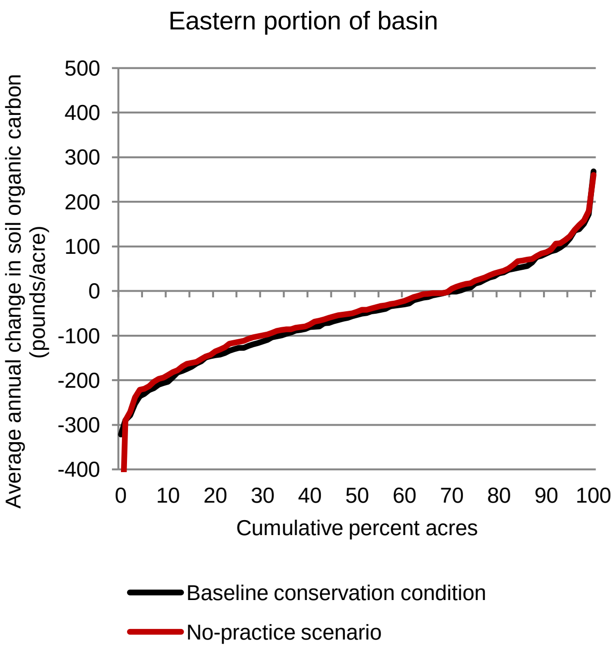
Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Cropped acres		
Entire region (30 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	123	162	39	24%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-48	-54	6*	--
Eastern portion of region (11 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	116	143	27	19%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-56	-48	8	--
Western portion of region (19 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	127	174	46	27%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-43	-57	14*	--
		Land in long-term conserving cover		
Entire region (6.0 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	6	56	50	88%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	88	7	81*	--

***** Gain in soil organic carbon due to conservation practices. In the eastern portion, a small reduction in the change in soil organic carbon occurs with the use of conservation practices.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 14 subregions.

Figure 31. Estimates of average annual change in soil organic carbon for cropped acres in the Arkansas-White-Red Basin



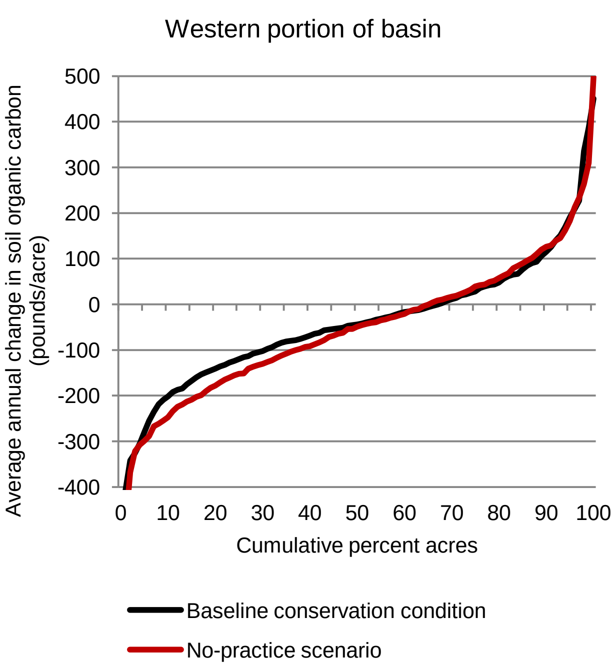
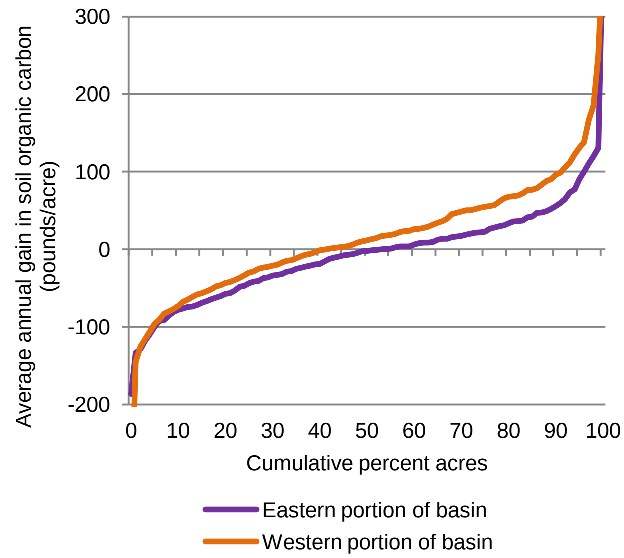


Figure 32. Estimates of average annual gain in soil organic carbon due to the use of conservation practices on cropped acres in the Arkansas-White-Red Basin



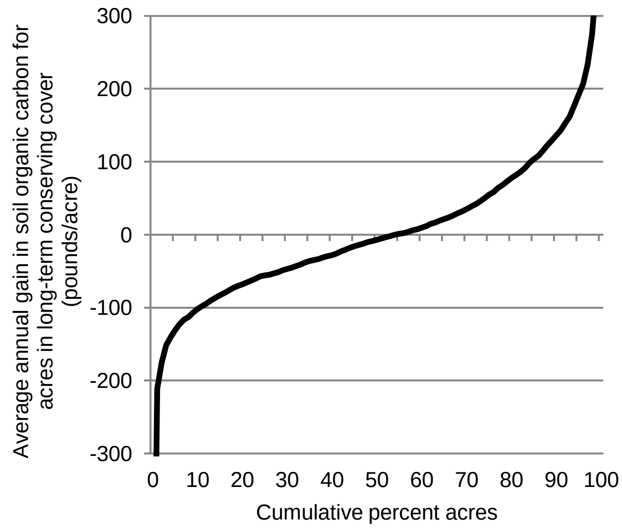
Note: Some acres in each portion of the basin lose soil organic carbon due to use of conservation practices, indicated in the figure by negative gains—53 percent and 41 percent of cropped acres in the eastern and western portions, respectively. For these acres, soil organic carbon increases in the no-practice scenario are higher than in the baseline conservation condition because of the higher fertilization rates, including manure application rates, used in the no-practice scenario to simulate the effects of nutrient management practices.

Land in long-term conserving cover

For land in long-term conserving cover, the annual gain in soil organic carbon for the baseline conservation condition averages 88 pounds per acre per year (table 17). If these acres were still being cropped without any conservation practices, the annual average change in soil organic carbon would be a gain of 7 pounds per acre per year. Thus, for these 6 million acres, the gain in soil organic carbon averages 81 pounds per acre compared to a cropped condition without conservation practices. Gains vary throughout the region, as shown in figure 33.

These gains are equivalent to a carbon dioxide emission reduction of 1.6 million U.S. tons of carbon dioxide for the region. However, the rate of emission reduction due to conservation practices varies considerably among acres in long-term conserving cover, as indicated by the wide range of average annual gains in soil organic carbon shown in figure 33.

Figure 33. Estimates of average annual gain in soil organic carbon due to conversion to long-term conserving cover in the Arkansas-White-Red Basin



Note: About 54 percent of the acres have decreases in annual carbon gain compared to a cropped condition. Biomass production under long-term conserving cover is typically nitrogen limited. The higher biomass production and resulting crop residue from the fertilization of cropped acres can exceed the carbon benefits of long-term conserving cover under some conditions.

Effects of Practices on Nitrogen Loss

Baseline condition for cropped acres

Plant-available nitrogen sources include application of commercial fertilizer, application of manure, nitrogen produced by legume crops (soybeans, alfalfa, dry beans, and peas), a small amount of manure deposited by grazing livestock, and atmospheric nitrogen deposition. On average, these sources provide about 88 pounds of nitrogen per acre per year for cropped acres in the Arkansas-White-Red Basin (table 18). Nitrogen sources are higher in the eastern portion of the basin, averaging 107 pounds per acre per year compared to an average of 76 pounds per acre per year in the western portion. Nitrogen from biofixation is much lower in the western portion because of the fewer acres of legume crops compared to the eastern portion.

Model simulations show that about 72 percent of these nitrogen sources are taken up by the crop and removed at harvest in the crop yield, on average, and the remainder is lost from the field through various loss pathways.[20]

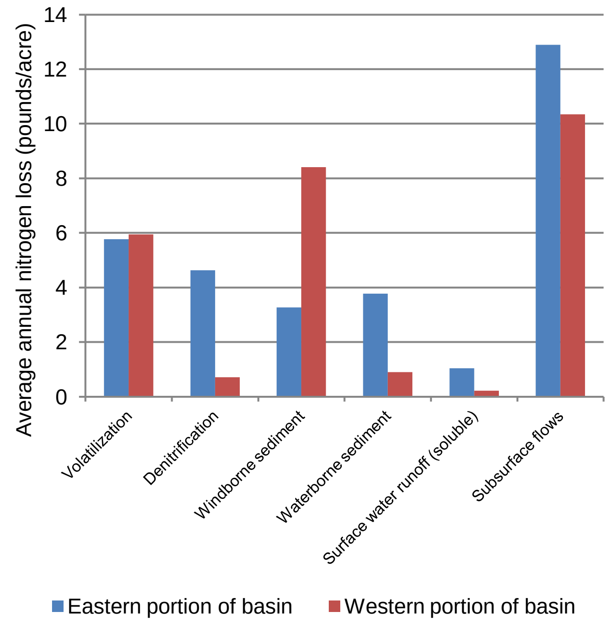
For the baseline conservation condition, the annual average amount of nitrogen lost from the field, other than the nitrogen removed from the field at harvest, is about 28.3 pounds per acre—31.4 pounds per acre in the eastern portion of the basin and 26.5 pounds per acre in the western portion (table 18). These nitrogen loss pathways are (fig. 34 and table 18)—

- nitrogen lost due to volatilization associated primarily with fertilizer and manure application and decomposition of residue (average of 5.9 pounds per acre per year);
- nitrogen returned to the atmosphere through denitrification (average of 2.2 pounds per acre per year);
- nitrogen lost with windborne sediment (average of 6.5 pounds per acre per year);
- nitrogen lost with surface runoff (average of 2.5 pounds per acre per year), most of which is nitrogen lost with waterborne sediment; and
- nitrogen loss in subsurface flow pathways (average of 11.3 pounds per acre per year).

Losses are higher in the eastern portion of the basin than in the western portion for all loss pathways except nitrogen lost with windborne sediment, which is significantly higher in the western portion. Volatilization losses were about the same in both portions of the region.

In the eastern portion of the basin, nitrogen loss in subsurface flows is the dominant loss pathway for 47 percent of cropped acres, volatilization loss is the dominant loss pathway for 21 percent of the acres, and windborne sediment is the dominant nitrogen loss pathway for 14 percent of the acres. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) In the western portion, nitrogen lost with windborne sediment is the dominant loss pathway for 45 percent of cropped acres, followed by nitrogen volatilization for 21 percent of cropped acres and nitrogen loss in subsurface flows for 25 percent of cropped acres.

Figure 34. Average annual nitrogen loss by loss pathway, Arkansas-White-Red Basin, baseline conservation condition

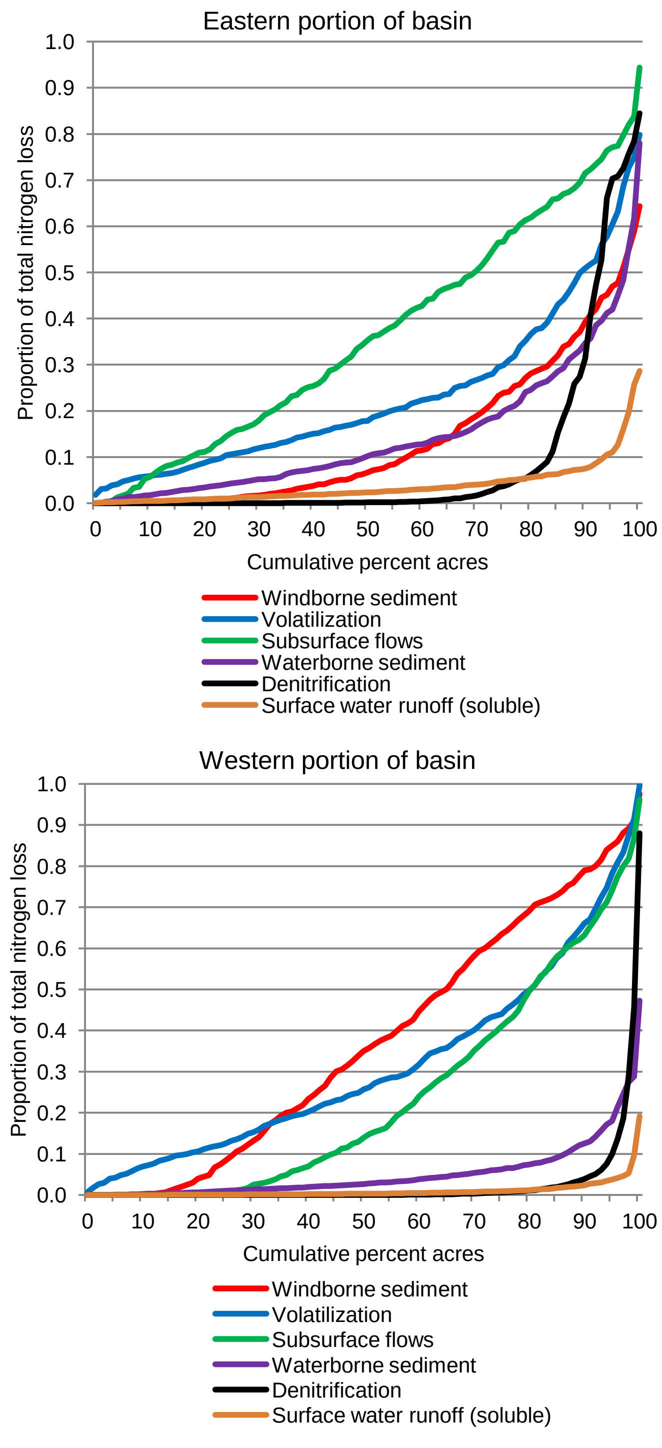


[20] A small amount may also build up in the soil or be mined from the soil, as shown in table 18 for the variable "change in soil nitrogen."

Nitrogen loss in subsurface flows is higher for irrigated acres than for non-irrigated acres, especially in the western portion of the basin (table 18). For the baseline conservation condition, nitrogen loss in subsurface flows for irrigated acres averages 14.4 pounds per acre in the eastern portion and 17.7 pounds per acre in the western portion, compared to 12.7 pounds per acre and 7.9 pounds per acre for non-irrigated acres, respectively.

As shown in figure 35, the proportion of total nitrogen loss for all loss pathways varies considerably throughout the region and throughout both the eastern and western portions of the region. Figure 35 clearly shows that the loss of nitrogen with windborne sediment occurs at a higher proportion for acres in the western portion of the region than for acres in the eastern portion. Figure 35 further shows that loss of nitrogen in subsurface flows occurs at a higher proportion for cropped acres in the eastern portion of the basin than in the western portion.

Figure 35. Cumulative distributions of proportions of nitrogen lost through six loss pathways, Arkansas-White-Red Basin



Note: The horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same sample point on another curve.

Table 18. Field-level effects of conservation practices on nitrogen sources and nitrogen loss pathways for cropped acres in the Arkansas-White-Red Basin

	Average annual values in pounds per acre			
Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Entire region			
Nitrogen sources				
Atmospheric deposition	5	5	0	0
Biofixation by legumes	10	9	-1	-12
Nitrogen applied as commercial fertilizer and manure	73	114	41	36
All nitrogen sources	88	128	40	32
Nitrogen in crop yield removed at harvest	63	76	13*	17*
Nitrogen loss pathways				
Nitrogen loss by volatilization	5.9	8.6	2.7	31
Nitrogen loss through denitrification	2.2	3.2	1.1	34
Nitrogen lost with windborne sediment	6.5	8.9	2.4	27
Nitrogen loss with surface runoff, including waterborne sediment	2.5	5.1	2.6	51
Nitrogen loss with surface water (soluble)	0.5	1.4	0.9	62
Nitrogen loss with waterborne sediment	2.0	3.7	1.7	47
Nitrogen loss in subsurface flow pathways	11.3	26.1	14.9	57
Total nitrogen loss for all loss pathways	28.3	52.0	23.7	46
Change in soil nitrogen	-4.2	-0.1	4.1	--
	Eastern portion of region			
Nitrogen sources				
Atmospheric deposition	6	6	0	0
Biofixation by legumes	22	20	-2	-13
Nitrogen applied as commercial fertilizer and manure	79	128	49	39
All nitrogen sources	107	154	47	30
Nitrogen in crop yield removed at harvest	83	99	16*	16*
Nitrogen loss pathways				
Nitrogen loss by volatilization	5.8	8.6	2.8	33
Nitrogen loss through denitrification	4.6	4.7	0.1	1
Nitrogen lost with windborne sediment	3.3	4.2	0.9	22
Nitrogen loss with surface runoff, including waterborne sediment	4.8	8.2	3.4	42
Nitrogen loss with surface water (soluble)	1.0	2.3	1.3	56
Nitrogen loss with waterborne sediment	3.8	5.9	2.1	36
Nitrogen loss in subsurface flow pathways	12.9	32.0	19.1	60
Irrigated acres	14.4	20.0	5.5	28
Non-irrigated acres	12.7	33.4	20.7	62
Total nitrogen loss for all loss pathways	31.4	57.6	26.3	46
Change in soil nitrogen	-7.5	-3.2	4.3	--
	Western portion of basin			
Nitrogen sources				
Atmospheric deposition	4	4	0	0
Biofixation by legumes	2	2	0	-4
Nitrogen applied as commercial fertilizer and manure	70	106	37	35
All nitrogen sources	76	113	37	32
Nitrogen in crop yield removed at harvest	51	62	11*	17*
Nitrogen loss pathways				
Nitrogen loss by volatilization	5.9	8.6	2.6	31
Nitrogen loss through denitrification	0.7	2.4	1.7	70
Nitrogen lost with windborne sediment	8.4	11.7	3.3	28
Nitrogen loss with surface runoff, including waterborne sediment	1.1	3.2	2.1	65
Nitrogen loss with surface water (soluble)	0.2	0.8	0.6	73
Nitrogen loss with waterborne sediment	0.9	2.4	1.5	63
Nitrogen loss in subsurface flow pathways	10.3	22.7	12.4	54
Irrigated acres	17.7	31.4	13.7	44
Non-irrigated acres	7.9	19.8	12.0	60
Total nitrogen loss for all loss pathways	26.5	48.7	22.1	45
Change in soil nitrogen	-2.2	1.7	3.9	--

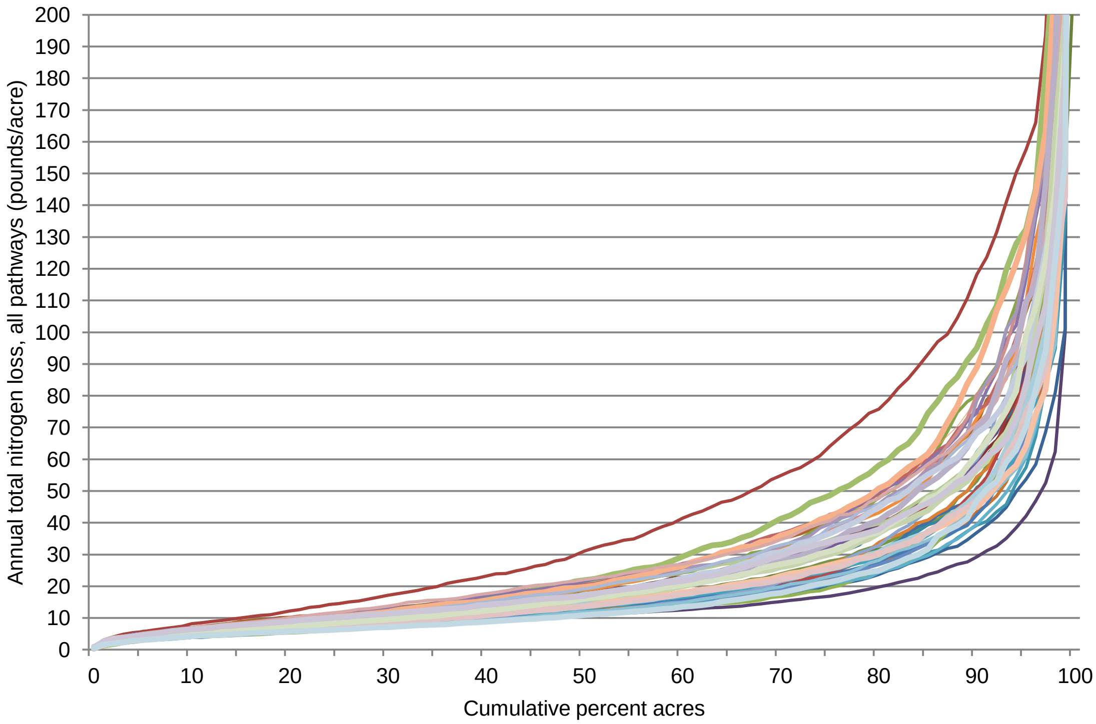
* The reduction in yield reflects the increase in nutrients in the representation in the no-practice scenario for nutrient management.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 14 subregions.

Model simulations for the baseline conservation condition indicate that some cropped acres in the Arkansas-White-Red Basin are much more susceptible to the effects of weather than other acres and lose much larger amounts of nitrogen. Figure 36 shows that, with the conservation practices currently in use in the Arkansas-White-Red Basin, annual nitrogen loss from fields can exceed 50 pounds per acre for about one-third of the acres in one or more years. In years with the most extreme weather, up to 12 percent of the acres lose over 100 pounds of nitrogen in one or more years.

Figure 36 also shows that acres with high nitrogen losses through all loss pathways are restricted to a minority of the acres within the region. Nearly 50 percent of cropped acres have relatively low levels of nitrogen loss (less than 30 pounds per acre) under all conditions, including years with high precipitation. About 35 percent of cropped acres have less than 20 pounds per acre of nitrogen loss in all years.

Figure 36. Distribution of annual total nitrogen loss (all loss pathways, baseline conservation condition) for each year of the 47-year model simulation, Arkansas-White-Red Basin



Note: This figure shows how annual total nitrogen loss (pounds per acre per year) varied within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total nitrogen loss varied over the region in that year, starting with the acres with the lowest total nitrogen loss and increasing to the acres with the highest total nitrogen loss. The family of curves shows how annual total nitrogen loss varied from year to year.

Note: Nitrogen loss is highest for the year 1973, which has the highest annual precipitation over the 47 years in both portions of the basin.

Effects of conservation practices on cropped acres

Total nitrogen loss, all pathways. Model simulations show that the conservation practices in use in the region have reduced total nitrogen loss from cropped acres by an average of 24 pounds per acre per year, representing a 46-percent reduction, on average (table 18). Without conservation practices, about 48 percent of the cropped acres would have average annual total nitrogen loss exceeding 40 pounds per acre per year; with conservation practices, 18 percent of acres exceed this level of loss (fig. 37).

The effects of conservation practices vary from acre to acre, as shown in figure 38, depending on the extent to which conservation practices are used and the inherent vulnerability of the soils to losses through the various pathways. Most acres have reductions of 10 pounds of nitrogen or more due to conservation practices.

Figure 38 also shows that about 8 percent of the acres in the region have an *increase* in total nitrogen loss due to conservation practice use—11 percent of cropped acres in the eastern portion of the basin and 7 percent in the western portion. Most of these increases are small; only 4 percent of the acres have increases of more than 4 pounds per acre for the region. This result primarily occurs on soils with relatively high soil nitrogen content and generally with low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. Cropping systems that include legumes can have a higher soil nitrogen stock in the baseline conditions because legumes produce proportionately less biofixation of nitrogen under the higher fertilization rates simulated in the no-practice scenario.

Figure 37. Estimates of average annual total nitrogen loss for cropped acres in the Arkansas-White-Red Basin

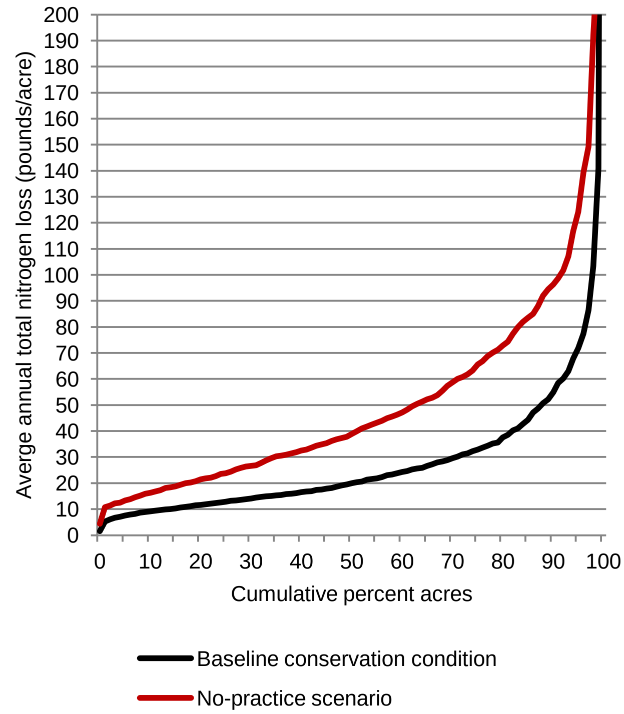
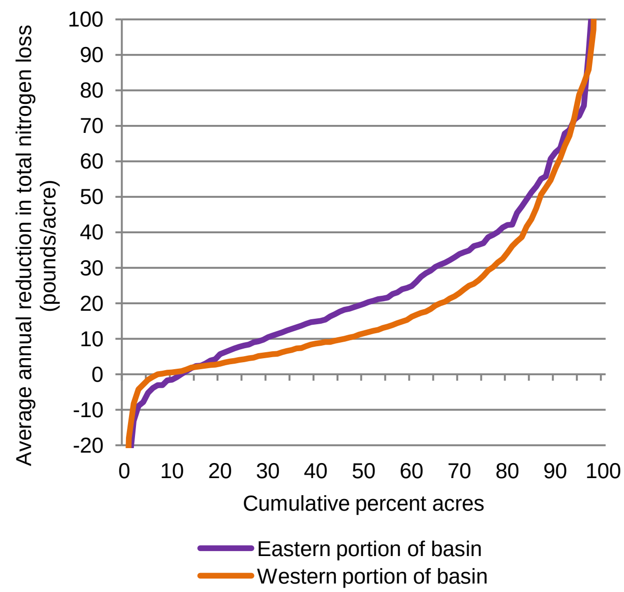


Figure 38. Estimates of average annual reduction in total nitrogen loss due to the use of conservation practices on cropped acres in the Arkansas-White-Red Basin



Note: See text for discussion of conditions that result in lower total nitrogen loss in the no-practice scenario than in the baseline conservation condition, shown in this figure as negative reductions.

Nitrogen loss in subsurface flows. About 40 percent of the nitrogen loss for all loss pathways is lost in subsurface flows in this region.

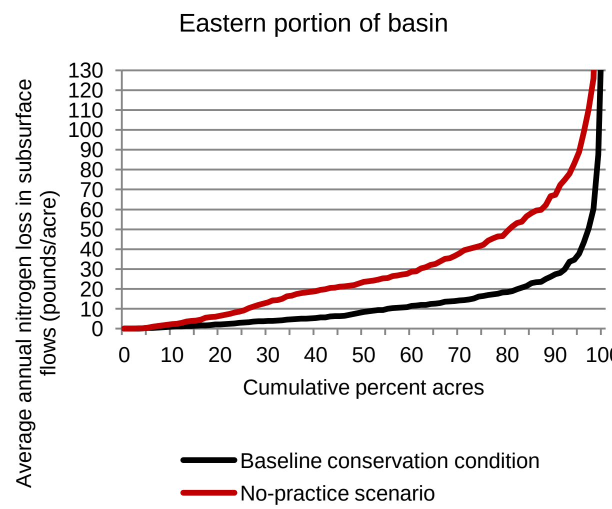
On average for the entire region, conservation practices have reduced nitrogen loss in subsurface flows from 26 pounds per acre without practices to 11 pounds per acre with practices, representing an average reduction of 15 pounds per acre per year (57-percent reduction) (fig. 39, table 18). The average reduction is similar in both the western and eastern portions of the region, but is lower for irrigated acres than for nonirrigated acres in both portions of the region.

Conservation practices are effective in reducing nitrogen loss in subsurface flows on most cropped acres throughout the region (fig. 40). Average annual reductions in nitrogen loss in subsurface flows exceed 10 pounds per acre for 54 percent of cropped acres in the eastern portion of the basin and 33 percent in the western portion.

For about 30 percent of cropped acres in the eastern portion and about 50 percent in the western portion, however, conservation practices make little difference and even result in small increases in nitrogen loss in subsurface flows for about 15 percent of cropped acres (fig. 40). (Increases in nitrogen loss in subsurface flows due to conservation practices are represented in figure 40 as negative reductions.)

The small reductions in nitrogen loss in subsurface flows due to conservation practices (including negative reductions) are largely due to relatively weak nutrient management practices on acres with erosion control treatment. A portion of the reduction in nitrogen lost with surface runoff is re-routed to subsurface loss pathways, resulting in gains or only small reductions in nitrogen loss in subsurface flows. This re-routing of surface water runoff to subsurface flow pathways results in additional nitrogen being leached from the soil, diminishing and sometimes offsetting the overall positive effects of conservation practices on total nitrogen loss. *These model simulation results underscore the importance of pairing water erosion control practices with effective nutrient management practices so that the full suite of conservation practices will provide the environmental protection needed.*

Figure 39. Estimates of average annual nitrogen loss in subsurface flows for cropped acres in the Arkansas-White-Red Basin



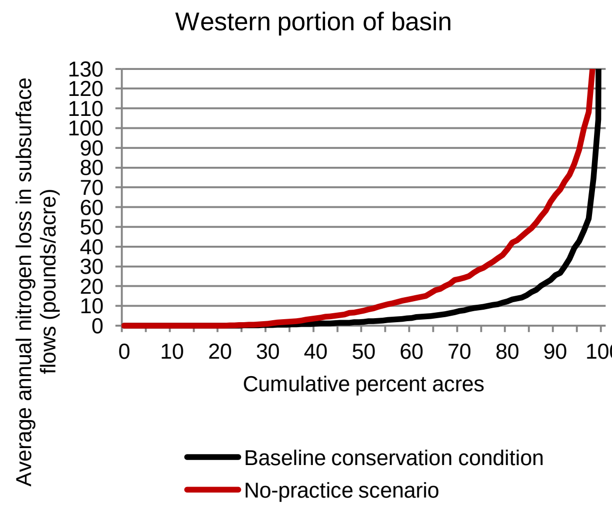
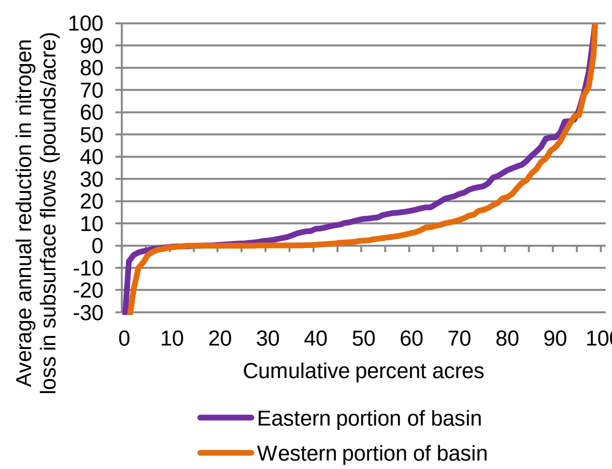


Figure 40. Estimates of average annual reductions in nitrogen loss in subsurface flows due to the use of conservation practices on cropped acres in the Arkansas-White-Red Basin



Note: See text for discussion of conditions that result in negative reductions in loss of nitrogen in subsurface flows due to conservation practice use.

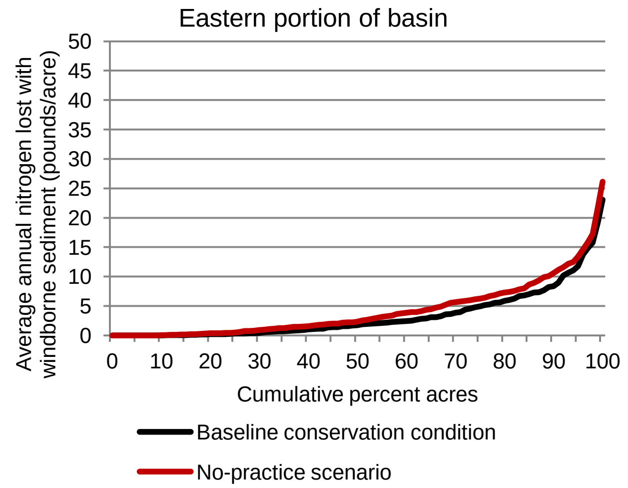
Nitrogen lost with windborne sediment. About 23 percent of the total nitrogen loss for all loss pathways is lost with windborne sediment in this region, mostly in the western portion of the basin.

In the western portion of the basin, conservation practice use has reduced nitrogen lost with windborne sediment from cropped acres by an average of 3.3 pounds per acre per year, representing an average reduction of 28 percent (table 18, fig. 41). In the eastern portion, conservation practice use has reduced nitrogen lost with windborne sediment by 0.9 pound per acre per year, representing a 22-percent reduction.

Figure 42 shows the distributions of the reductions in nitrogen lost with windborne sediment. The largest reductions are in the western portion of the basin, where wind erosion losses are highest; reductions are larger than 5 pounds per acre for about 24 percent of the acres. Figure 42 also shows, however, that 44 percent of the cropped acres in the western portion of the basin and 73 percent of cropped acres in the eastern portion have average reductions of less than 1 pound per acre due to conservation practices.[21]

[21] Small negative reductions in windborne sediment, shown in figure 27, also result in small negative reductions in nitrogen lost with windborne sediment, shown in figure 42.

Figure 41. Estimates of average annual nitrogen lost with windborne sediment for cropped acres in the Arkansas-White-Red Basin



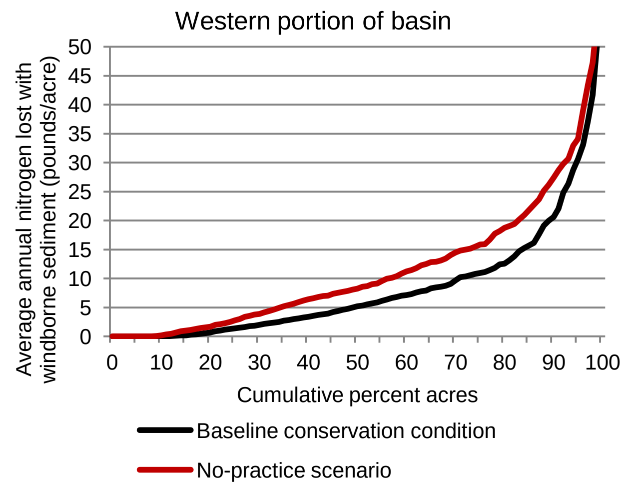
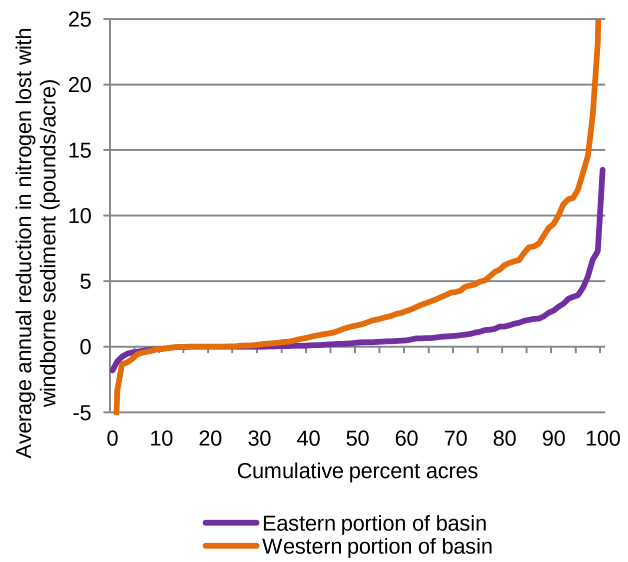


Figure 42. Estimates of average annual reductions in nitrogen lost with windborne sediment due to the use of conservation practices on cropped acres in the Arkansas-White-Red Basin



Nitrogen volatilization loss. Nitrogen loss through volatilization is an important loss pathway for some cropped acres in both the eastern and western portions of the basin. For some acres in this region, nitrogen volatilization is the dominant nitrogen loss pathway. Conservation practices in use within the region are effective at reducing these losses, as shown in figure 43. Conservation practices have reduced nitrogen volatilization losses by an average of 2.7 pounds per acre, reducing loss from an average of 8.6 pounds per acre without conservation practices to an average of 5.9 pounds per acre for the baseline, representing a 31-percent reduction overall for the region (table 18).

However, conservation practice use has enhanced nitrogen volatilization on some acres, as shown by the negative reductions in figure 43. About 17 percent of cropped acres have increases in nitrogen volatilization with conservation practice use. Most of these increases are small; 4 percent of cropped acres have increases greater than 2 pounds per acre per year. Reduced tillage practices, which leave more crop residue on the soil surface and less nitrogen fertilizer and manure incorporated, can contribute to increased nitrogen volatilization.

Nitrogen lost with surface runoff. Although nitrogen lost with surface runoff, including waterborne sediment, is low relative to losses in other pathways for most acres in this region, conservation practices have been effective in reducing these losses. Model simulations show that, on average, nitrogen lost with surface runoff has been reduced 51 percent due to use of conservation practices in the region (table 18). In the eastern portion of the basin, conservation practices have reduced nitrogen lost with surface runoff from an average of 8.2 pounds per acre without practices to 4.8 pounds per acre with practices, representing an average reduction of 3.4 pounds per acre per year (42-percent reduction) (table 18). Average reduction is lower in the western portion, averaging 2.1 pounds per acre, but results in a higher percent reduction (65-percent reduction).

Figure 44 shows that about 26 percent of the cropped acres have reductions in nitrogen lost with surface runoff greater than 4 pounds per acre per year due to conservation practice use in the eastern portion of the basin, compared to 13 percent in the western portion.

Figure 43. Estimates of average annual reductions in nitrogen volatilization due to the use of conservation practices on cropped acres in the Arkansas-White-Red Basin

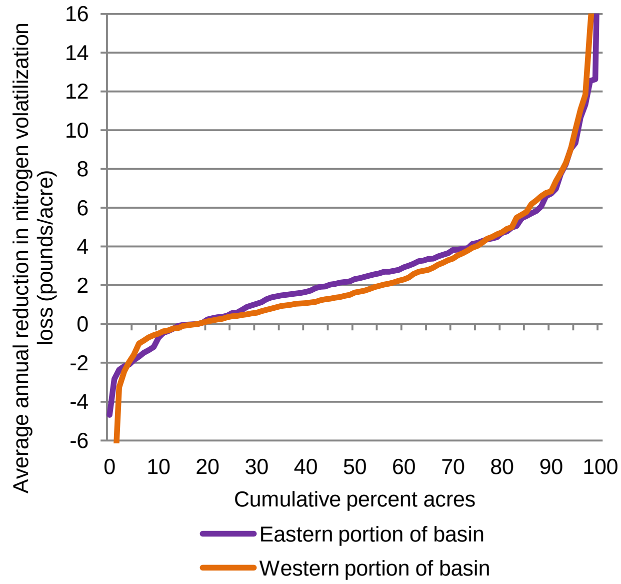
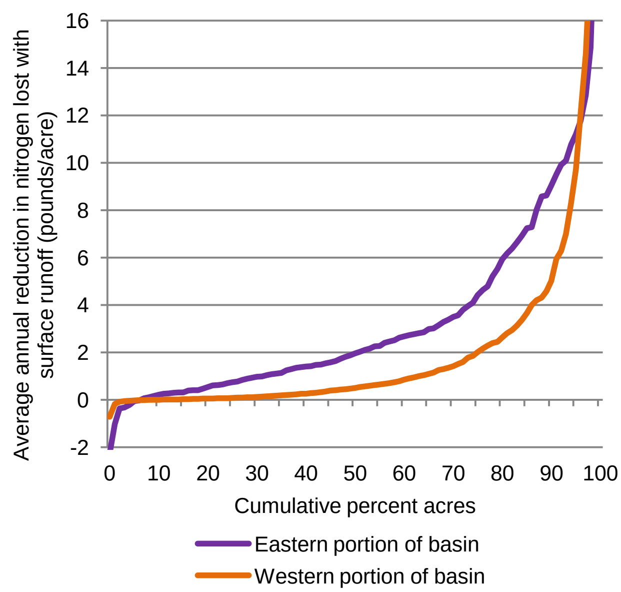


Figure 44. Estimates of average annual reductions in nitrogen loss with surface runoff, including waterborne sediment, due to the use of conservation practices on cropped acres in the Arkansas-White-Red Basin



Tradeoffs in Conservation Treatment

Conservation practices applied on cropland are, for the most part, synergistic. The benefits accumulate as more practices are added to the designed systems. However, when only a single resource concern is addressed (such as soil erosion), antagonism between the practices and other resource concerns may occur. That is why it is essential that all resource concerns be considered during the conservation planning process. Most of the time the tradeoffs are much smaller than the magnitude of the primary resource concerns. Common examples are:

- Terraces and conservation tillage are planned to solve a serious water erosion problem. However, in some areas there may be concern about seeps at the lower part of the field. The planned practices will solve the erosion problem, but could exacerbate the seep problem under some conditions. Ignoring that fact does not make for an adequate conservation plan.
- Conservation tillage is planned for erosion control on a cropland field with a high water table. The reduction in runoff may increase leaching of nitrates into the shallow water table. A complete and comprehensive conservation plan would provide a suite of conservation practices that addressed both problems.
- Implementation of a nutrient management plan may reduce the amount of manure added to a field and thus reduce the loss of nutrients to surface or groundwater. However, the reduction in organic material added to the field may also reduce the soil organic matter content or reduce the rate of change in soil organic matter.
- About 8 percent of cropped acres in this region have an increase in total nitrogen loss (fig. 38) and 15 percent of cropped acres have an increase in nitrogen loss in subsurface flows due to conservation practice use (fig. 40). This result occurs primarily on soils with relatively high soil nitrogen content and generally low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. For these fields, the nutrient management component of a farmer's conservation plan would need to be enhanced to reduce or eliminate the negative effects of soil erosion control practices on nitrogen loss.

A *comprehensive planning process* is used to identify the appropriate combination of practices needed to address multiple resource concerns by taking into account the specific inherent vulnerabilities associated with each field. To ensure that proper consideration is given to the effects of conservation practices on *all* of the resource concerns, USDA/NRCS developed a comprehensive planning tool referred to as CPPE (Conservation Practice Physical Effects). The CPPE is included in the Field Office Technical Guide. Conservation planners are expected to use CPPE as a reference to ensure that *all* resource concerns are addressed in conservation plans.

Land in long-term conserving cover

Conversion of cropped acres to conserving cover, such as grasses and, in some cases, trees, reduces the nitrogen sources to about 9 pounds per acre for land in long-term conserving cover in this region (table 19). Of this, one-third comes from atmospheric deposition (wet and dry) and two-thirds comes from legumes, such as forbs and clovers. Since there is no harvest and removal associated with these acres, the nitrogen taken up by the plants is recycled each year when the plants die and decompose. In addition, nitrogen stored in the soil can be brought to the surface by plant uptake and decomposition. These surface deposits of nitrogen are subject to the forces of wind and water and some of this nitrogen is lost from the fields each year. Nitrogen loss from land in long-term conserving cover averages about 7.2 pounds per acre per year for all loss pathways, on average.

Converting cropped acres to long-term conserving cover is very effective in reducing total nitrogen loss, as demonstrated in figures 45–47 and table 19. Total nitrogen loss has been reduced by an average of 28 pounds per acre per year—about 79 percent—on the 6 million acres in long-term conserving cover in this region, compared to conditions that would be expected had the acres remained in crops without use of conservation practices. Nitrogen loss for loss pathways other than nitrogen volatilization have been reduced by more than 90 percent, on average (table 19). Figures 45–47 also show, however, that reductions are much higher for some acres converted to long-term conserving cover than others.

Converting cropped acres to long-term conserving cover had little net effect on nitrogen volatilization losses (table 19). About half of the acres had increases in nitrogen volatilization losses when converted to long-term conserving cover, and about half had reductions in nitrogen volatilization losses. Nitrogen volatilization represents, on average, about 90 percent of total nitrogen loss for land in long-term conserving cover in this region.

Nitrogen volatilization from long-term conserving cover can occur in two ways: (1) living plant material can influence ammonia loss to the atmosphere, and (2) decomposing plant material, especially from nitrogen-rich legumes and other forbs, release ammonia directly to the atmosphere. The presence of high levels of urease on the soil surface promotes ammonia volatilization activity. Plants can both emit ammonia to the atmosphere and absorb it from the atmosphere. This compound can be used directly as a precursor for organic nitrogen products. Actively growing plants also influence the soil's temperature and water regimes, which in turn can regulate the rate of ammonia volatilization from the soil surface.

Figure 45. Estimates of average annual total nitrogen loss for land in long-term conserving cover in the Arkansas-White-Red Basin

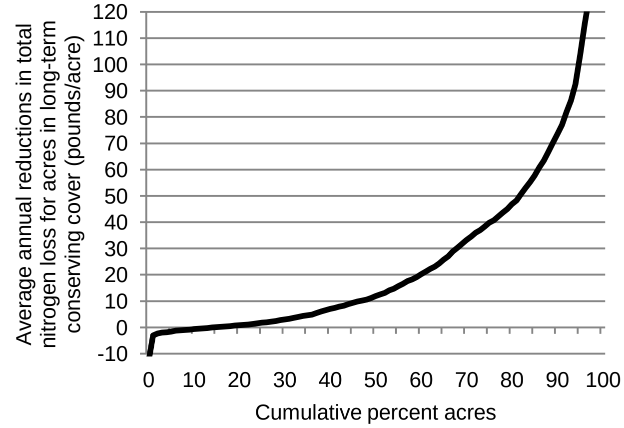


Figure 46. Estimates of average annual nitrogen lost with windborne sediment for land in long-term conserving cover in the Arkansas-White-Red Basin

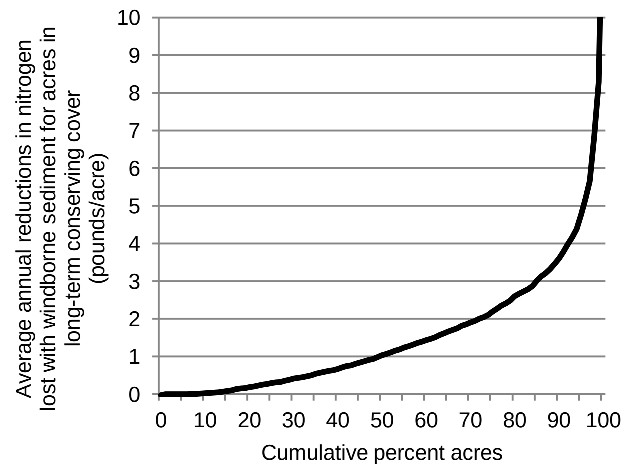


Figure 47. Estimates of average annual nitrogen loss in subsurface flows for land in long-term conserving cover in the Arkansas-White-Red Basin

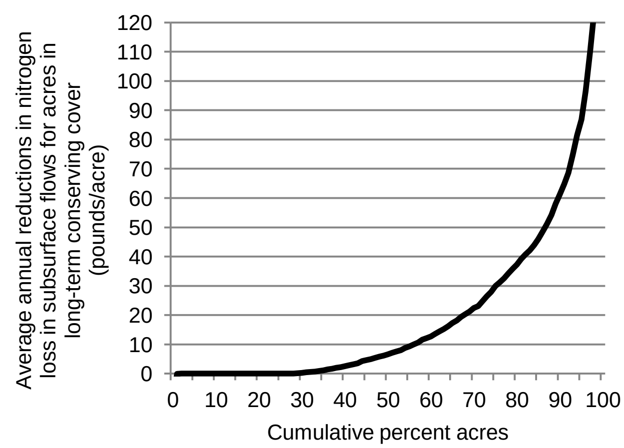


Table 19. Effects of conservation practices on nitrogen sources and nitrogen loss pathways for land in long-term conserving cover (6 million acres), Arkansas-White-Red Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Average annual values in pounds per acre			
Nitrogen sources				
Atmospheric deposition	3	3	0	0
Bio-fixation by legumes	6	2	-3	-137
Nitrogen applied as commercial fertilizer and manure	0	96	96	100
All nitrogen sources	9	102	93	91
Nitrogen in crop yield removed at harvest	<1*	56	56	100
Nitrogen loss pathways				
Nitrogen loss by volatilization	6.4	7.1	0.6	9
Nitrogen loss through denitrification	0.1	1.4	1.3	95
Nitrogen lost with windborne sediment	0.0	1.5	1.5	100
Nitrogen loss with surface runoff, including waterborne sediment	0.2	3.2	3.0	95
Nitrogen loss with surface water (soluble)	0.0	0.6	0.6	97
Nitrogen loss with waterborne sediment	0.1	2.5	2.4	94
Nitrogen loss in subsurface flow pathways	0.6	22.0	21.5	97
Total nitrogen loss for all pathways	7.2	35.2	28.0	79
Change in soil nitrogen	1.1	10.0	8.8	--

* Harvest was simulated on acres planted to trees where expected tree age is less than the 47 years included in the model simulation. At tree harvest time, the grass also is removed and replanted.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Effects of Practices on Phosphorus Loss

Phosphorus, like nitrogen, is an essential element needed for crop growth. Unlike nitrogen, phosphorus rarely occurs in a gaseous form so the agricultural model has no atmospheric component. Phosphorus compounds that are soluble in water are available for plants to use. Although total phosphorus is plentiful in the soil, only a small fraction is available at any one time for plant uptake. Farmers apply commercial phosphate fertilizers to supplement low quantities of plant-available phosphorus in the soil.

Throughout this report, phosphorus results are reported in terms of elemental phosphorus (i.e., not as the phosphate fertilizer equivalent).

Baseline condition for cropped acres

Based on responses to the CEAP NRI survey for the Arkansas-White-Red Basin, about 12 pounds per acre of phosphorus are applied as commercial fertilizer or in manure to cropped acres, on average, in each year of the model simulation (table 20). Phosphorus applications are higher in the eastern portion of the basin, averaging 15 pounds per acre per year, compared to 11 pounds per acre per year in the western portion of the basin.

Model simulations show that the amount of phosphorus taken up by the crop and removed at harvest in the crop yield is about 73 percent of the amount of phosphorus applied, on average. The remainder is lost from the field through various loss pathways. [22]

Total phosphorus loss for all loss pathways averages 2.35 pounds per acre per year in the baseline conservation condition—2.77 pounds per acre in the eastern portion of the basin and 2.11 pounds per acre in the western portion (table 20). These phosphorus loss pathways are—

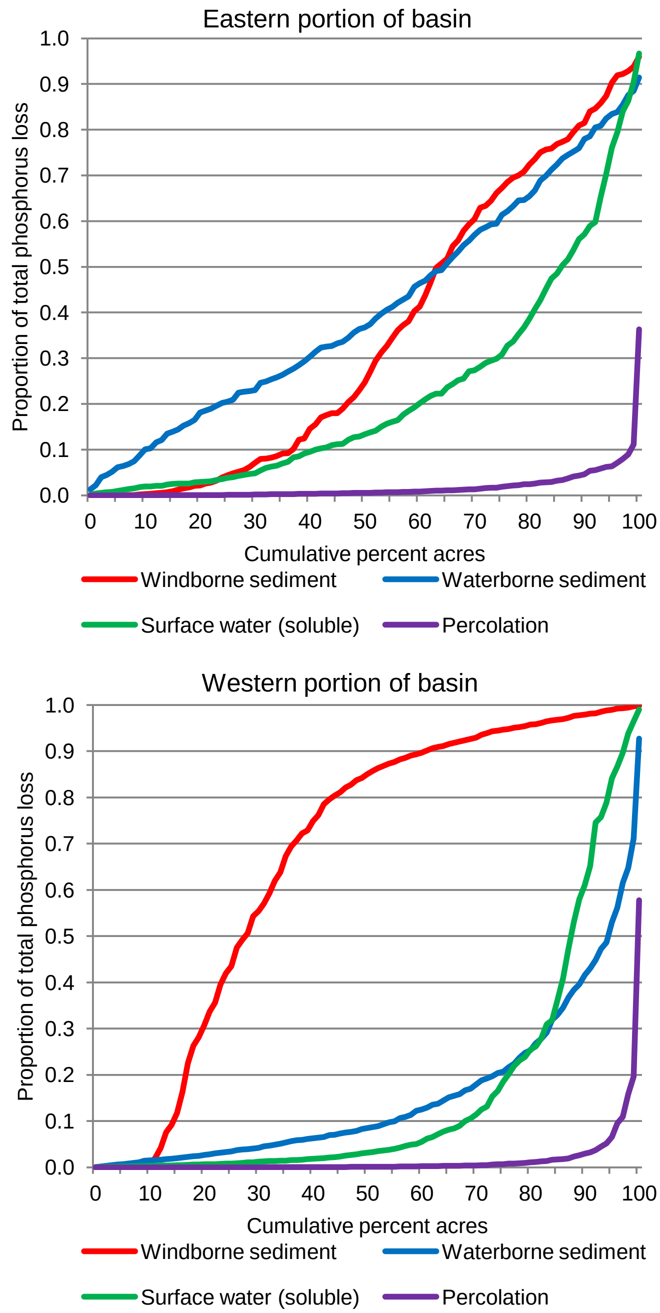
- phosphorus lost with windborne sediment (average of 1.49 pounds per acre per year);
- phosphorus lost with waterborne sediment (average of 0.51 pound per acre per year);
- soluble phosphorus lost to surface water, including soluble phosphorus in surface water runoff, and soluble phosphorus that infiltrates into the soil profile but quickly returns to surface water either through quick return lateral flow or intercepted by drainage systems (average of 0.34 pounds per acre per year); and
- soluble phosphorus that percolates through the soil profile into the groundwater (average of 0.01 pound per acre per year).

Losses are higher in the eastern portion of the basin than in the western portion for all loss pathways except phosphorus lost with windborne sediment, which is substantially higher in the western portion.

[22] A small amount may also build up in the soil or be mined from the soil, as shown in table 20 for the variable "change in soil phosphorus."

As shown in figure 48, the proportion of total phosphorus loss for all loss pathways varies considerably throughout the region. Figure 48 shows that the loss of phosphorus with windborne sediment occurs at a much higher proportion for acres in the western portion of the region than for acres in the eastern portion.

Figure 48. Cumulative distributions of the proportion of phosphorus lost through various loss pathways, Arkansas-White-Red Basin, baseline conservation condition



Note: The horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same sample point on another curve.

Table 20. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for cropped acres in the Arkansas-White-Red Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Average annual values in pounds per acre			
	Entire region			
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	12.41	19.93	7.51	38
Phosphorus in crop yield removed at harvest	9.02	10.64	1.62	15
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.49	2.47	0.98	40
Phosphorus lost to surface water (sediment attached and soluble)*	0.85	1.99	1.14	57
Soluble phosphorus lost to surface water*	0.34	0.83	0.49	59
Phosphorus loss with waterborne sediment	0.51	1.16	0.65	56
Soluble phosphorus loss to groundwater	0.01	0.01	0.00	14
Total phosphorus loss for all loss pathways	2.35	4.48	2.12	47
Change in soil phosphorus	0.98	4.76	3.79	--
	Eastern portion of basin			
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	14.84	23.77	8.93	38
Phosphorus in crop yield removed at harvest	11.70	13.74	2.03	15
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.09	1.63	0.53	33
Phosphorus lost to surface water (sediment attached and soluble)*	1.65	3.60	1.95	54
Soluble phosphorus lost to surface water*	0.60	1.42	0.82	58
Phosphorus loss with waterborne sediment	1.06	2.18	1.12	52
Soluble phosphorus loss to groundwater	0.02	0.02	0.00	7
Total phosphorus loss for all loss pathways	2.77	5.25	2.48	47
Change in soil phosphorus	0.33	4.73	4.40	--
	Western portion of basin			
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	11.00	17.69	6.69	38
Phosphorus in crop yield removed at harvest	7.46	8.84	1.38	16
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.72	2.97	1.24	42
Phosphorus lost to surface water (sediment attached and soluble)*	0.38	1.05	0.67	64
Soluble phosphorus lost to surface water*	0.19	0.48	0.29	60
Phosphorus loss with waterborne sediment	0.19	0.57	0.38	67
Soluble phosphorus loss to groundwater	0.01	0.01	0.00	24
Total phosphorus loss for all loss pathways	2.11	4.03	1.92	48
Change in soil phosphorus	1.35	4.78	3.43	--

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 14 subregions.

In the eastern portion of the basin, phosphorus lost with windborne sediment is the dominant loss pathway for 41 percent of cropped acres and phosphorus lost with waterborne sediment is the dominant loss pathway for 42 percent of cropped acres. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) Soluble phosphorus lost to surface water is the dominant loss pathway for the remaining cropped acres—16 percent.

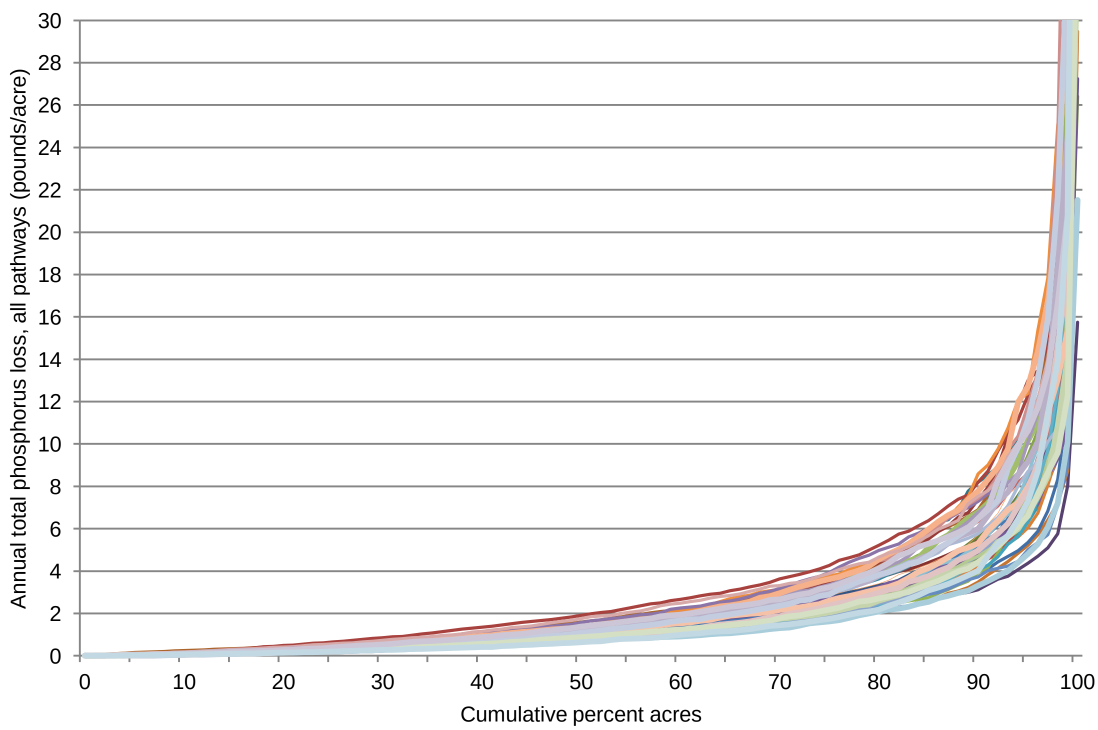
In the western portion of the basin, 82 percent of the phosphorus is lost with windborne sediment. Windborne sediment is the dominant loss pathway in this portion of the basin for 76 percent of cropped acres. The dominant loss pathway for 15 percent of the cropped acres is soluble phosphorus lost to surface water and the dominant loss pathway for remaining acres is phosphorus lost with waterborne sediment.

A very small amount of soluble phosphorus is lost through percolation into groundwater throughout the region.

Model simulations for the baseline conservation condition indicate that some cropped acres in the Arkansas-White-Red Basin lose much larger amounts of phosphorus than other acres. Figure 49 shows that, with the conservation practices currently in use in the Arkansas-White-Red Basin, annual phosphorus loss from fields can exceed 8 pounds per acre for about 10 percent of the acres in one or more years. In years with the most extreme weather, some acres lose over 20 pounds of phosphorus.

Figure 49 also shows that acres with high phosphorus losses through all loss pathways are restricted to a minority of the acres within the region. Over half of cropped acres have relatively low levels of phosphorus loss (less than 2 pounds per acre) under all conditions, including years with high precipitation. About 75 percent of cropped acres have less than 4 pounds per acre of phosphorus loss in all years.

Figure 49. Distribution of annual total phosphorus loss (all loss pathways) for each year of the 47-year model simulation, Arkansas-White-Red Basin



Note: This figure shows how annual total phosphorus loss (pounds per acre per year) varied within the region and from year to year in the model simulation on cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total phosphorus loss varied over the region in that year, starting with the acres with the lowest total phosphorus loss and increasing to the acres with the highest total phosphorus loss. The family of curves shows how annual total phosphorus loss varied from year to year.

Effects of conservation practices on cropped acres

Total phosphorus loss, all pathways. Model simulations show that the conservation practices in use in the region have reduced total phosphorus loss from cropped acres by an average of 2.12 pounds per acre per year, representing a 47-percent reduction, on average (table 20). Without conservation practices, about 40 percent of the cropped acres would have average annual total phosphorus loss exceeding 4 pounds per acre per year; with conservation practices, only 17 percent of acres exceed this level of loss (fig. 50).

The use of conservation practices is somewhat more effective in reducing total phosphorus losses from fields in the eastern portion of the basin than in the western portion (fig. 51). In the eastern portion, the conservation practices in use have reduced total phosphorus loss from cropped acres by an average of 2.48 pounds per acre per year, compared to an average reduction of 1.92 pounds per acre per year in the western portion (table 20).

The effects of conservation practices vary from acre to acre, as shown in figure 51, depending on the extent to which conservation practices are used and the inherent vulnerability of the soils to losses through the various loss pathways. Over half of the cropped acres in the western portion have reductions of 1 pound of phosphorus or more due to conservation practices. In the eastern portion, over half of the cropped acres have reductions of 2 pounds of phosphorus or more due to conservation practices.

Figure 50. Estimates of average annual total phosphorus loss (all loss pathways) for cropped acres in the Arkansas-White-Red Basin

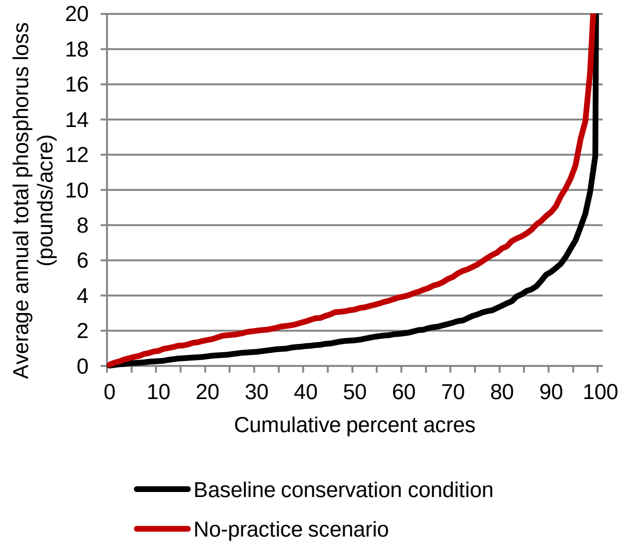
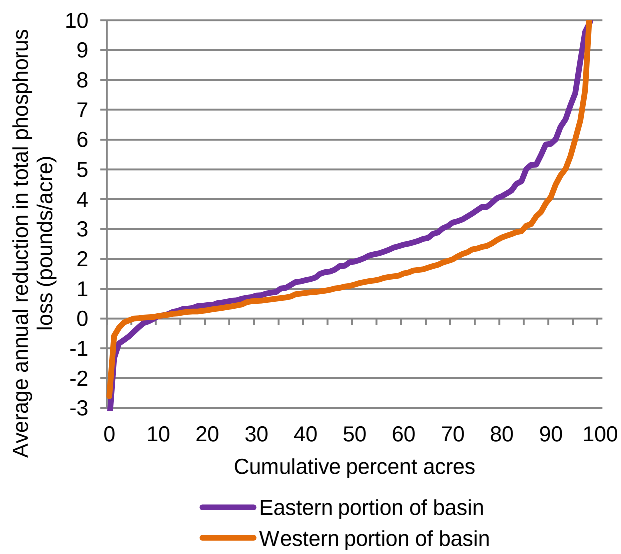


Figure 51. Estimates of average annual reduction in total phosphorus loss due to conservation practices on cropped acres in the Arkansas-White-Red Basin



Note: About 6 percent of cropped acres in the region have negative reductions in phosphorus loss due to conservation practices. Most of these acres were on nearly level soils and soluble phosphorus was the primary loss pathway. In these cases, the additional tillage in the no-practice scenario reduced the loss of soluble phosphorus.

Phosphorus lost with windborne sediment. The majority (63 percent) of phosphorus lost from fields in the Arkansas-White-Red basin is lost with windborne sediment. Of the 2.11 pounds per acre per year of total phosphorus loss in the western portion of the basin, 1.72 pounds are lost with windborne sediment—85 percent. The proportion is less for the eastern portion—39 percent.

Conservation practice use in the region has been effective in reducing losses with windborne sediment, more so in the western portion of the basin than in the eastern portion (figs.52 and 53).

In the western portion of the basin, conservation practice use has reduced phosphorus lost with windborne sediment from cropped acres by an average of 1.24 pounds per acre per year, representing an average reduction of 42 percent (table 20).

In the eastern portion, conservation practice use has reduced phosphorus lost with windborne sediment by 0.53 pound per acre per year, representing a 33-percent reduction (table 20).

Figure 53 shows the distributions of the reductions in phosphorus lost with windborne sediment. The largest reductions are in the western portion of the basin, where wind erosion losses are highest. About 40 percent of the acres in the western portion of the basin have reductions of 1 pound per acre or more due to conservation practices, compared to 20 percent of cropped acres in the eastern.[23]

Figure 52. Estimates of average annual phosphorus lost with windborne sediment for cropped acres in the Arkansas-White-Red Basin

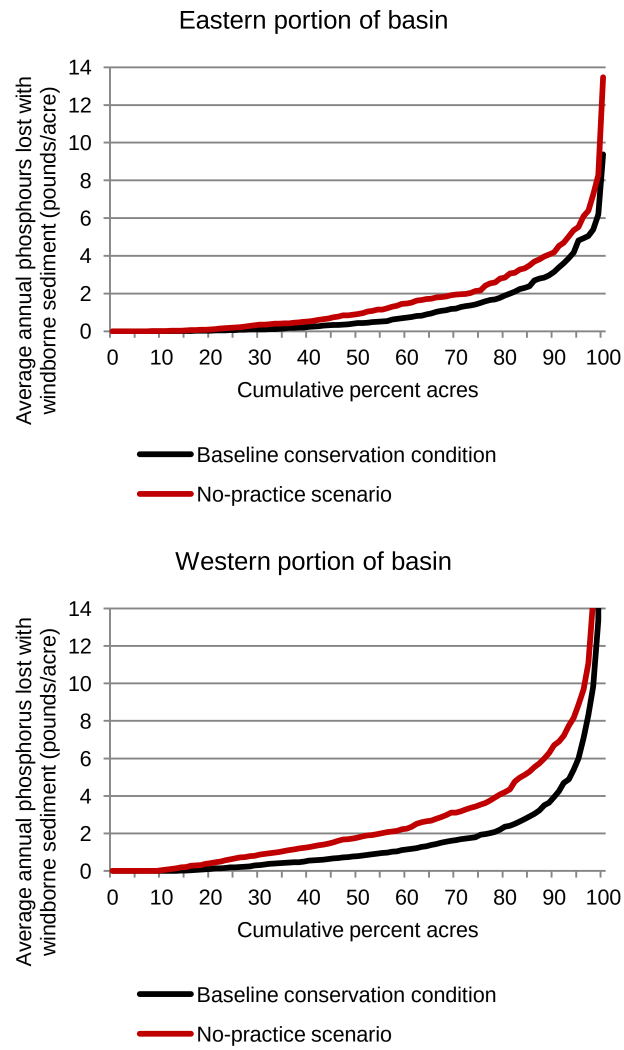
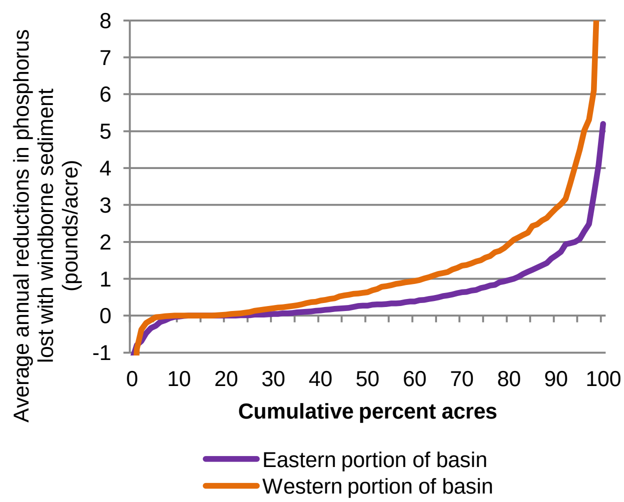


Figure 53. Estimates of average annual reduction in phosphorus lost with windborne sediment due to conservation practices for cropped acres in the Arkansas-White-Red Basin



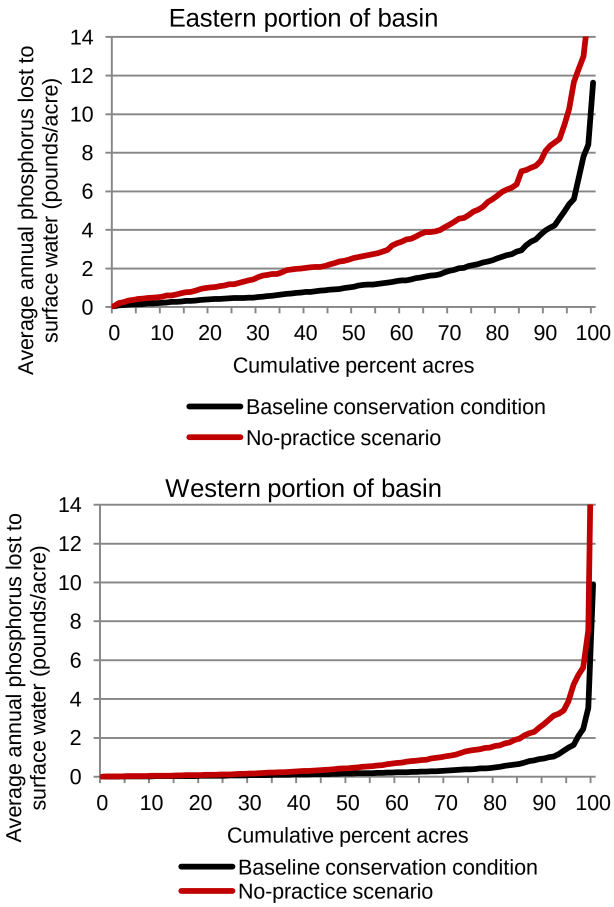
[23] Small negative reductions in windborne sediment, shown in figure 27, also result in small negative reductions in phosphorus lost with windborne sediment for about 5 percent of cropped acres in the region, shown in figure 53.

Phosphorus lost to surface water. Phosphorus lost to surface water includes phosphorus lost with waterborne sediment and soluble phosphorus in surface water runoff and in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps, which ultimately contributes to surface water. Phosphorus losses through this pathway are low in the western portion of the basin, but are important in the eastern portion (fig. 54).

In the eastern portion of the basin, about 1.65 pounds per acre per year of phosphorus are lost from fields through this pathway—about two-thirds attached to sediment and one-third as soluble phosphorus (table 20). Conservation practice use has reduced phosphorus lost to surface water from cropped acres by an average of 1.95 pounds per acre per year, representing an average reduction of 54 percent (table 20). Without conservation practices, about 31 percent of the cropped acres would have phosphorus lost to surface water in excess of an average of 4 pounds per acre per year, compared to only 9 percent in the baseline (fig. 54). Per-acre reductions are high for some acres in this portion of the basin, as shown in figure 55. About half of the acres have reductions less than 1 pound per acre per year, however.[24]

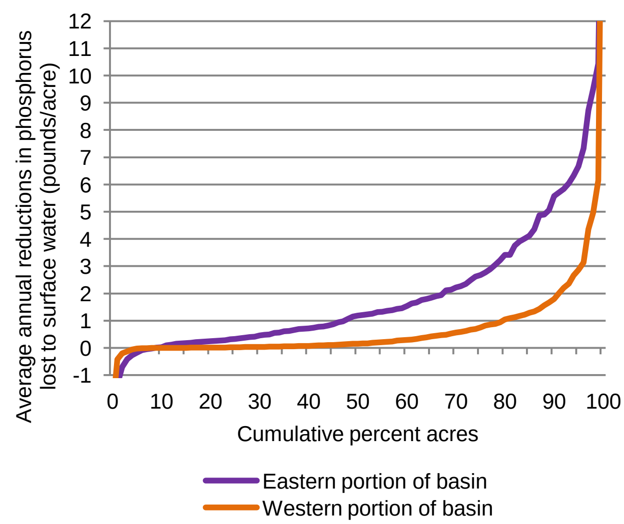
Although losses of phosphorus to surface water are much lower in the western portion of the basin, conservation practices are effective in reducing these losses. In the western portion of the basin, conservation practice use has reduced phosphorus lost to surface water from cropped acres by an average of 0.67 pound per acre per year, representing an average reduction of 64 percent (table 20).

Figure 54. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble*) for cropped acres in the Arkansas-White-Red Basin



* Soluble phosphorus lost to surface water includes phosphorus in surface water runoff and in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

Figure 55. Estimates of average annual reduction in phosphorus lost to surface water (sediment attached and soluble) due to conservation practices for cropped acres in the Arkansas-White-Red Basin



[24] Small negative reductions in surface water runoff, shown in figure 20, also result in small negative reductions in phosphorus lost to surface water for about 5 percent of cropped acres in the region, shown in figure 55.

Land in long-term conserving cover

Conversion of cropped acres to conserving cover eliminates applied phosphorus sources for plant growth. However, phosphorus stored in the soil is brought to the soil surface by plant growth and released through decomposition of the plant material, thereby subjecting the surface phosphorus to the forces of wind and water, resulting in continuous losses over time of small amounts of phosphorus from these fields.

Phosphorus loss from land in long-term conserving cover (all loss pathways) averages only about 0.03 pound per acre per year in this region, primarily as soluble phosphorus lost to surface water (including lateral subsurface flows) and phosphorus lost with waterborne sediment (table 21).

Converting cropped acres to long-term conserving cover essentially eliminates phosphorus loss (table 21). Per-acre reductions can be quite high for acres where phosphorus applications are high for the no-practice cropped condition (figs. 56–58 and table 21).

Figure 56. Estimates of average annual reduction in total phosphorus loss due to conversion to long-term conserving cover in the Arkansas-White-Red Basin

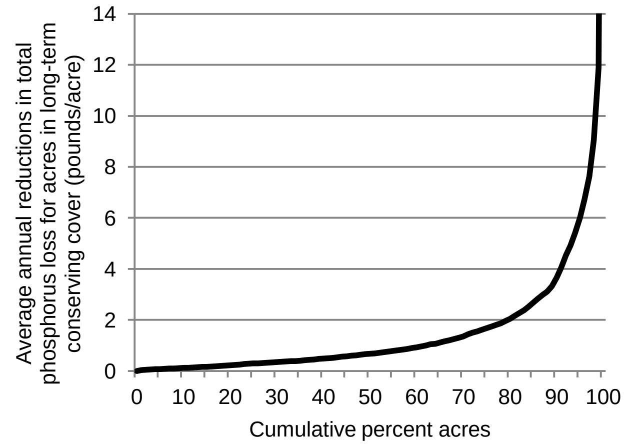


Figure 57. Estimates of average annual reduction in phosphorus lost with windborne sediment due to conversion to long-term conserving cover in the Arkansas-White-Red Basin

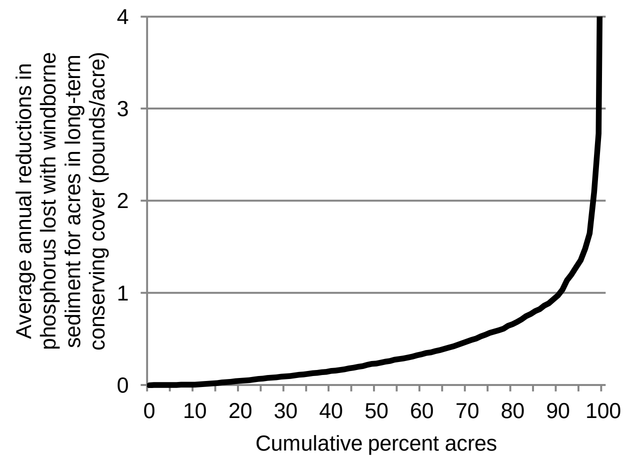


Figure 58. Estimates of average annual reduction in phosphorus lost to surface water due to conversion to long-term conserving cover in the Arkansas-White-Red Basin

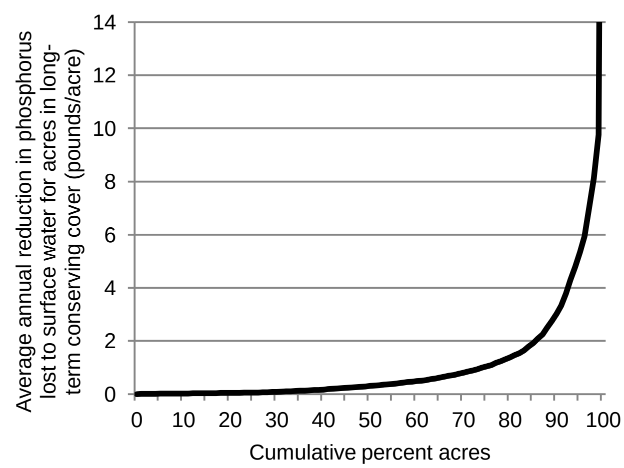


Table 21. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for land in long-term conserving cover (6 million acres) in the Arkansas-White-Red Basin

Model simulated outcome	Average annual values in pounds per acre Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	0.0	16.0	16.0	100
Phosphorus in crop yield removed at harvest	<0.1**	8.2	8.1	100
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	<0.01	0.42	0.42	100
Phosphorus lost to surface water (sediment attached and soluble)*	0.02	1.11	1.08	98
Soluble phosphorus lost to surface water*	0.01	0.45	0.44	98
Phosphorus loss with waterborne sediment	0.01	0.65	0.64	98
Soluble phosphorus loss to groundwater	<0.01	0.01	<0.01	31
Total phosphorus loss for all loss pathways	0.03	1.53	1.50	98
Change in soil phosphorus	-0.12	6.34	6.46	--

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.
** Harvest was simulated on acres planted to trees where expected tree age is less than the 47 years included in the model simulation. At tree harvest time, the grass also is removed and replanted.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Effects of Practices on Pesticide Residues and Environmental Risk

Use of pesticides to protect crops from weeds, insects, and diseases is an integral part of crop production. While pesticides are essential for large-scale agriculture, pesticide residues can migrate from the application site and lead to unintentional risk to humans and non-target plants and animals. Most pesticides are applied at much lower rates than nutrients. The fraction of pesticides applied that migrates offsite with water is generally less than 1 to 2 percent. Nevertheless, small amounts of pesticide residue can create water quality concerns depending on the toxicity of the pesticide residues to non-target species and even exceed EPA drinking water standards at times.

Model simulations incorporated pesticide use information from the CEAP survey conducted in 2003–06 (active ingredient, application rate, application method, and time of application).

The effects of converting cultivated cropland to long-term conserving cover were not evaluated for pesticides because the survey did not provide information on pesticide use on land enrolled in CRP General Signups. It was thus assumed that there was no pesticide residues lost from land in long-term conserving cover.

A total of 134 different pesticides are used in the region, as reported in the survey. The most commonly applied pesticides are presented in table 22. The pesticide applied in the largest amount for the entire reigon was glyphosate isopropylamine salt at 34 percent of the total weight of all pesticides applied, followed by atrazine at 23 percent, and S-metolachlor at 6 percent. These three herbicides accounted for 63 percent of the pesticides applied in the region, by weight.

Table 22. Pesticides most commonly used in the Arkansas-White-Red Basin

Pesticide (active ingredient name)	Pesticide type	Percent of the total amount of pesticides applied (by weight) in the Arkansas-White-Red basin
Glyphosate, isopropylamine salt	Herbicide	34
Atrazine	Herbicide	23
S-Metolachlor	Herbicide	6
Propanil	Herbicide	4
Trifluralin	Herbicide	3
2,4-D, 2-ethylhexyl ester	Herbicide	3
Acetochlor	Herbicide	2
Chlorpyrifos	Insecticide	2
Alachlor	Herbicide	2
2,4-Dichlorophenoxyacetic acid	Herbicide	2
2,4-D, dimethylamine salt	Herbicide	2
Glyphosate	Herbicide	2
Metolachlor	Herbicide	2
Pendimethalin	Herbicide	1
Propargite	Insecticide	1
Dimethenamide-P	Herbicide	1
Ethephon	Herbicide	1
Methyl parathion	Insecticide	1
Clomazone	Herbicide	1
Total*		91

* Pesticides not listed each represented less than 1 percent of the total applied in the entire region. Percents may not add to total due to rounding.

Baseline condition for pesticide loss

The APEX model tracks the mass loss for three pesticide loss pathways:[25]

- pesticides dissolved in surface water runoff,
- pesticides adsorbed to sediment lost through water erosion, and
- pesticides dissolved in subsurface flow pathways, which include surface and tile drainage systems, lateral subsurface flow, and percolation through the root zone.

Pesticides dissolved in surface water runoff, which accounts for 62 percent of the total loss of pesticides by weight, is the most important pesticide loss pathway in this region. Pesticides lost with waterborne sediment accounted for about 21 percent, and pesticides in subsurface flows accounted for 17 percent. Losses in the eastern portion of the basin are much higher than losses in the western portion, as illustrated in figure 59.

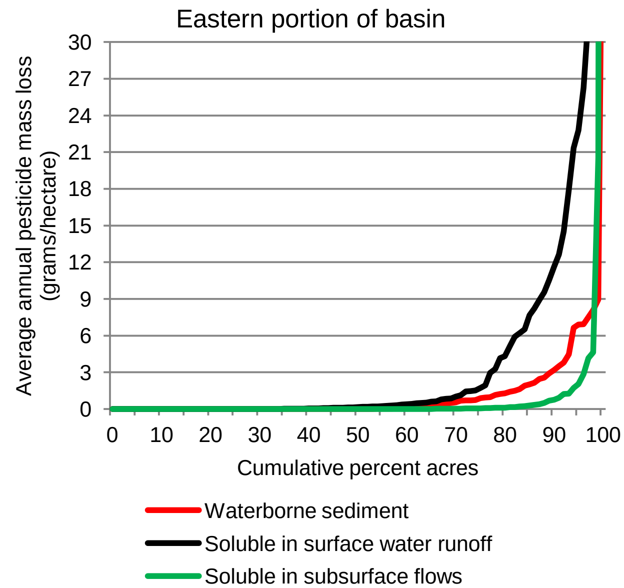
Overall, loss of pesticides from fields in the eastern portion of the basin accounted for 86 percent of the total mass loss of all pesticides in the region. In this portion of the basin, the dominant pesticide loss pathway was pesticides dissolved in surface water runoff for 41 percent of cropped acres. Pesticide loss with waterborne sediment was the dominant loss pathway for 20 percent of cropped acres, and soluble pesticide loss in subsurface flow was the dominant loss pathway for 9 percent. About 30 percent of cropped acres had no pesticide losses in this portion of the basin. (The dominant loss pathway was determined for each sample point as the pathway with the highest pesticide mass loss.) About half of the cropped acres in the western portion of the basin have negligible amounts of pesticide loss from farm fields, as shown in figure 59.

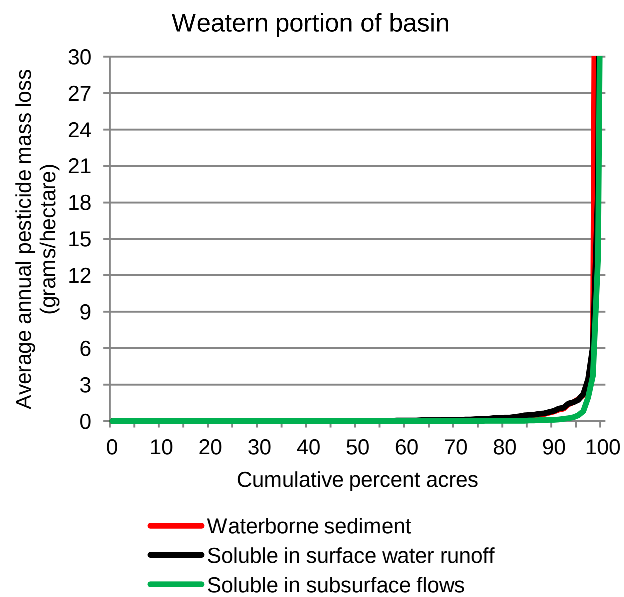
Over 80 percent of the cropped acres in the western portion of the basin had negligible amounts of pesticide loss from farm fields. About 37 percent of cropped acres have no pesticide loss in this portion of the basin. The dominant loss pathway is pesticides dissolved in surface water runoff for 31 percent of cropped acres.

The most common pesticide residues lost from farm fields in the Arkansas-White-Red Basin are presented in table 23. For the entire region, five herbicides account for 79 percent of all pesticide residues lost from fields in the model simulations—atrazine (56 percent of total mass loss), glyphosate isopropylamine salt (10 percent), alachlor (5 percent), metolachlor (4 percent), and S-metolachlor (4 percent).

The average annual amount of pesticide lost from farm fields in the Arkansas-White-Red Basin is about 2.8 grams of active ingredient per hectare per year (table 24).[26] As shown in figure 59, however, a few acres have much greater losses (fig. 59).

Figure 59. Estimates of average annual pesticide loss (mass loss of all pesticides combined) for three loss pathways, Arkansas-White-Red Basin, baseline conservation condition





[25] The APEX model currently does not estimate pesticides lost in spray drift, volatilization, or with windblown sediment.

[26] Grams per hectare is the standard reporting unit for pesticide active ingredients.

Table 23. Most common pesticides contributing to losses from farm fields in the Arkansas-White-Red Basin

Pesticide (active ingredient name)	Pesticide type	Percent of total pesticide mass loss from fields in the Arkansas-White-Red basin
Atrazine	Herbicide	56
Glyphosate, isopropylamine salt	Herbicide	10
Alachlor	Herbicide	5
Metolachlor	Herbicide	4
S-Metolachlor	Herbicide	4
Sodium chlorate	Herbicide	3
Acetochlor	Herbicide	2
Quinclorac	Herbicide	2
Carbofuran	Insecticide	1
Chlorsulfuron	Herbicide	1
Dimethenamide-P	Herbicide	1
Total*		90

* Pesticides not listed each represented less than 1 percent of the total loss in the entire region. Percents may not add to total due to rounding.

Table 24. Field-level effects of conservation practices on pesticide loss and associated edge-of-field environmental risk for cropped acres in the Arkansas-White-Red Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Entire region		
Pesticide sources				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	558	627	69	11
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	2.8	5.0	2.2	44
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	1.7	2.6	0.9	35
Average annual surface water pesticide risk indicator for humans	0.3	0.5	0.2	38
Average annual groundwater pesticide risk indicator for humans	0.1	0.1	<0.1	49
		Eastern portion of basin		
Pesticide sources				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	616	704	88	13
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	6.2	7.7	1.5	19
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	1.8	2.1	0.3	13
Average annual surface water pesticide risk indicator for humans	0.5	0.5	<0.1	10
Average annual groundwater pesticide risk indicator for humans	0.1	0.1	<0.1	12
		Western portion of basin		
Pesticide sources				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	525	583	58	10
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	0.8	3.5	2.7	76
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	1.6	2.8	1.2	44
Average annual surface water pesticide risk indicator for humans	0.2	0.5	0.3	54
Average annual groundwater pesticide risk indicator for humans	0.1	0.2	<0.1	49

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 14 subregions.

Effects of conservation practices on pesticide residues and risk

Management practices that reduce the potential for loss of pesticides from farm fields consist of a combination of Integrated Pest Management (IPM) techniques and water erosion control practices. Water erosion control practices mitigate the loss of pesticides from farm fields by reducing surface water runoff and sediment loss, both of which carry pesticide residues from the farm field to the surrounding environment. IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environmental condition. IPM consists of a management strategy for prevention, avoidance, monitoring, and suppression of pest populations. When the use of pesticides is necessary to protect crop yields, selection of pesticides that have the least environmental risk is an important aspect of the suppression component of IPM.

Model simulations show that conservation practices—primarily water erosion control practices—are effective in reducing the loss of pesticide residues from farm fields. Use of conservation practices has reduced the loss of pesticides (summed over all pesticides) in the region by an average of 2.2 grams of active ingredient per hectare per year, representing a 44-percent reduction from the 5.0 grams per hectare for the no-practice scenario (table 24). In the eastern portion, pesticide loss has been reduced by an average of 1.5 grams of active ingredient per hectare per year (19-percent reduction), compared to a reduction of 2.7 grams per acre per year in the western portion (76-percent reduction).

However, the total quantity of pesticide residues lost from the field is not the most useful outcome measure for assessing the environmental benefits of conservation practices on reducing pesticide residues. The environmental impact of pesticide residues is specific to the toxicity of each pesticide to the non-target species that may be exposed to the pesticide. For example, some pesticides used in large quantities, such as glyphosate, have relatively low toxicity thresholds for most non-target species.

Pesticide risk indicators were therefore developed to represent risk at the edge of the field (bottom of soil profile for groundwater) and for aggregating pesticide risk over the 134 pesticides included in the model for this region.[27] These edge-of-field risk indicators are based on the ratio of average annual pesticide concentrations in water leaving the field to safe concentrations (toxicity thresholds) for each pesticide. As such, these risk indicators do not have units. Risk indicator values of less than 1 are considered "safe" because the concentration is below the toxicity threshold for exposure at the edge of the field.[28]

Three edge-of-field risk indicators are used here to assess the effects of conservation practices: (1) surface water pesticide risk indicator for aquatic ecosystems, (2) surface water pesticide risk indicator for humans, and (3) groundwater pesticide risk indicator for humans. The surface water risk indicator includes pesticide residues in solution in surface water runoff and in all subsurface water flow pathways that eventually return to surface water (water flow in a surface or tile drainage system, lateral subsurface water flow, and groundwater return flow). The pesticide risk indicator for aquatic ecosystems was based on chronic toxicities for fish and aquatic invertebrates, and acute toxicities for algae and vascular aquatic plants. The pesticide risk indicators for humans were based on drinking water standards or the equivalent for pesticides where standards have not been set.

These indicators provide a consistent measure that is comparable from field to field and that represents the effects of farming activities on risk reduction without being influenced by other landscape factors. In most environmental settings, however, non-target species are exposed to concentrations that have been diluted by water from other sources, even when those environments are located adjacent to a field. Consequently, these edge-of-field risk indicators cannot be used to predict actual environmental impacts.

Figure 60 shows that for most years the overall risk for aquatic ecosystems is very low, in part because of the conservation practices in use. Over 80 percent of cropped acres in this region have aquatic ecosystem risk indicator scores below 1 in all years. But in some years the edge-of-field concentrations can be high relative to toxicity thresholds.

The pesticide risk indicator for aquatic ecosystems averaged 1.7 over all years and cropped acres for the baseline conservation condition (table 24). The 1.7 value indicates that average annual pesticide concentrations in water leaving cropped fields in the Arkansas-White-Red Basin are, on average, 1.7 times the "safe" concentration for non-target plant and animal species when exposed to concentrations at the edge of the field.

The two pesticide risk indicators for humans are much lower than for the aquatic ecosystems, averaging only 0.3 for surface water and 0.1 for groundwater (table 24).

Atrazine was the dominant pesticide contributing to all three risk indicators (table 25). Based on the model simulations, the edge-of-field risk indicator for atrazine exceeded 1 for 12 percent of the cropped acres for risk to aquatic ecosystems, 9 percent of the cropped acres for surface water risk to humans, and 1 percent of the cropped acres for groundwater risk to humans.

Atrazine's dominance in the risk indicators is due to its widespread use, its mobility (solubility = 30 mg/L; Koc = 100 g/ml), its persistence (field half-life = 60 days), its toxicity to aquatic ecosystems (aquatic plant toxicity = 1 ppb), and the human drinking water standard (EPA Maximum Contaminant Level = 3 ppb).

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[27] For a complete documentation of the development of the pesticide risk indicators, see "Pesticide risk indicators used in the CEAP cropland modeling," found at http://www.nrcs.usda.gov/technical/nri/ceap.

[28] A threshold value of 1 for the pesticide risk indicator applies when assessing the risk for a single pesticide. Since the indicator is summed over all pesticides in this study, a threshold value of 1 would still apply if pesticide toxicities are additive and no synergistic or antagonistic effects are produced when non-target species are exposed to a mix of pesticides.

Pesticide Risk Indicators

Three ***edge-of-field*** pesticide risk indicators were used to assess the effects of conservation practices:

1. surface water pesticide risk indicator for aquatic ecosystems,
2. surface water pesticide risk indicator for humans, and
3. groundwater pesticide risk indicator for humans.

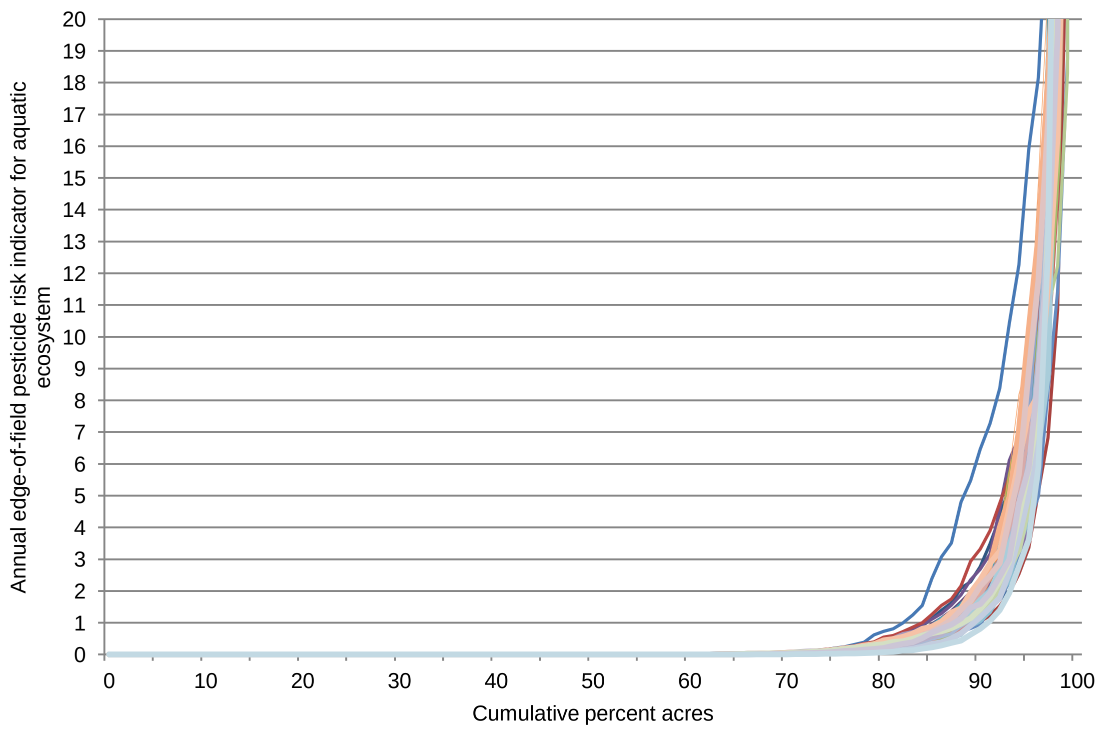
Pesticide risk indicators were calculated for each pesticide as the ratio of the concentration in water leaving the field to the "safe" concentration (toxicity thresholds) for each pesticide, where both are expressed in units of parts per billion. This ratio is called the Aquatic Risk Factor (ARF). ARFs are unit-less numbers that represent the relative toxicity of pesticides in solution. A risk indicator value of less than 1 is considered "safe" because the concentration is below the toxicity threshold for exposure at the edge-of-the field.

$$ARF = \frac{\text{(Annual Concentration)}}{\text{(Toxicity Threshold)}} < 1 \quad \rightarrow \text{Little or no potential adverse impact}$$

Two aquatic toxicity thresholds were used in estimating potential risk:

- Human drinking water lifetime toxicity thresholds. These thresholds are either taken from the EPA Office of Water Standards, or derived from EPA Reference Doses or Cancer Slopes using the methods employed by the EPA Office of Water.
- Aquatic ecosystem toxicity thresholds. The lowest (most sensitive) toxicity is used from the fish chronic NOEL (No Observable Effect Concentration), invertebrate chronic NOEL, aquatic vascular plant acute EC50 (Effective Concentration that is lethal to 50 percent of the population), and aquatic nonvascular plant acute EC50.

Figure 60. Distribution of annual values of the edge-of-field surface water pesticide risk indicator for aquatic ecosystems for each year of the 47-year model simulation, baseline conservation condition, Arkansas-White-Red Basin



Note: This figure shows how the annual values of the risk indicator varied within the region and from year to year in the model simulation on cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual values of the risk indicator varied over the region in that year, starting with the acres with the lowest value and increasing to the acres with the highest value. The family of curves shows how annual values vary from year to year.

Table 25. Dominant pesticides determining edge-of-field environmental risk, Arkansas-White-Red Basin

Pesticide (active ingredient name)	Pesticide type	Percent of cropped acres in the region with average annual edge-of-field risk indicator greater than 1
Risk indicator for aquatic ecosystem		
Atrazine	Herbicide	12
2,4-D, 2-ethylhexyl ester	Herbicide	3
Chlorsulfuron	Herbicide	2
Chlorpyrifos	Insecticide	2
Metolachlor	Herbicide	1
Alachlor	Herbicide	1
Acetochlor	Herbicide	<1
Sulfentrazone	Herbicide	<1
S-Metolachlor	Herbicide	<1
Parathion	Insecticide	<1
Triasulfuron	Herbicide	<1
Fipronil	Miticide	<1
All other pesticides	--	2
Risk indicator for humans, surface water		
Atrazine	Herbicide	9
Alachlor	Herbicide	1
All other pesticides	--	1
Risk indicator for humans, groundwater		
Atrazine	Herbicide	1
All other pesticides	--	<1

The use of conservation practices has reduced the pesticide risk indicator for aquatic ecosystems by 35 percent for the region (13 percent for the eastern portion and 44 percent for the western portion) (table 24, fig. 61). The surface water pesticide risk indicator for humans has been reduced by an average of 38 percent (10 percent for the eastern portion and 54 percent for the western portion) (table 24, fig. 62). The groundwater pesticide risk indicator for humans, which is very low throughout the region, has been reduced by an average of 49 percent due to conservation practice use (table 24).

Figure 63 shows the distribution of the reductions in the two pesticide risk indicators due to conservation practices. Significant risk reductions for aquatic ecosystems occur on only about 10 percent of the acres, while significant risk reductions for humans occur on only about 5 percent of the acres.[29] The benefits of conservation practices were significant for both aquatic ecosystem risks and human risks on the acres that had those risks, but aquatic ecosystem risks were more widespread than human risks so conservation practices have greater total benefit for aquatic ecosystems than for human drinking water.

[29] Small negative reductions in surface water runoff, shown in figure 20, also result in small negative reductions in pesticide risk indicators, shown in figure 63. Small negative reductions can also occur on these landscapes as a result of reduced tillage.

Figure 61. Estimates of average annual edge-of-field surface water pesticide risk indicator for aquatic ecosystems, Arkansas-White-Red Basin

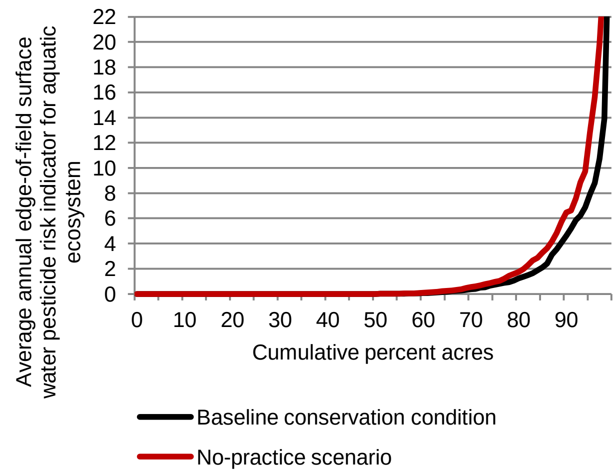


Figure 62. Estimates of average annual edge-of-field surface water pesticide risk indicator for humans, Arkansas-White-Red Basin

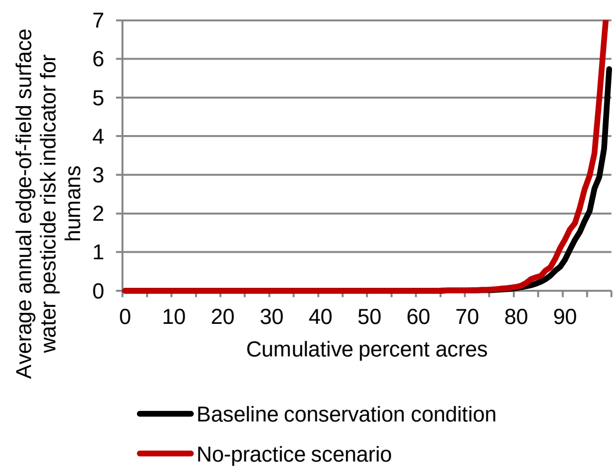
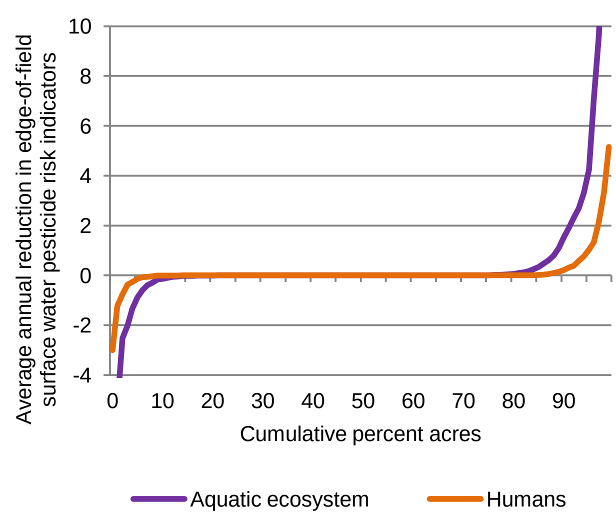


Figure 63. Estimates of average annual reductions in the edge-of-field surface water pesticide risk indicators for aquatic ecosystems in the Arkansas-White-Red Basin



Chapter 5
Assessment of Conservation Treatment Needs

The adequacy of conservation practices in use in the Arkansas-White-Red Basin was evaluated to identify remaining conservation treatment needs for controlling wind and water erosion and nutrient loss from fields. The evaluation was based on conservation practice use for the time period 2003 through 2006.

In summary, findings for the Arkansas-White-Red Basin indicate that—

- *4 percent of cropped acres (1.3 million acres) have a **high** level of need for additional conservation treatment,*
- *30 percent of cropped acres (9.1 million acres) have a **moderate** level of need for additional conservation treatment, and*
- *66 percent of cropped acres (20.1 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.*

The 10.4 million acres with additional conservation treatment needs—under-treated acres—were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Derivation of conservation treatment levels and inherent soil vulnerability classes are described in the next two sections, followed by estimates of under-treated acres.

Field-level model simulation results for the baseline conservation condition were used to make the assessment. Five resource concerns were evaluated for the Arkansas-White-Red Basin:

1. Sediment loss due to water erosion
2. Nitrogen loss with surface runoff (nitrogen attached to sediment and in solution)
3. Nitrogen loss in subsurface flows
4. Phosphorus lost to surface water (phosphorus attached to sediment and in solution, including soluble phosphorus in subsurface lateral flow pathways)
5. Wind erosion

The identification of conservation treatment needs was done separately for the eastern and western portions of the basin to better account for the differences in precipitation, land use, use of conservation practices, and resource concerns within the basin.

The conservation treatment needs for controlling pesticide loss were not evaluated because the assessment requires information on pest infestations, which was not available for the CEAP sample points. Meeting soil erosion control treatment needs would provide partial protection against loss of pesticide residues from farm fields. Integrated Pest Management (IPM) practices are also effective in reducing the risk associated with pesticide residues leaving the farm field. Determination of adequate IPM, however, is highly dependent on the specific site conditions and the nature and extent of the pest problems.

Adequate conservation treatment consists of combinations of conservation practices that treat the specific inherent vulnerability factors associated with each field. Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres to reduce field-level losses to acceptable levels. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Conservation Treatment Levels

Drawing from the evaluation of practice use presented in chapter 3, four levels of conservation treatment (high, moderately high, moderate, and low) were defined for each of the five resource concerns. A "high" level of treatment was shown by model simulations (see chapter 6) to reduce sediment and nutrient losses to low levels for nearly all cropped acres in the Arkansas-White-Red Basin.

For sediment loss due to water erosion, conservation treatment levels were defined by a combination of structural practices and residue and tillage management practices, as defined in figure 64. A high level of water erosion control treatment is in use on about 17 percent of cropped acres, mostly in the western portion of the basin. The majority of cropped acres—52 percent—have a moderate level of conservation treatment for water erosion control, and 26 percent have a low level of treatment.

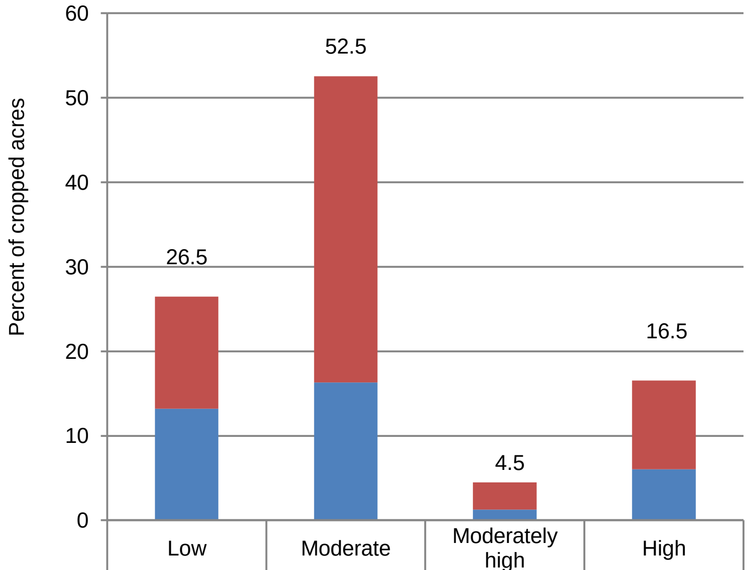
For nitrogen loss with surface runoff, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and nitrogen management practices, as defined in figure 65. A high level of treatment for nitrogen runoff is in use on only 4 percent of cropped acres. Twenty-nine percent have combinations of practices that indicate a moderately high level of treatment. The bulk of cropped acres—60 percent—has a moderately high level of treatment. About 8 percent of cropped acres have a low level of treatment for nitrogen runoff.

For phosphorus lost to surface water, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and phosphorus management practices, as defined in figure 66. A high level of treatment for phosphorus runoff is in use on only 7 percent of cropped acres. About 75 percent of cropped acres have combinations of practices that indicate a moderately high or moderate level of treatment. Nineteen percent of cropped acres have a low level of phosphorus management.

The nitrogen management level presented in figure 11 (see chapter 3) was used to evaluate the adequacy of conservation treatment for nitrogen loss in subsurface flows. A high level of treatment for nitrogen loss in subsurface flows is in use on 34 percent of the acres, most of which are in the western portion of the basin. About 61 percent of cropped acres have combinations of practices that indicate a moderately high or moderate level of treatment. Only 3 percent of cropped acres have a low level of nitrogen management.

For wind erosion, a combination of structural practices and tillage intensity was used to evaluate the adequacy of conservation treatment, as defined in figure 67. A high level of treatment for wind erosion is in use on less than 2 percent of cropped acres. About 80 percent have a low or moderate level of treatment. Eighteen percent of cropped acres have a moderately high level of treatment for controlling wind erosion.

Figure 64. Percent of cropped acres at four conservation treatment levels for water erosion control in the baseline conservation condition, Arkansas-White-Red Basin



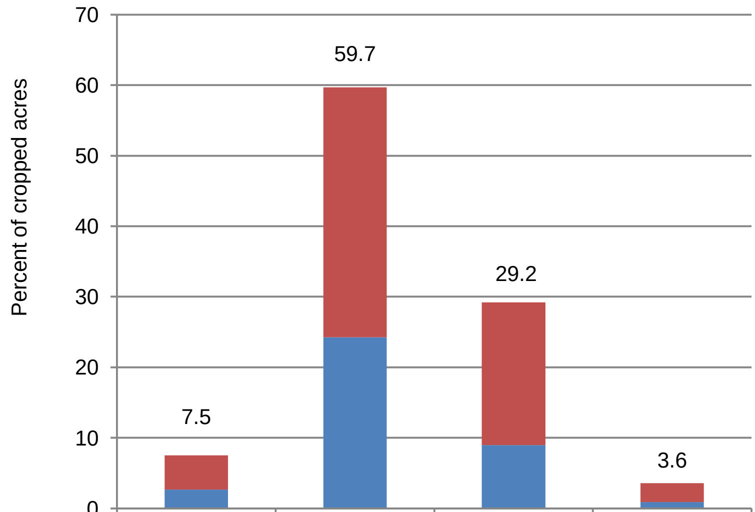
	Low	Moderate	Moderately high	High
Western portion	13.3	36.2	3.2	10.5
Eastern portion	13.2	16.3	1.3	6.0

Criteria for water erosion control treatment levels were derived using a combination of structural practice treatment levels and residue and tillage management treatment levels. Scores were first assigned to each of these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1 (see figs. 9 and 10). If slope was 2 percent or less, the water erosion control treatment level is the same as the residue and tillage management level. If slope was greater than 2 percent, the water erosion control treatment level is determined as follows:

- **High treatment**: Sum of scores is equal to 8. (High treatment level for both structural practices and residue and tillage management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.

Figure 65. Percent of cropped acres at four conservation treatment levels for nitrogen runoff control in the baseline conservation condition, Arkansas-White-Red Basin



	Low	Moderate	Moderately high	High
Western portion	4.8	35.5	20.2	2.7
Eastern portion	2.7	24.2	9.0	0.9

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and nitrogen management treatment levels. Scores were first assigned to each of these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1 (see figs. 9–11).

If slope was 2 percent or less, the nitrogen runoff control treatment level is determined as follows:

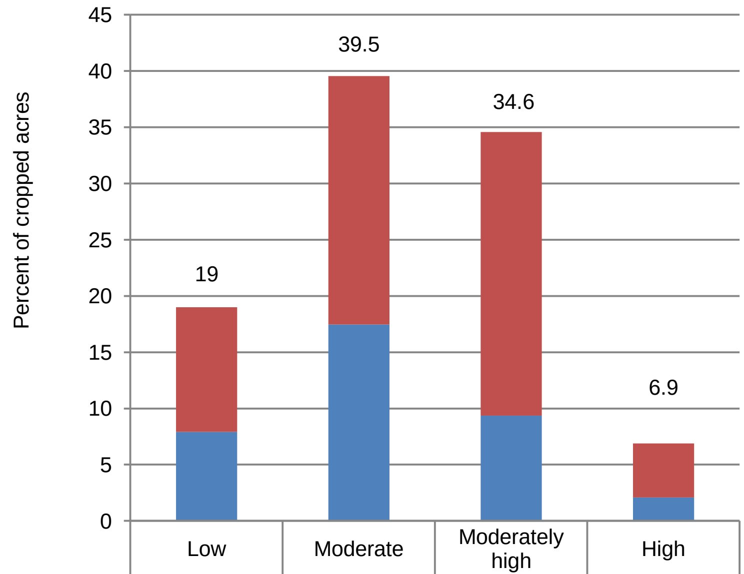
- **High treatment**: Sum of residue and tillage management score and nitrogen management score is equal to 8. (High treatment level for both structural practices and nitrogen management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the nitrogen runoff control treatment level is determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and nitrogen management score is equal to 12. (High treatment level for all three treatment types.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.

Figure 66. Percent of cropped acres at four conservation treatment levels for phosphorus runoff control in the baseline conservation condition, Arkansas-White-Red Basin



	Low	Moderate	Moderately high	High
Western portion	11.1	22.1	25.2	4.8
Eastern portion	7.9	17.5	9.4	2.1

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and phosphorus management treatment levels (see figs. 9, 10, and 12) in the same manner as the nitrogen runoff control treatment level. Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1.

If slope was 2 percent or less, the phosphorus runoff control treatment level is determined as follows:

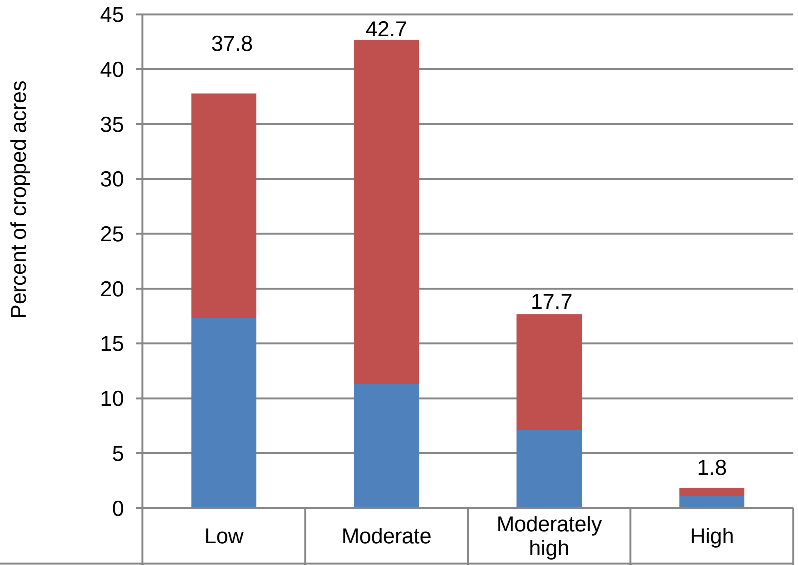
- **High treatment**: Sum of residue and tillage management score and phosphorus management score is equal to 8. (High treatment level for both structural practices and phosphorus management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the phosphorus runoff control treatment level is determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and phosphorus management score is equal to 12. (High treatment level for all three treatment types.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.

Figure 67. Percent of cropped acres at four conservation treatment levels for wind erosion management, baseline conservation condition, Arkansas-White-Red Basin



	Low	Moderate	Moderately high	High
Western portion	20.5	31.4	10.6	0.8
Eastern portion	17.3	11.3	7.1	1.1

Criteria were derived using a combination of structural practices for wind erosion control and residue and tillage management. Criteria for four levels of treatment are:

- **High treatment**: *All crops* meet tillage intensity criteria for either no-till or mulch till and at least one wind erosion control structural practice is in use.
- **Moderately high treatment**: A*ll crops* meet tillage intensity criteria for either no-till or mulch till without any wind erosion control structural practice or *average annual* tillage intensity meets criteria for mulch till or no-till and a wind erosion control structural practice is in use.
- **Moderate treatment**: A*verage annual* tillage intensity meets criteria for mulch till or no-till without any wind erosion control structural practice in use.
- **Low treatment**: No wind erosion control structural practices and *average annual* tillage intensity meets criteria for mulch till or no-till.

Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.

Inherent Vulnerability Factors

Not all acres require the same level of conservation treatment because of differences in inherent vulnerabilities due to soils and climate. Inherent vulnerability factors for surface runoff include soil properties that promote surface water runoff and erosion—soil hydrologic group, slope, and soil erodibility (the water erosion equation K-factor). Inherent vulnerability factors for loss of nutrients in subsurface flows include soil properties that promote infiltration—soil hydrologic group, slope, water erosion equation K-factor, and coarse fragment content of the soil. Because the vulnerability indicators are based on soils characteristics, they are referred to as "soil vulnerability potentials."

Soil runoff and leaching potentials were estimated for each sample point on the basis of vulnerability criteria. A single set of criteria was developed for all regions and soils in the United States to allow for regional comparisons. Thus, some soil vulnerability potentials are not well represented in every region.

The criteria for the soil runoff potential are presented in figure 68, followed by the spatial distribution of the soil runoff potential within the Arkansas-White-Red Basin in figure 69. The criteria and spatial distribution for the soil leaching potential are presented in figures 70 and 71. The criteria for the soil wind erosion potential are presented in figures 72 and 73. The maps show the vulnerability potentials for all soils and land uses in the region. For the assessment of conservation treatment needs, however, only the vulnerability potentials for cropped acres were used.

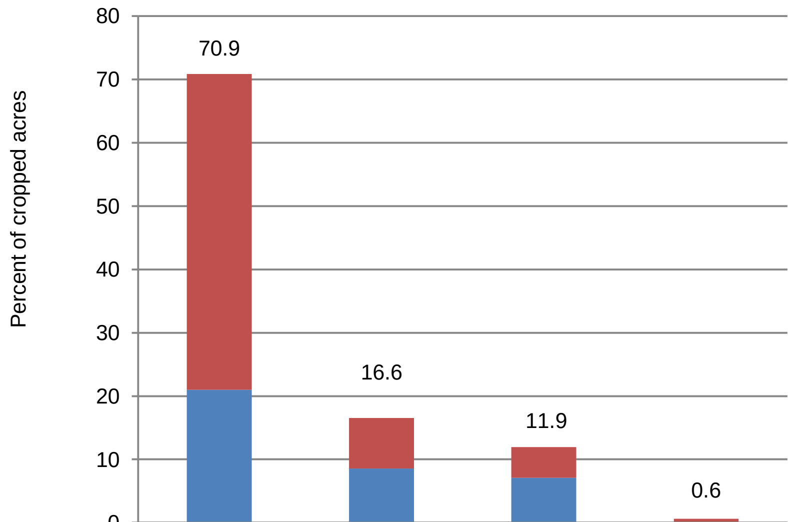
Cropped acres in the Arkansas-White-Red Basin have relatively low soil vulnerability potential compared to other regions of the country. A significant minority of acres, however, have either a high or moderately high vulnerability to one or more of the three vulnerability potentials.

- The majority of cropped acres—71 percent—have a low soil runoff potential (fig. 68). Less than 1 percent have a high soil runoff potential. Twelve percent of cropped acres have a moderately high soil runoff potential.
- Most acres in this region have a moderate soil leaching potential—66 percent (fig. 70). Twenty-one percent have

a low soil leaching potential. The remaining 13 percent have a high or moderately high soil leaching potential.

- While less than 2 percent of cropped acres have a high inherent potential for wind erosion based on soil properties and precipitation (fig. 72), about 12 percent of cropped acres have a moderately high potential. Nearly all of these acres are in the western portion of the basin. About 45 percent of cropped acres have a moderate level of soil wind erosion potential, nearly all in the western portion of the basin. About 42 percent of cropped acres have a low level of soil wind erosion potential, mostly in the eastern portion of the region.

Figure 68. Soil runoff potential for cropped acres in the Arkansas-White-Red Basin



	Low	Moderate	Moderately high	High
Western portion	49.9	8.0	4.9	0.5
Eastern portion	21.0	8.5	7.1	0.2

Criteria for four classes of soil runoff potential were derived using a combination of soil hydrologic group, percent slope, and K-factor, as shown in the table below:

Soil runoff potential	Acres with soil hydrologic group A	Acres with soil hydrologic group B	Acres with soil hydrologic group C	Acres with soil hydrologic group D
Low	All acres	Slope<4	Slope<2	Slope<2 and K-factor<0.28
Moderate	None	Slope >=4 and <=6 and K-factor<0.32	Slope >=2 and <=6 and K-factor<0.28	Slope<2 and K-factor>=0.28
Moderately high	None	Slope >=4 and <=6 and K-factor>=0.32	Slope >=2 and <=6 and K-factor>=0.28	Slope >=2 and <=4
High	None	Slope>6	Slope>6	Slope>4

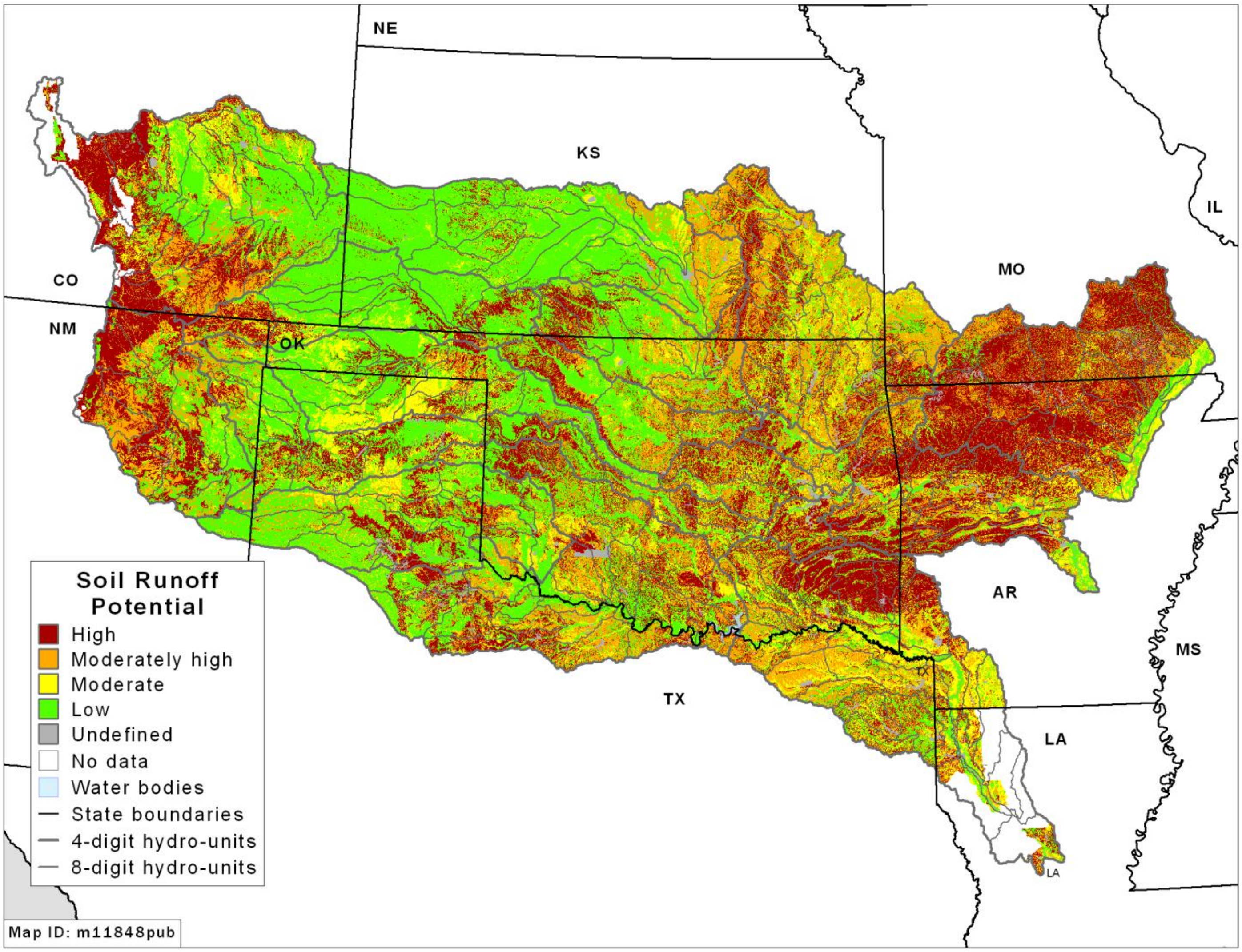
Hydrologic soil groups are classified as:

- **Group A**—sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- **Group D**—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.

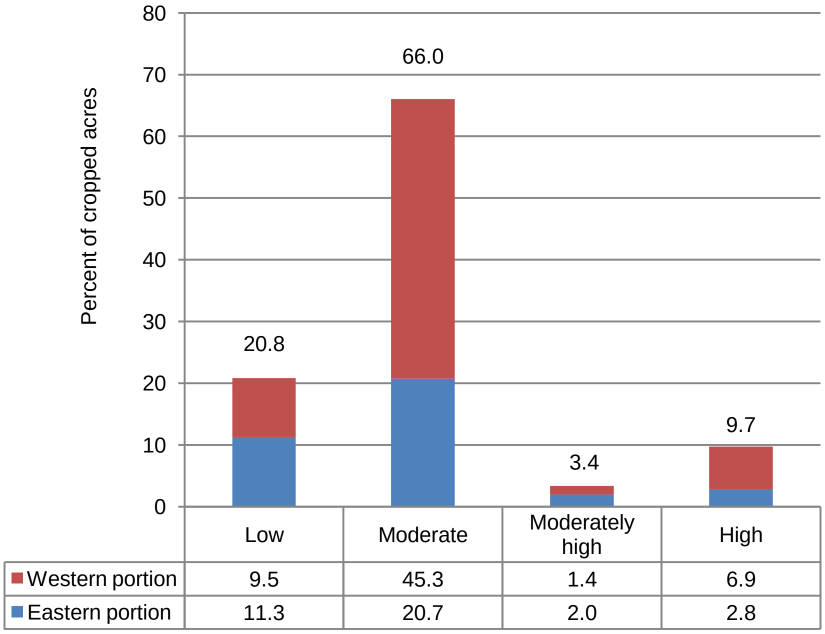
Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.
Note: See appendix B, table B4, for a breakdown of soil runoff potential by subregion.

Figure 69. Soil runoff potential for soils in the Arkansas-White-Red Basin



Note: The soil runoff potential shown in this map was derived using the criteria presented in figure 68 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 70. Soil leaching potential for cropped acres in the Arkansas-White-Red Basin



Criteria for four classes of soil leaching potential were derived using a combination of soil hydrologic group, percent slope, and K-factor, as shown in the table below:

Soil leaching potential	Acres with soil hydrologic group A	Acres with soil hydrologic group B	Acres with soil hydrologic group C	Acres with soil hydrologic group D
Low	None	None	None	All acres except organic soils
Moderate	None	Slope <=12 and K-factor>=0.24 or slope>12	All acres except organic soils	None
Moderately high	Slope>12	Slope >=3 and <=12 and K-factor<0.24	None	None
High	Slope<=12 or acres classified as organic soils	Slope<3 and K-factor <0.24 or acres classified as organic soils	Acres classified as organic soils	Acres classified as organic soils

Coarse fragments (stones and rocks) in the soil make it easier for water to infiltrate rather than run off. If the coarse fragment content of the soil was greater than 30 percent, the soil leaching potential was increased two levels (moderate and moderately high to high, and low to moderately high). If the coarse fragment content was greater than 10 percent but less than 30 percent, the soil leaching potential was increased one level.

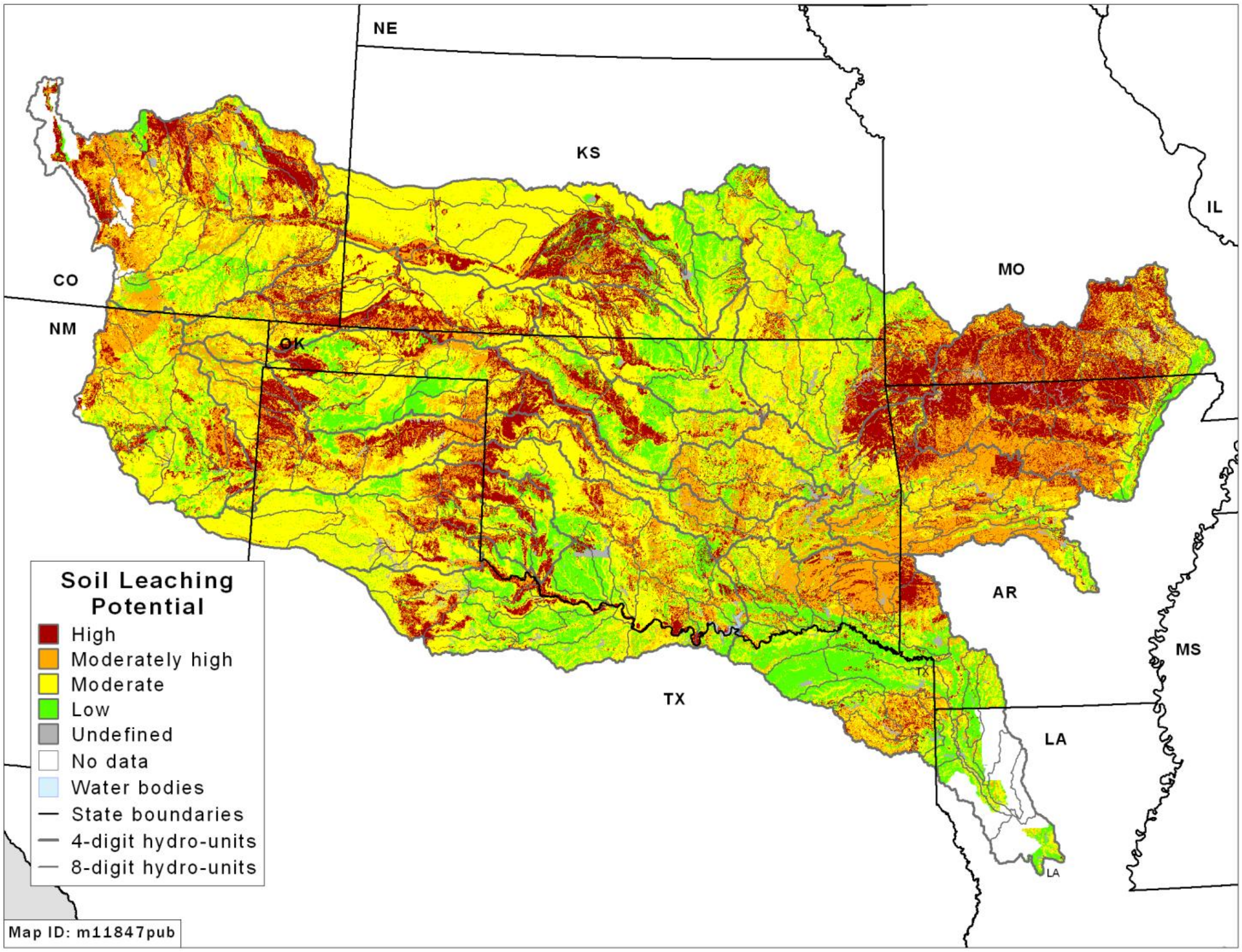
Hydrologic soil groups are classified as:

- **Group A**—sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- **Group D**—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

Note: K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.

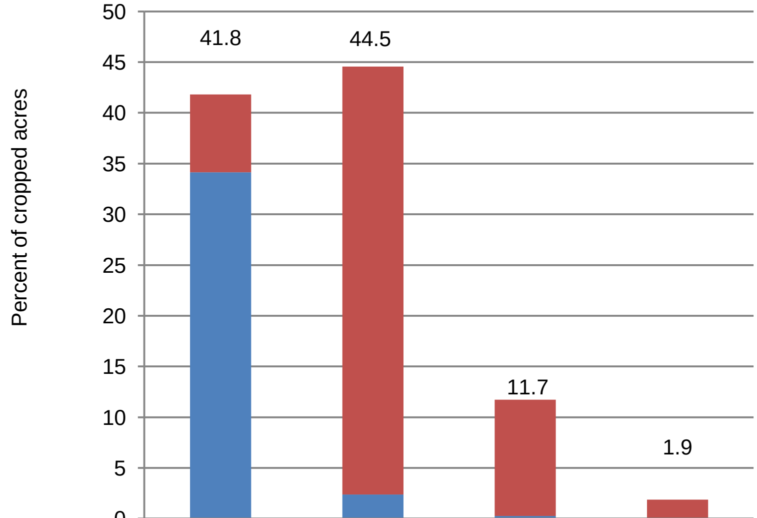
Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.
Note: See appendix B, table B4, for a breakdown of soil leaching potential by subregion.

Figure 71. Soil leaching potential for soils in the Arkansas-White-Red Basin



Note: The soil leaching potential shown in this map was derived using the criteria presented in figure 70 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 72. Soil wind erosion potential for cropped acres in the Arkansas-White-Red Basin



	Low	Moderate	Moderately high	High
Western portion	7.7	42.2	11.5	1.9
Eastern portion	34.1	2.4	0.3	0.0

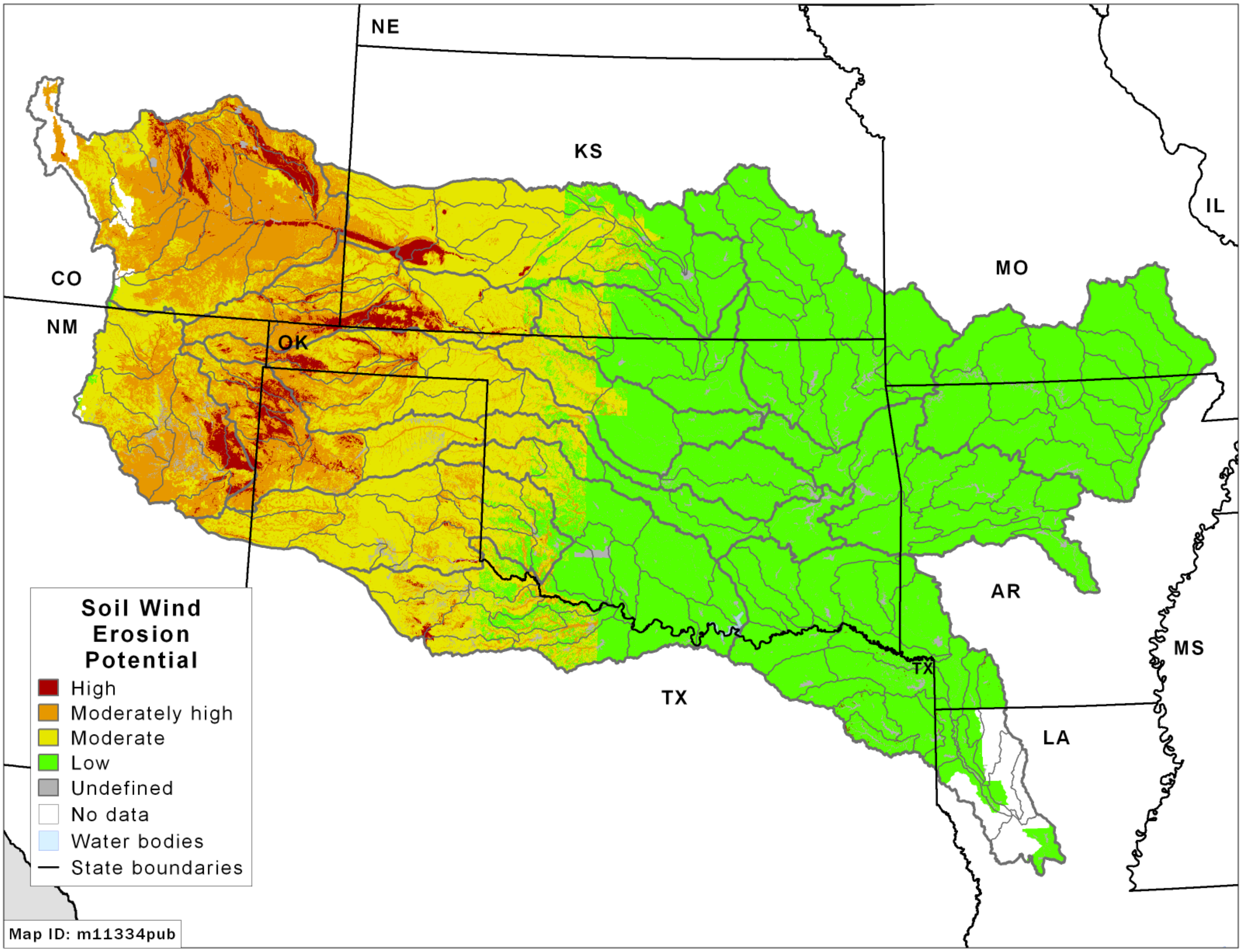
Criteria for four classes of wind erosion potential were derived using a combination of annual precipitation, percent slope, and the I-factor from the wind erosion equation*, as shown in the table below:

Soil wind erosion potential	Acres with I-factor <56	Acres with I-factor <134 and >=56	Acres with I-factor <250 and >=134	Acres with I-factor >=250
Low	Precipitation>=635 mm	Precipitation>=767 mm	Precipitation>=767 mm	None
Moderate	Precipitation<635 mm but >380mm	Precipitation<767 mm but >=508mm and slope>0.5	Precipitation <767 mm but >=635 mm <u>or</u> Precipitation <635 mm but >=508 mm and slope>=3	None
Moderately high	Precipitation<=380 mm	Precipitation<767 mm but >=508 mm and slope<=0.5 <u>or</u> Precipitation <508 mm	Precipitation <635 mm but >=508 mm and slope<3	None
High	None	None	Precipitation<508mm	All acres

* The I-factor from the wind erosion equation is a soil-erodibility index related to cloddiness.

Note: About 37 percent of the cropped acres in the basin are in the eastern portion and 63 percent are in the western portion.
Note: See appendix B, table B3, for a breakdown of soil wind erosion potential by subregion.

Figure 73. Soil wind erosion potential for soils in the Arkansas-White-Red Basin

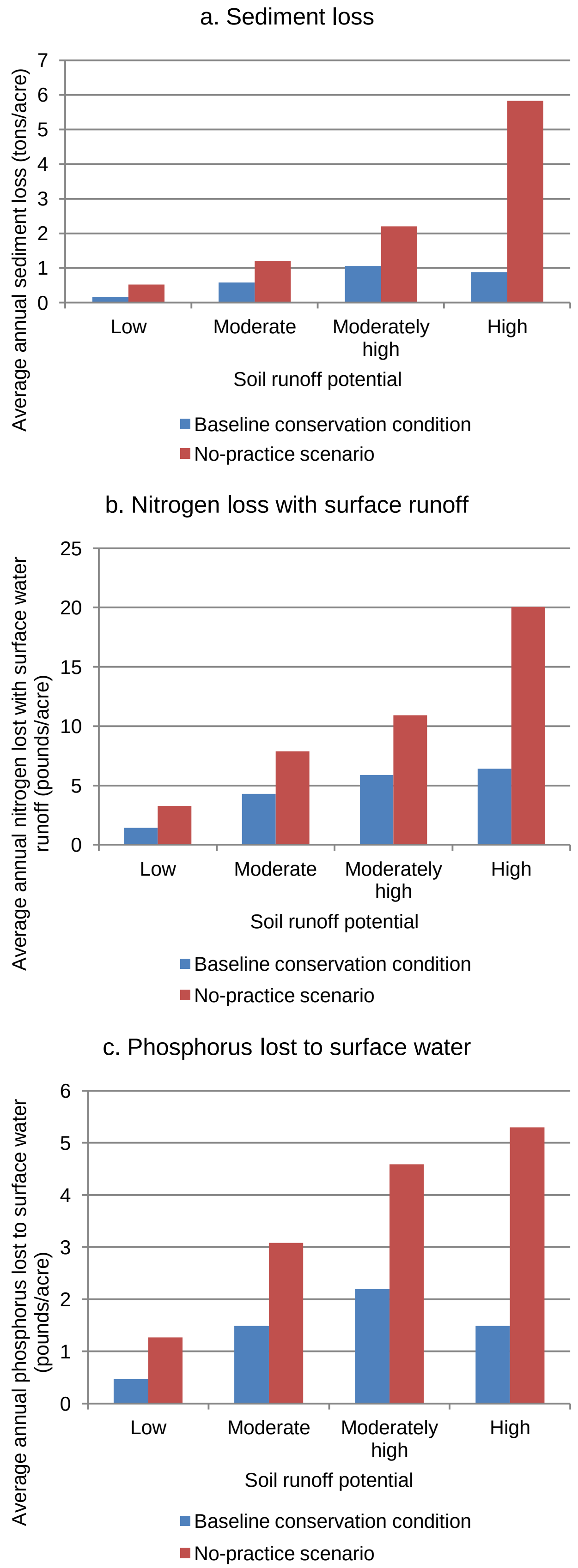


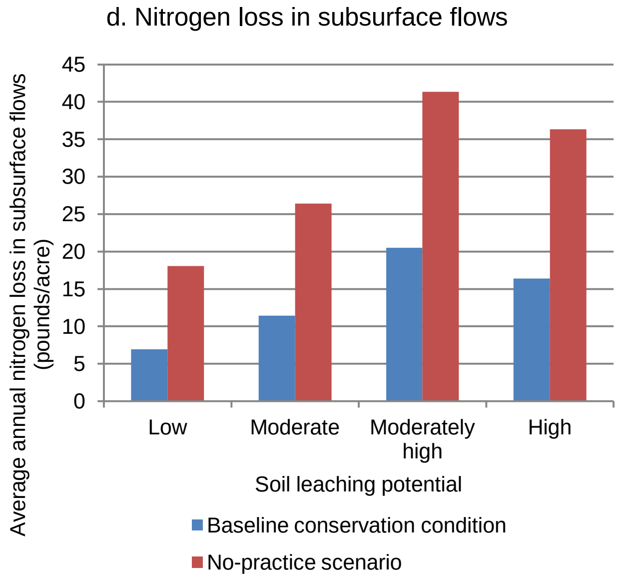
Note: The soil wind erosion potential shown in this map was derived using the criteria presented in figure 72 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

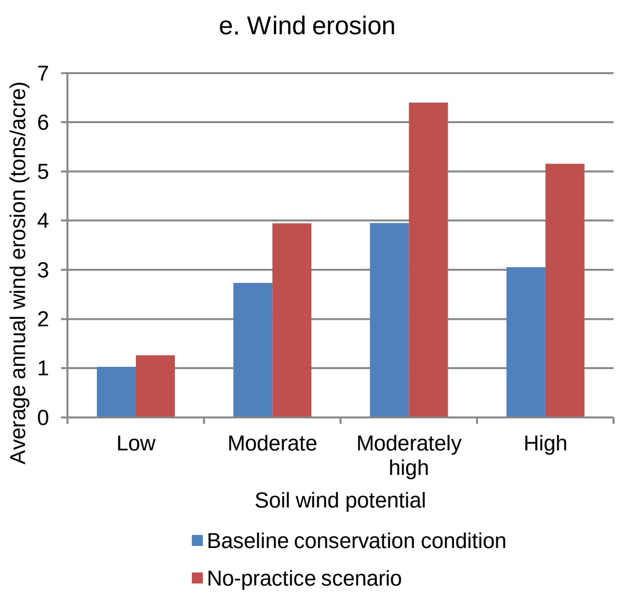
Soil vulnerability has a profound influence on the amount of soil and nutrients lost from farm fields and the extent to which conservation practices are effective in reducing those losses. Estimates of sediment and nutrient losses for the no-practice scenario (without conservation practices), presented in figure 74, demonstrate how vulnerability factors influence losses in the Arkansas-White-Red Basin. Estimates for the baseline are also presented in figure 74 to show how current levels of conservation treatment have reduced losses at each of the four vulnerability levels.

- Sediment loss for acres with a high soil runoff potential would have averaged nearly 5.8 tons per acre per year without conservation practices, compared to 0.5 ton per acre per year for acres with a low soil runoff potential (fig. 74a). The average annual reduction due to conservation practices is 4.7 tons per acre for soils with a high soil runoff potential, compared to a reduction of only 0.3 ton per acre for soils with a low soil runoff potential.
- Nitrogen loss with surface runoff for acres with a high soil runoff potential would have averaged 20 pounds per acre per year without conservation practices, compared to 3.3 pounds per acre per year for acres with a low soil runoff potential (fig. 74b). The average annual reduction due to conservation practices is 13.7 pounds per acre for soils with a high soil runoff potential, compared to a reduction of only 1.8 pounds per acre for soils with a low soil runoff potential.
- Phosphorus lost to surface water for acres with a high soil runoff potential would have averaged 5.3 pounds per acre per year without conservation practices, compared to 1.3 pounds per acre per year for acres with a low soil runoff potential (fig. 74c). The average annual reduction due to conservation practices is 3.8 pounds per acre for soils with a high soil runoff potential, compared to a reduction of only 0.8 pound per acre for soils with a low soil runoff potential.
- Nitrogen loss in subsurface flows for acres with a high soil leaching potential would have averaged 36 pounds per acre per year without conservation practices, compared to 18 pounds per acre per year for acres with a low soil leaching potential (fig. 74d). The average annual reduction due to conservation practices is 20 pounds per acre for soils with a high soil leaching potential, compared to a reduction of only 11 pounds per acre for soils with a low soil leaching potential.
- Wind erosion for acres with a high wind erosion potential would have averaged 5 tons per acre per year without conservation practices, compared to 1.3 tons per acre per year for acres with a low wind erosion potential (fig. 74e). The average annual reduction due to conservation practices is 2.1 tons per acre for soils with a high soil wind erosion potential, compared to a reduction of only 0.2 ton per acre for soils with a low wind erosion potential.

Figure 74. Average annual wind erosion, sediment loss, and nutrient losses for four levels of vulnerability potentials, Arkansas-White-Red Basin







Evaluation of Conservation Treatment

The "matrix approach"

A "matrix approach" was used to identify acres where the level of conservation treatment is inadequate relative to the level of inherent vulnerability. These acres are referred to as "under-treated acres." Cropped acres were divided into 16 groups—defined by the four soil vulnerability potentials and four conservation treatment levels. The evaluation of conservation treatment needs was conducted by identifying which of the 16 groups of acres are inadequately treated with respect to the vulnerability potential.

The matrixes are presented for each of the five resource concerns in tables 26 through 30. Separate matrixes are used for the eastern and western portions of the basin to improve the capability of discriminating between high losses and lower losses. Each table includes seven sets of matrixes for each area that, taken together, capture the effects of conservation practices in the region and identifies the need for additional conservation treatment.

Acres and model results for each of the 16 groupings are presented in the first five matrixes in each table. The combination of the four soil vulnerability potentials and the four conservation treatment levels separates the acres with high losses from the acres with low losses. There generally is a trend of decreasing losses with increasing conservation treatment levels within each vulnerability potential. The tables also demonstrate that the high and moderately high treatment levels are effective in reducing losses for all vulnerability potentials.

The last two matrixes in each table show how conservation treatment needs were identified. Three levels of conservation treatment need were defined.

- **Acres with a "high" level of need** for conservation treatment consist of the most critical under-treated acres in the region. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest erosion and/or loss of nutrients.

- **Acres with a "moderate" level of need** for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability or have more conservation practice use than acres with a high level of need. The treatment level required is not necessarily less, although it can be, but rather the soil and nutrient losses are lower and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment.

- **Acres with a "low" level of need** for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. While gains can be attained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

Specific criteria were used to identify the groups of acres that fall into each of the three levels of conservation treatment need. Criteria were not tailored to a specific region, but were derived for use in all regions of the country to allow for comparisons of under-treated acres across regions using a consistent analytical framework.

The criteria and steps in the process are as follows—

1. The percentage of acres that exceeded a given level of loss was estimated for each cell in the matrix as a guide to determining the extent of excessive losses. These are referred to as “acceptable levels.” *Losses above these levels were treated as unacceptable levels of loss.* “Acceptable levels”[30] for field-level losses used in this study are—
   - Average of 2 tons per acre per year for sediment loss,
   - Average of 15 pounds per acre per year for nitrogen loss with surface runoff (soluble and sediment attached),
   - Average of 25 pounds per acre per year for nitrogen loss in subsurface flows,
   - Average of 4 pounds per acre per year for phosphorus lost to surface water (soluble and sediment attached), and
   - Average wind erosion rate of 4 tons per acre per year.
2. Groups of acres with less than 30 percent of the acres exceeding acceptable levels were defined as adequately treated acres and designated as having a **low level of conservation treatment need**.
3. Groups of acres with more than 60 percent of the acres in excess of acceptable levels were designated as having a **high level of conservation treatment need,** indicated by darker shaded cells in the matrixes.
4. The remaining acres were designated as having a **moderate level of conservation treatment need**, indicated by lighter shaded cells in the matrix.

Under-treated acres—those groups of acres with either a high or moderate level of conservation treatment need—are shown in the last matrix in each table. In most cases, under-treated acres consist of acres where the conservation treatment level was one step or more below the soil vulnerability potential.

Acceptable levels were initially derived through a series of forums held at professional meetings of researchers working on fate and transport of sediment and nutrients in agriculture. Those meetings produced a range of estimates for edge-of-field sediment loss, nitrogen loss, and phosphorus loss, representing what could be realistically achieved with today’s production and conservation technologies. The range was narrowed by further examination of APEX model output, which also showed that the levels selected were agronomically feasible in all agricultural regions of the country. In the Arkansas-White-Red Basin, for example, percentages of acres that can attain these acceptable levels with additional soil erosion control and nutrient management practices on all under-treated acres are (see the next chapter)—

- 99 percent of cropped acres for sediment loss,
- 99 percent of cropped acres for nitrogen loss with surface runoff,
- 92 percent of cropped acres for nitrogen loss in subsurface flows,
- 99 percent of cropped acres for phosphorus lost to surface water, and
- 88 percent of cropped acres for wind erosion.

The criteria used to identify acres that need additional conservation treatment, including acceptable levels, are not intended to provide adequate protection of water quality, although for some environmental settings they may be suitable for that purpose. Evaluation of how much conservation treatment is needed to meet Federal, State, and/or local water quality goals in the region is beyond the scope of this study.

[30] The long-term average loss was used as the criteria because losses vary considerably from year to year, and the evaluation is intended to assess the adequacy of conservation treatment over all years, on average. Average annual losses derived from APEX model output simulated over 47 years of actual weather (1960 through 2006) were compared to the acceptable level criteria for each sample point.

Why Was a Threshold Approach Not Used?

A threshold approach is where all acres with edge-of-field losses above a specific level are identified as under-treated acres; and thus, all acres below that level of loss are considered adequately treated.

A threshold approach is impractical for use in evaluating the adequacy of conservation practice use at the field level. Determination of the threshold level would need to be based on the environmental goals for a watershed, which would be expected to vary from watershed to watershed. Different thresholds would likely be needed for each field, depending on the cropping system. Moreover, sediment and nutrient losses vary from year to year; a specific set of practices shown to reduce losses below a specific level in some years will fail to do so in other years, even among acres that are fully treated. Inexpensive monitoring technologies do not exist for estimating sediment and nutrient losses on a field-by-field basis to determine what level of treatment is needed to meet an edge-of-field loss threshold, further hampering adaptive management efforts by producers.

The conservation goal is full treatment—not treatment to an arbitrary threshold. Protocols for full treatment—avoid, control, and trap—apply equally to all fields in all settings. The hallmark of the matrix approach is that the acres with treatment needs can be readily identified by farmers and conservation planners and treated as needed. Soil vulnerability levels and the existing conservation treatment levels can be readily determined during the conservation planning process.

Table 26. Identification of under-treated acres for sediment loss due to water erosion in the Arkansas-White-Red Basin

	Conservation treatment levels for sediment loss due to water erosion									
	Low	Moderate	Moderately high	High	All	Low	Moderate	Moderately high	High	All
Soil runoff potential	**Eastern portion of basin**					**Western portion of basin**				
Estimated cropped acres										
Low	2,489,662	2,723,186	171,580	1,013,705	6,398,132	2,745,256	8,940,010	889,300	2,621,228	15,195,794
Moderate	785,702	1,032,377	117,442	670,034	2,605,554	818,783	1,076,719	50,464	496,781	2,442,746
Moderately high	735,652	1,171,087	99,297	153,804	2,159,840	392,631	988,954	19,556	79,722	1,480,863
High	10,454	42,643	0	0	53,098	89,533	34,633	16,507	0	140,673
All	4,021,470	4,969,293	388,319	1,837,543	11,216,624	4,046,202	11,040,317	975,827	3,197,730	19,260,076
Percent of cropped acres										
Low	22	24	2	9	57	14	46	5	14	79
Moderate	7	9	1	6	23	4	6	<1	3	13
Moderately high	7	10	1	1	19	2	5	<1	<1	8
High	<1	<1	0	0	<1	<1	<1	<1	0	1
All	36	44	3	16	100	21	57	5	17	100
Sediment loss estimates *without* conservation practices (no-practice scenario), average annual tons/acre										
Low	0.47	0.95	0.48	0.85	0.73	0.70	0.29	0.48	0.65	0.44
Moderate	1.61	1.88	1.14	1.61	1.69	0.74	0.53	0.74	0.87	0.67
Moderately high	3.52	2.73	3.61	2.65	3.03	0.78	1.13	0.84	0.22	0.98
High	25.44	1.68	NA	NA	6.36	7.94	2.15	0.44	NA	5.63
All	1.31	1.57	1.48	1.28	1.43	0.88	0.40	0.50	0.67	0.55
Sediment loss estimates for the baseline conservation condition, average annual tons/acre										
Low	0.24	0.44	0.25	0.29	0.33	0.20	0.07	0.04	0.04	0.08
Moderate	1.09	0.94	0.52	0.68	0.90	0.48	0.14	0.10	0.10	0.24
Moderately high	2.47	1.10	0.88	0.70	1.53	0.45	0.38	0.66	0.03	0.38
High	6.13	0.58	NA	NA	1.67	0.64	0.61	0.17	NA	0.58
All	0.83	0.70	0.49	0.47	0.70	0.29	0.10	0.06	0.05	0.13
Percent reduction in sediment loss due to conservation practices, average annual tons/acre										
Low	49	54	48	66	55	72	76	92	94	81
Moderate	32	50	55	58	47	36	75	86	89	64
Moderately high	30	60	76	73	50	42	67	22	85	61
High	76	65	NA	NA	74	92	72	61	NA	90
All	37	55	67	63	51	67	74	89	93	76
Percent of acres in baseline with average annual sediment loss more than 2 tons/acre										
Low	0	3	6	1	2	0	0	0	0	0
Moderate	11	9	11	6	9	7	0	0	0	2
Moderately high	35	16	0	0	21	2	0	0	0	0
High	NA*	0	NA	NA	20	0	0	0	NA	0
All	9	7	6	3	7	2	0	0	0	0
Estimate of under-treated acres for sediment loss										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	0	0	0	0	0	0	0	0	0	0
Moderately high	735,652	0	0	0	735,652	0	0	0	0	0
High	10,454	0	0	0	10,454	0	0	0	0	0
All	746,106	0	0	0	746,106	0	0	0	0	0

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.

* This group of acres was classified as under-treated acres because a lower level of soil vulnerability met the criteria for under-treated acres. Sample size was very small for this cell.

Table 27. Identification of under-treated acres for nitrogen loss with surface runoff (sediment attached and soluble) in the Arkansas-White-Red Basin

	Conservation treatment levels for nitrogen runoff control									
	Low	Moderate	Moderately high	High	All	Low	Moderate	Moderately high	High	All
Soil runoff potential	**Eastern portion of basin**					**Western portion of basin**				
Estimated cropped acres										
Low	391,383	4,288,628	1,538,690	179,431	6,398,132	983,232	8,446,838	5,059,751	705,972	15,195,794
Moderate	294,915	1,637,620	589,381	83,638	2,605,554	269,018	1,346,247	715,544	111,937	2,442,746
Moderately high	120,738	1,431,941	597,905	9,257	2,159,840	174,647	933,586	372,631	0	1,480,863
High	10,454	29,951	12,692	0	53,098	45,666	78,500	16,507	0	140,673
All	817,490	7,388,140	2,738,669	272,325	11,216,624	1,472,563	10,805,171	6,164,432	817,909	19,260,076
Percent of cropped acres										
Low	3	38	14	2	57	5	44	26	4	79
Moderate	3	15	5	1	23	1	7	4	1	13
Moderately high	1	13	5	<1	19	1	5	2	0	8
High	<1	<1	<1	0	<1	<1	<1	<1	0	1
All	7	66	24	2	100	8	56	32	4	100
Estimates of nitrogen loss with surface water runoff *without* conservation practices (no-practice scenario), average annual pounds/acre										
Low	4	4	5	7	5	4.9	2.7	2.4	2.1	2.7
Moderate	13	10	13	11	11	3.0	5.1	4.3	2.9	4.5
Moderately high	19	16	12	38	15	3.0	5.4	4.4	NA	4.9
High	112	9	7	NA	29	8.5	24.2	3.6	NA	16.7
All	11	8	8	10	8	4.5	3.4	2.7	2.2	3.2
Estimates of nitrogen loss with surface water runoff for the baseline conservation condition, average annual pounds/acre										
Low	3	3	3	3	3	1.4	0.9	0.7	0.5	0.8
Moderate	8	6	7	9	7	2.1	2.2	1.4	1.2	1.9
Moderately high	15	9	5	8	8	2.2	2.4	2.2	NA	2.3
High	36	4	6	NA	11	6.4	4.2	2.3	NA	4.7
All	7	5	4	5	5	1.8	1.2	0.8	0.6	1.1
Percent reduction in nitrogen loss with surface water runoff due to conservation practices, average annual pounds/acre										
Low	29	36	44	53	38	72	66	72	76	69
Moderate	39	38	48	16	40	29	58	68	60	59
Moderately high	22	43	56	79	45	27	56	50	NA	52
High	68	56	20	NA	63	24	82	38	NA	72
All	37	39	49	43	42	61	64	69	73	65
Percent of acres in baseline with average annual nitrogen loss with surface runoff more than 15 pounds/acre										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	9	3	2	0	4	0	0	0	0	0
Moderately high	NA	18	2	0	15	0	0	0	NA	0
High	NA	0	0	0	20	0	0	0	NA	0
All	10	4	1	0	4	0	0	0	0	0
Estimate of under-treated acres for nitrogen loss with surface runoff										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	0	0	0	0	0	0	0	0	0	0
Moderately high	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0
All	0	0	0	0	0	0	0	0	0	0

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.

Table 28. Identification of under-treated acres for nitrogen loss in subsurface flows in the Arkansas-White-Red Basin

	Conservation treatment levels for nitrogen leaching									
	Low	Moderate	Moderately high	High	All	Low	Moderate	Moderately high	High	All
Soil leaching potential	**Eastern portion of basin**					**Western portion of basin**				
Estimated cropped acres										
Low	348,877	886,328	1,469,578	740,861	3,445,644	122,754	839,159	740,088	1,205,876	2,907,877
Moderate	109,040	1,471,367	2,213,026	2,526,899	6,320,333	664,573	5,461,532	2,953,214	4,727,465	13,806,783
Moderately high	83,486	259,395	137,007	116,329	596,217	67,826	232,754	72,939	55,284	428,804
High	0	218,747	379,243	256,440	854,430	63,000	517,994	759,245	776,373	2,116,612
All	541,403	2,835,837	4,198,854	3,640,530	11,216,624	918,153	7,051,439	4,525,487	6,764,997	19,260,076
Percent of cropped acres										
Low	3	8	13	7	31	1	4	4	6	15
Moderate	1	13	20	23	56	3	28	15	25	72
Moderately high	1	2	1	1	5	<1	1	<1	<1	2
High	0	2	3	2	8	<1	3	4	4	11
All	5	25	37	32	100	5	37	24	35	100
Estimates of nitrogen loss in subsurface flows *without* conservation practices (no-practice scenario), average annual pounds/acre										
Low	25	18	25	26	23	8	9	16	12	12
Moderate	16	32	35	37	35	43	15	32	23	23
Moderately high	145	12	54	28	44	51	26	80	20	38
High	NA	39	41	36	39	82	40	32	32	35
All	42	26	32	34	32	42	16	30	22	23
Estimates of nitrogen loss in subsurface flows for the baseline conservation condition, average annual pounds/acre										
Low	19	12	6	7	9	2	8	3	3	5
Moderate	14	22	10	10	13	41	13	8	5	11
Moderately high	117	8	22	9	27	24	8	15	8	12
High	NA	29	17	11	18	61	28	9	10	16
All	33	18	10	9	13	36	14	8	5	10
Percent reduction in nitrogen loss in subsurface flows due to conservation practices, average annual pounds/acre										
Low	25	34	76	74	62	76	9	79	75	61
Moderate	13	30	70	73	62	4	10	75	77	53
Moderately high	19	32	60	69	39	53	67	81	62	69
High	NA	26	58	70	53	25	30	71	69	56
All	21	31	70	73	60	13	16	75	75	54
Percent of acres in baseline with average annual nitrogen loss in subsurface flows more than 25 pounds/acre										
Low	29	6	5	2	7	0	12	0	5	6
Moderate	16*	33	10	6	14	24	14	10	3	10
Moderately high	NA*	NA*	32	0	17	47	5	19	0	14
High	NA*	34	11**	0	13	87	29	8	8	16
All	32	22	9	5	12	27	15	8	4	10
Estimate of under-treated acres for nitrogen loss in subsurface flows										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	109,040	1,471,367	0	0	1,580,407	0	0	0	0	0
Moderately high	83,486	259,395	137,007	0	479,888	67,826	0	0	0	67,826
High	0	218,747	379,243	0	597,990	63,000	0	0	0	63,000
All	192,526	1,949,509	516,250	0	2,658,285	130,827	0	0	0	130,827

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.
Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.
* This group of acres was classified as under-treated acres because a higher level of conservation treatment met the criteria for under-treated acres. Sample size was very small for these cells.
** This group of acres was classified as under-treated acres because a lower level of soil vulnerability met the criteria for under-treated acres. Sample size was very small for this cell.

Table 29. Identification of under-treated acres for phosphorus lost to surface water (attached to sediment and in solution) in the Arkansas-White-Red Basin

	Conservation treatment levels for phosphorus runoff control									
	Low	Moderate	Moderately high	High	All	Low	Moderate	Moderately high	High	All
Soil runoff potential	**Eastern portion of basin**					**Western portion of basin**				
Estimated cropped acres										
Low	1,355,837	2,994,584	1,666,794	380,917	6,398,132	2,652,573	4,853,577	6,442,928	1,246,716	15,195,794
Moderate	561,355	1,206,811	663,214	174,174	2,605,554	461,774	855,565	943,459	181,948	2,442,746
Moderately high	489,995	1,079,811	511,854	78,181	2,159,840	250,883	895,952	292,158	41,870	1,480,863
High	0	40,405	12,692	0	53,098	17,359	123,314	0	0	140,673
All	2,407,186	5,321,612	2,854,555	633,271	11,216,624	3,382,589	6,728,408	7,678,545	1,470,534	19,260,076
Percent of cropped acres										
Low	12	27	15	3	57	14	25	33	6	79
Moderate	5	11	6	2	23	2	4	5	1	13
Moderately high	4	10	5	1	19	1	5	2	<1	8
High	0	<1	<1	0	0	<1	1	0	0	1
All	21	47	25	6	100	18	35	40	8	100
Estimates of phosphorus lost to surface water *without* conservation practices (no-practice scenario), average annual pounds/acre										
Low	1.44	1.98	2.92	3.27	2.19	1.59	0.81	0.60	1.10	0.9
Moderate	3.61	4.47	4.94	7.94	4.64	1.31	1.85	0.98	1.95	1.4
Moderately high	5.66	5.98	8.15	6.42	6.44	1.88	1.77	2.40	1.03	1.9
High	NA	8.55	2.55	NA	7.12	2.41	4.92	NA	NA	4.6
All	2.81	3.41	4.33	4.94	3.60	1.58	1.15	0.71	1.20	1.1
Estimates of phosphorus lost to surface water for the baseline conservation condition, average annual pounds/acre										
Low	1.28	0.84	0.79	0.66	0.91	0.61	0.30	0.15	0.23	0.28
Moderate	2.96	2.39	1.88	1.71	2.34	1.04	0.53	0.37	0.68	0.58
Moderately high	4.62	2.88	2.08	1.20	3.03	1.44	0.85	1.10	0.21	0.98
High	NA	1.91	1.49	NA	1.81	1.09	1.41	NA	NA	1.37
All	2.35	1.62	1.28	1.02	1.65	0.73	0.42	0.21	0.29	0.38
Percent reduction in phosphorus lost to surface water due to conservation practices, average annual pounds/acre										
Low	11	58	73	80	58	62	63	75	79	68
Moderate	18	46	62	78	50	21	71	62	65	59
Moderately high	18	52	74	81	53	23	52	54	79	48
High	NA	78	41	NA	75	55	71	NA	NA	70
All	16	53	70	79	54	54	63	70	76	64
Percent of acres in baseline with average annual phosphorus lost to surface water more than 4 pounds/acre										
Low	6	1	0	0	2	0	0	0	0	0
Moderate	25	16	2	0	13	8	0	0	0	2
Moderately high	66	19	9	0	27	11	2	8	0	5
High	NA	26	0	0	20	0	0	NA	NA	0
All	23	9	2	0	9	2	0	0	0	1
Estimate of under-treated acres for phosphorus lost to surface water										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	0	0	0	0	0	0	0	0	0	0
Moderately high	489,995	0	0	0	489,995	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0
All	489,995	0	0	0	489,995	0	0	0	0	0

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.
Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.

Table 30. Identification of under-treated acres for wind erosion in the Arkansas-White-Red Basin

Soil wind erosion potential	Conservation treatment levels for wind erosion control									
	Low	Moderate	Moderately high	High	All	Low	Moderate	Moderately high	High	All
	Eastern portion of basin					**Western portion of basin**				
Estimated cropped acres										
Low	4,978,726	3,229,104	1,922,818	274,006	10,404,655	1,884,238	231,148	222,267	4,878	2,342,531
Moderate	288,804	192,738	191,851	56,673	730,066	3,605,297	7,061,837	1,976,915	202,348	12,846,398
Moderately high	11,684	23,510	46,709	0	81,903	678,948	1,835,602	956,901	24,230	3,495,681
High	0	0	0	0	0	71,881	439,462	64,122	0	575,465
All	5,279,213	3,445,353	2,161,378	330,680	11,216,624	6,240,364	9,568,049	3,220,205	231,457	19,260,076
Percent of cropped acres										
Low	44	29	17	2	93	10	1	1	0	12
Moderate	3	2	2	1	7	19	37	10	1	67
Moderately high	<1	<1	<1	0	1	4	10	5	<1	18
High	0	0	0	0	0	<1	2	<1	0	3
All	47	31	19	3	100	32	50	17	1	100
Wind erosion estimates *without* conservation practices (no-practice scenario), average annual tons/acre										
Low	1.51	0.94	1.08	0.72	1.23	1.35	1.68	1.36	0.00	1.38
Moderate	3.63	1.87	1.62	1.92	2.50	5.06	3.81	3.11	2.21	4.03
Moderately high	0.91	3.02	3.89	NA	3.21	9.46	5.97	5.48	0.60	6.48
High	NA	NA	NA	NA	NA	NA	5.23	7.21	NA	5.16
All	1.63	1.00	1.19	0.93	1.33	4.39	4.24	3.78	2.00	4.18
Wind erosion estimates for the baseline conservation condition, average annual tons/acre										
Low	1.50	0.59	0.44	0.13	0.98	1.34	0.92	0.67	0.00	1.23
Moderate	3.91	0.85	0.66	0.30	1.97	4.85	2.22	1.19	0.54	2.78
Moderately high	1.07	2.85	1.89	NA	2.05	9.02	3.34	1.80	0.01	4.00
High	NA	NA	NA	NA	NA	NA	3.14	1.61	NA	3.05
All	1.63	0.62	0.49	0.16	1.05	4.23	2.45	1.34	0.47	2.82
Percent reduction in wind erosion due to conservation practices, average annual tons/acre										
Low	1	37	59	82	20	1	45	51	91	11
Moderate	-8	55	59	85	21	4	42	62	76	31
Moderately high	-17	5	51	NA	36	5	44	67	99	38
High	NA	NA	NA	NA	NA	NA	40	78	NA	41
All	0	38	59	83	21	4	42	64	76	33
Percent of acres in baseline with average annual wind erosion more than 4 tons/acre										
Low	10	1	0	0	5	6	0	0	0	5
Moderate	41	0	0	0	16	34	18	10	0	21
Moderately high	NA*	0	0	NA	0	66	35	21	0	37
High	NA	NA	NA	NA	.	NA*	34	15	.	37
All	11	1	0	0	6	29	21	13	0	22
Estimate of under-treated acres for wind erosion										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	288,804	0	0	0	288,804	3,605,297	0	0	0	3,605,297
Moderately high	11,684	0	0	0	11,684	678,948	1,835,602	0	0	2,514,550
High	0	0	0	0	0	71,881	439,462	0	0	511,343
All	300,487	0	0	0	300,487	4,356,126	2,275,064	0	0	6,631,190

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.
Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.
* This group of acres was classified as under-treated acres because a lower level of soil vulnerability met the criteria for under-treated acres. Sample size was very small for these cells.

Conservation treatment needs by resource concern

Most of the cropped acres in the Arkansas-White-Red Basin were determined to have a low need for additional conservation treatment for all five resource concerns. The percentage of cropped acres in the Arkansas-White-Red Basin with a high or moderate need for additional conservation treatment was determined to be (fig. 75 and table 31)—

- 2.5 percent for sediment loss (none with a high need for treatment),
- none for nitrogen loss with surface runoff,
- 1.6 percent for phosphorus lost to surface water (all with a high need for treatment),
- 9.2 percent for nitrogen loss in subsurface flows (0.2 percent with a high need for treatment), most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow, and
- 22.7 percent for wind erosion (2.5 percent with a high need for treatment).

Nearly all of the under-treated acres for wind erosion are in the western portion of the basin (table 31). Nearly all of the under-treated acres for nutrient and sediment loss with water are in the eastern portion of the basin.

Under-treated acres in the Arkansas-White-Red Basin are presented by combinations of resource concerns in table 32. Nearly 92 percent of the under-treated acres are under-treated for wind erosion (65.7 percent), nitrogen loss in subsurface flows (25.2 percent), or both (1.0 percent).

Conservation treatment needs for one or more resource concern

Some acres require additional treatment for only one of the five resource concerns, while other acres require additional treatment for two or more resource concerns. After accounting for acres that need treatment for multiple resource concerns, the evaluation of treatment needs for the Arkansas-White-Red Basin determined the following (fig. 76):

- 4 percent of cropped acres (1.3 million acres) have a **high** level of need for additional conservation treatment,
- 30 percent of cropped acres (9.1 million acres) have a **moderate** level of need for additional conservation treatment, and
- 66 percent of cropped acres (20.1 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.

High level of need for conservation treatment. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients. In the Arkansas-White-Red Basin, these 1.3 million acres lose (per acre per year, on average) 1 ton of sediment by water erosion, 6.9 pounds of phosphorus, and 50 pounds of nitrogen. Wind erosion averages 5.2 tons per acre per year (table 33).

Moderate level of need for conservation treatment. Acres with a "moderate" level of need for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability and/or have more conservation practice use than do acres with a high level of need. In the Arkansas-White-Red Basin, these 9.1 million acres lose (per acre per year, on average) 0.3 ton of sediment by water erosion, 2.4 pounds of phosphorus, and 33 pounds of nitrogen. Wind erosion averages 3.2 tons per acre per year (table 33).

Low level of need for conservation treatment. Acres with a low level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. In the Arkansas-White-Red Basin, these 20.1 million acres lose (per acre per year, on average) 0.3 ton of sediment by water erosion, 2.0 pounds of phosphorus, and 25 pounds of nitrogen. Wind erosion averages 1.5 tons per acre per year (table 33). While gains can be attained by adding conservation practices to some of these acres with a low treatment need, additional conservation treatment would reduce average field losses by only a small amount.

Figure 75. Percent of cropped acres that are under-treated in the Arkansas-White-Red Basin, by resource concern

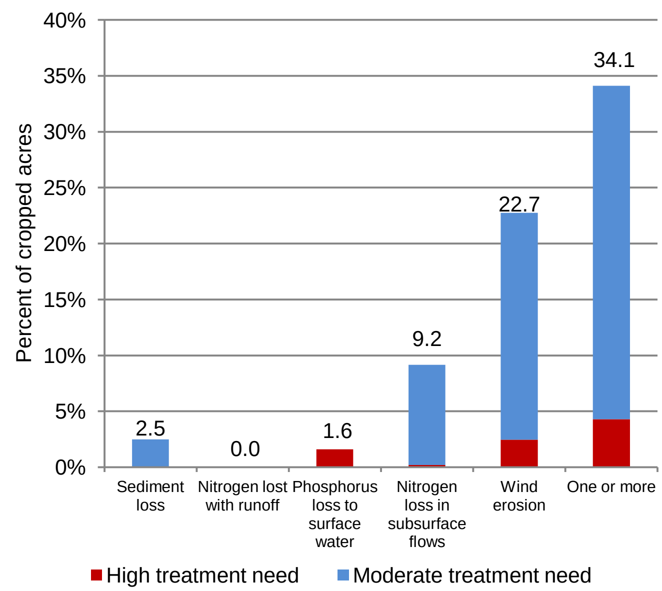


Figure 76. Percent of cropped acres with a high, moderate, or low level of need for additional conservation treatment for one or more resource concern in the Arkansas-White-Red Basin

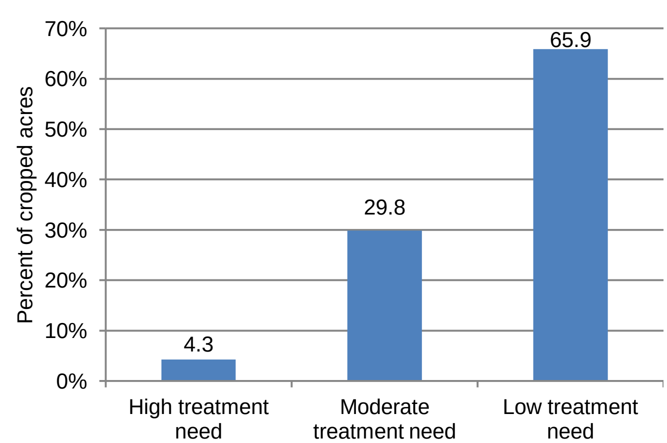


Table 31. Percent of cropped acres in the Arkansas-White-Red Basin with conservation treatment needs for each of the five resource concerns

	Sediment loss	Nitrogen loss with surface runoff	Nitrogen loss in subsurface flows	Phosphorus lost to surface water	Wind erosion	One or more
			High level of conservation treatment need			
Eastern portion of basin	0.0	0.0	0.0	1.6	0.0	1.6
Western portion of basin	0.0	0.0	0.2	0.0	2.5	2.7
Total for basin	0.0	0.0	0.2	1.6	2.5	4.3
			Moderate level of conservation treatment need			
Eastern portion of basin	2.5	0.0	8.7	0.0	1.0	10.4
Western portion of basin	0.0	0.0	0.2	0.0	19.3	19.4
Total for basin	2.5	0.0	8.9	0.0	20.3	29.8
			Low level of conservation treatment need			
Eastern portion of basin	34.3	36.8	28.1	35.2	35.8	24.8
Western portion of basin	63.2	63.2	62.8	63.2	41.4	41.1
Total for basin	97.5	100.0	90.8	98.4	77.3	65.9

Table 32. Under-treated acres with resource concerns needing treatment in the Arkansas-White-Red Basin

Reason for treatment need	Percent of cropped acres in basin	Percent of under-treated acres in basin
Eastern portion of region		
Wind erosion only	0.7	2.2
Phosphorus runoff only	0.3	0.9
Nitrogen leaching only	8.3	24.2
Nitrogen leaching and wind erosion	0.2	0.7
Nitrogen leaching and phosphorus runoff	0.0	0.1
Sediment loss only	1.2	3.4
Sediment loss and phosphorus runoff	1.1	3.2
Sediment loss, nitrogen leaching, and phosphorus runoff	0.2	0.6
All resource concerns in eastern portion	12.0	35.2
Western portion of region		
Wind erosion only	21.7	63.5
Nitrogen leaching only	0.3	1.0
Nitrogen leaching and wind erosion	0.1	0.3
All resource concerns in western portion	22.1	64.8
Entire Region		
Wind erosion only	22.4	65.7
Phosphorus runoff only	0.3	0.9
Nitrogen leaching only	8.6	25.2
Nitrogen leaching and wind erosion	0.3	1.0
Nitrogen leaching and phosphorus runoff	0.0	0.1
Sediment loss only	1.2	3.4
Sediment loss and phosphorus runoff	1.1	3.2
Sediment loss, nitrogen leaching, and phosphorus runoff	0.2	0.6
All resource concerns in region	34.1	100.0

Note: This table summarizes the under-treated acres identified in tables 26-30 and reports the joint set of acres that need treatment according to combinations of resource concerns.

Note: Percents may not add to totals because of rounding.

What is "Adequate Conservation Treatment?"

This study found that about 66 percent of the cropped acres in the Arkansas-White-Red Basin had a "low" level of conservation treatment need and were considered to be "adequately treated." This is in part due to the relatively lower vulnerability potential for most cropped acres in this region as compared to other regions. As shown in the next chapter, additional conservation treatment for these acres with a "low" need for treatment is expected to provide small per-acre reductions in erosion and nutrient losses, requiring a large number of acres to be treated in order to have a significant impact at the subregional and regional levels.

Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment, nutrient, and pesticide losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to soluble nutrient and pesticide losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

In practice, a *comprehensive planning process* is used to identify the appropriate combination of nutrient management techniques, soil erosion control practices, and other conservation practices needed to address the specific inherent vulnerabilities associated with each field. A field with adequate conservation practice use will have combinations of practices that address all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses. Full treatment consists of a suite of practices that—

- avoid or limit the potential for contaminant losses by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- control overland flow where needed; and
- trap materials leaving the field using appropriate edge-of-field mitigation.

In this report, adequate conservation treatment is limited to the use of practices that will not require changes in the cropping systems or changes in regional crop production levels. In spite of the small per-acre potential gains, however, it may be necessary in some environmental settings to go beyond "adequate conservation treatment" to achieve local environmental goals.

Table 33. Baseline conservation condition model simulation results for subsets of under-treated and adequately treated acres in the Arkansas-White-Red Basin

Model simulated outcome	Acres with a *low* need for treatment	Acres with a *moderate* need for treatment	Acres with a *high* need for treatment	All acres
Cultivated cropland acres in subset	20,080,018	9,092,858	1,303,824	30,476,700
Percent of acres	65.9%	29.8%	4.3%	100.0%
Water flow				
Average annual surface runoff (inches)	2.6	1.9	2.5	2.4
Average annual subsurface water flow (inches)	2.3	3.3	2.7	2.6
Erosion and sediment loss				
Average annual wind erosion (tons/acre)	1.51	3.18	5.23	2.17
Average annual sheet and rill erosion (tons/acre)	0.48	0.53	1.22	0.52
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.31	0.31	1.03	0.34
Soil organic carbon				
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-35	-66	-116	-48
Nitrogen				
Nitrogen sources (pounds/acre)				
Atmospheric deposition	5	5	5	5
Bio-fixation by legumes	10	10	5	10
Nitrogen applied as commercial fertilizer and manure	69	76	115	73
All nitrogen sources	84	91	124	88
Nitrogen in crop yield removed at harvest (pounds/acre)	62	63	73	63
Total nitrogen loss for all pathways (pounds/acre)	24.6	33.4	49.7	28.3
Average annual loss of nitrogen through volatilization (pounds/acre)	6.0	5.5	6.9	5.9
Average annual nitrogen returned to the atmosphere through denitrification (pounds/acre)	1.9	2.7	1.8	2.2
Average annual nitrogen lost with windborne sediment (pounds/acre)	5.6	7.9	11.3	6.5
Average annual loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	2.6	2.1	4.1	2.5
Average annual nitrogen loss in subsurface flows (pounds/acre)	8.6	15.2	25.6	11.3
Phosphorus				
Phosphorus applied (pounds/acre)	11.6	12.3	25.3	12.4
Phosphorus in crop yield removed at harvest (pounds/acre)	8.9	9.1	10.9	9.0
Total phosphorus loss for all pathways (pounds/acre)	2.0	2.4	6.9	2.4
Average annual phosphorus lost with windborne sediment (pounds/acre)	1.1	1.8	4.9	1.5
Loss of phosphorus to surface water, including both soluble and sediment attached (pounds/acre)*	0.9	0.6	2.0	0.9
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	2.8	2.8	2.4	2.8
Average annual surface water pesticide risk indicator for aquatic ecosystem	2.0	1.1	0.9	1.7
Average annual surface water pesticide risk indicator for humans	0.4	0.2	0.2	0.3

* Includes phosphorus lost with waterborne sediment and soluble phosphorus in subsurface flows that are intercepted by tile drains and drainage ditches, lateral subsurface outflow (seeps), and groundwater return flow.

Conservation treatment needs by cropping systems

Nine of the 13 cropping systems in this region have a disproportionately high percentage of acres that need additional treatment, shown in table 34, although most are only weakly disproportionate. Under-treated acres are disproportionately high for a given cropping system when the proportion of under-treated acres is greater than the proportion of cropped acres, as shown in table 34. Under-treated acres are most concentrated in the "cotton only" cropping system, which makes up 1.7 percent of the cropped acres in the basin but accounts for 3.7 percent of the under-treated acres in the basin. About 72 percent of the "cotton only" acres are under-treated, compared to 34 percent for all cropped acres.

For four cropping systems, the proportions of acres that are under-treated are lower than their proportion of acres in the region. The most striking is the cropping system consisting of soybeans only or soybeans with wheat (table 34). This cropping system makes up about 4.9 percent of the cropped acres in the region but has only 2.2 percent of the region's under-treated acres. For this cropping system, only 15 percent of the cropped acres are under-treated.

Conservation treatment needs by subregions

Under-treated acres in the Arkansas-White-Red Basin are distributed throughout all of the subregions, but are most concentrated in two subregions (table 35)—

- the Upper Arkansas River Basin (code 1102), where 63 percent of cropped acres are under-treated, and
- the Red-Little-Saline-Sulphur Creek River Basin (code 1114), where 52 percent of cropped acres are under-treated.

Seven other subregions have less pronounced disproportionately high percentages of under-treated acres, shown in table 35.

In contrast, 4 subregions have disproportionately low percentages of under-treated acres relative to cropped acres (table 35).

See appendix B, table B5, for a subregion breakdown of conservation treatment needs by resource concern.

Table 34. Percent of under-treated acres (acres with a *high* or *moderate* level of treatment need) by cropping system, Arkansas-White-Red Basin

Cropping system	Percent of cropped acres in Arkansas-White-Red Basin	Percent of under-treated acres in Arkansas-White-Red Basin	Percent of under-treated acres in cropping system
Disproportionately high percentage of under-treated acres			
Cotton only	1.7	3.7	72.5
Remaining row crops	1.8	2.6	48.0
Sorghum and soybeans with and without other crops	2.4	3.3	45.5
Corn-soybean with and without close grown crops	3.8	4.8	42.3
Hay-crop mix	5.4	6.6	42.0
Rice with other crops	2.2	2.4	37.5
Corn and close grown crops	5.3	5.7	37.0
Corn only	3.1	3.2	34.7
Wheat only	49.8	49.9	34.2
Disproportionately low percentage of under-treated acres			
Remaining mix of row and close-grown crops	5.7	5.7	33.9
Remaining close-grown crop systems	0.6	0.6	32.7
Sorghum-wheat and sorghum only	13.1	9.5	24.6
Soybean with or without wheat	4.9	2.2	15.0
Total	100.0	100.0	34.1*

Note: Percents may not add to totals because of rounding.
* Percent of cropped acres that are under-treated in the Arkansas-White-Red Basin.

Table 35. Percent of under-treated acres (acres with a *high* or *moderate* level of treatment need) by subregion, Arkansas-White-Red Basin

Subregion	Percent of cropped acres in Arkansas-White-Red Basin	Percent of under-treated acres in Arkansas-White-Red Basin	Percent of under-treated acres in subregion
Disproportionately high percentage of under-treated acres			
Upper Arkansas River Basin (code 1102)	3.4	6.2	63.2
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	2.8	4.2	51.7
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	1.5	2.0	44.2
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	4.3	5.3	42.6
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	8.9	10.0	38.3
Upper White River Basin (code 1101)	3.0	3.3	37.0
Upper Cimarron River Basin (code 1104)	9.4	9.9	35.9
Lower Cimarron River Basin (code 1105)	4.9	5.1	35.5
North Canadian including Beaver River Basin (code 1110)	10.1	10.3	34.8
Disproportionately low percentage of under-treated acres			
Red-Washita-Pease-Lake Texoma Basin (code 1113)	10.8	10.5	33.2
Middle Arkansas River Basin (code 1103)	25.9	22.1	29.1
Neosho-Verdigris River Basin (code 1107)	6.8	5.1	25.6
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	8.1	5.8	24.5
Total	100.0	100.0	34.1*

Note: Percents may not add to totals because of rounding.
* Percent of cropped acres that are under-treated in the Arkansas-White-Red Basin.

Chapter 6
Assessment of Potential Field-Level Gains from Further Conservation Treatment

Model simulations were used to evaluate the potential gains from further conservation treatment in the Arkansas-White-Red Basin. The simulated treatment levels were designed to minimally affect crop yields and maintain regional production capacity for food, feed, fiber, and fuel. The existing practices were augmented with additional practices to—

- avoid or limit the potential for loss by using nutrient management practices (appropriate rate, timing, form *and* method) on *all* crops in the rotation;
- control overland flow where needed; and
- trap materials leaving the field using appropriate edge-of-field mitigation where absent.

Three sets of additional conservation practices were simulated:

1. Additional wind and water erosion control practices consisting of four types of structural practices—overland flow practices, concentrated flow practices, edge-of-field mitigation—and wind erosion control practices.
2. Application of nitrogen and phosphorus using appropriate rate, timing, and method.
3. Increases in the efficiency of irrigation water application.

Four conservation treatment scenarios were simulated to evaluate the potential gains from further conservation treatment:

1. Treatment of the 1.3 million critical under-treated acres (acres with a high need for conservation treatment) with water erosion control practices only.
2. Treatment of all 10.4 million under-treated acres (acres with a high or moderate need for conservation treatment) with water erosion control practices only.
3. Treatment of the 1.3 million critical under-treated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.
4. Treatment of all 10.4 million under-treated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.

In summary, a large share of the potential field-level savings from conservation treatment, relative to losses simulated for the no-practice scenario, has been achieved in this region. The percent of potential savings represented by practices in use in 2003–06 are: 64 percent for sediment, 72 percent for nitrogen, and 63 percent for phosphorus. By treating all 10.4 million under-treated acres in the region with additional erosion control and nutrient management practices, an additional 15 percent in savings would be attained for sediment, 14 percent for nitrogen, and 17 percent for phosphorus. To achieve 100 percent of potential savings (i.e., an additional 22 percent for sediment, 19 percent for phosphorus, and 14 percent for nitrogen), additional conservation treatment for the remaining 20.1 million acres with a low need for additional treatment would be required, which would result in very small conservation gains on a per-acre basis.

The specific conservation practices used in the simulated treatments are not intended to be a prescription for how to construct conservation plans, but rather are a general representation of sets or suites of conservation practices that could be used to address multiple resource concerns. In actual planning situations a variety of alternative practice scenarios would be presented to the producer and selections would be based on the level of treatment need, cost of conservation implementation, impact on production goals, and preferences of the farm operator.

In the derivation of conservation plans, other conservation practices would be considered, such as cover crops, tillage and residue management, conservation crop rotations, drainage water management, and emerging conservation technologies. Only erosion control structural practices and consistent nutrient management techniques were simulated here to serve as a proxy for the more comprehensive suite of practices that is obtained through the conservation planning process. For example, a conservation plan may include tillage and residue management and cover crops instead of some of the structural practices included in the model simulation. Similarly, drainage water management or cover crops might be used as a substitute for—or in addition to—strict adherence to the right rate, timing, and method of nutrient application.

Long-term conserving cover was not included in the treatment scenarios. Long-term conserving cover represents the ultimate conservation treatment for acres that are highly vulnerable to sediment and nutrient loss, but if it was widely used, regional crop production levels could not be maintained. Enrolling more cultivated cropland acres in programs that provide the economic incentives for long-term conserving cover may be necessary in some areas to meet water quality goals for environmental protection.

Pesticide management was also not addressed in the treatment scenarios. While erosion control practices influence pesticide transport and loss, significant reductions in pesticide edge-of-field environmental risk within the region will require more intensive Integrated Pest Management (IPM) practices, including pesticide substitutions. Simulation of additional IPM and any associated pesticide substitutions is site specific and requires more information about the sample fields than was available from the farmer survey.

The level of conservation treatment is simulated to show *potential* environmental benefits, but is not designed to achieve specific environmental protection goals.

Nor were treatment scenarios designed to represent actual program or policy options for the Arkansas-White-Red Basin. Economic and programmatic aspects—such as producer costs, conservation program costs, and capacity to deliver the required technical assistance—were not considered in the assessment of the potential gains from further conservation treatment.

Simulation of Additional Erosion Control Practices

Treatment to control water erosion and surface water runoff consists of structural and vegetative practices that slow runoff water and capture contaminants that it may carry. Simulations of practices were added where needed (summarized in table 36) according to the following rules.

- **In-field mitigation:**
  - Terraces were added to all sample points with slopes greater than 6 percent, and to those with slopes greater than 4 percent *and* a high potential for excessive runoff (hydrologic soil groups C or D). Although terraces may be too expensive or impractical to implement in all cases, they serve here as a surrogate for other practices that control surface water runoff.
  - Contouring or stripcropping (overland flow practices) was added to all other fields with slope greater than 2 percent that did not already have those practices and did not have terraces.
  - Concentrated flow practices were not applied since they occur on unique landscape situations within the field; landscape data other than slope and slope length were not available for CEAP sample points.
- **Edge-of-field mitigation:**
  - Fields adjacent to water received a riparian buffer, if one was not already present.
  - Fields not adjacent to water received a filter strip, if one was not already present.

In addition, the implementation of structural and vegetative practices is simulated by an adjustment in the land condition parameter used to estimate the NRCS Runoff Curve Number (RCN). The RCN is an empirical parameter used in surface hydrology for predicting direct runoff or infiltration. The hydrologic condition (a component in the determination of the RCN) was adjusted from “poor” to “good” for sample points where these additional practices were simulated.

For additional wind erosion control, the proportion of the field protected from wind was increased. Practices such as windbreaks or shelterbelts, cross wind ridges, stripcropping or trap strips, and hedgerows are typically used for wind control. The effectiveness of these practices is simulated in the model by adjusting the unsheltered dimensions of the standard field that is modeled—a square field 400 meters (1,312 feet) on each side. For sample points where the wind erosion exceeded an average of 4 tons per acre per year in the baseline conservation condition (4.9 million cropped acres), wind erosion practices were added so as to reduce the unsheltered distance to 120 feet. This was typically achieved by adding crosswind trap strips.

Table 36. Summary of additional structural practices for water erosion control simulated for under-treated acres to assess the potential for gains from additional conservation treatment in the Arkansas-White-Red Basin

	Critical under-treated acres (acres with a high level of treatment need)		Non-critical under-treated acres (acres with a moderate level of treatment need)		All under-treated acres	
Additional practice	Treated acres	Percent of total	Treated acres	Percent of total	Treated acres	Percent of total
Overland flow practice only	0	0	0	0	0	0
Terrace only	0	0	0	0	0	0
Terrace plus overland flow practice	0	0	0	0	0	0
Filter only	918,274	70	7,265,556	80	8,183,830	79
Filter plus overland flow practice	81,531	6	414,033	5	495,564	5
Filter plus terrace	81,643	6	0	0	81,643	1
Filter plus overland flow practice plus terrace	18,077	1	39,046	0	57,123	1
Buffer only	173,842	13	1,150,197	13	1,324,039	13
Buffer plus overland flow practice	0	0	101,205	1	101,205	1
Buffer plus terrace	0	0	0	0	0	0
Buffer plus overland flow practice plus terrace	12,670	1	43,472	0	56,142	1
One or more additional practices	1,286,039	99	9,013,509	99	10,299,547	99
No structural practices added	17,785	1	79,349	1	97,134	1
Total	1,303,824	100	9,092,858	100	10,396,682	100

Note: Percents may not add to totals because of rounding

Simulation of Additional Nutrient Management Practices

The nutrient management treatment scenario consists of additional nutrient management practices where needed *in addition to* the erosion control practices. The nutrient management practices simulated the application of nutrients at an appropriate rate, in an appropriate form, at appropriate times, and using an appropriate method of application to provide sufficient nutrients for crop growth while minimizing losses to the environment. Simulation of nutrient management required changes to nutrient applications for one or more crops on all but about 23 percent of the acres (see table 10).

Specific rules for application timing

The goal for appropriate timing is to apply nutrients close to the time when the plant is likely to require them, thereby minimizing the opportunity for loss from the field. Rules for the timing of nutrient applications (both nitrogen and phosphorus) are:

- All commercial fertilizer applications were adjusted to 14 days prior to planting, except for acres susceptible to leaching loss.
- For acres susceptible to leaching loss (hydrologic soil group A, soils with sandy textures, or tile drained fields), nitrogen was applied in split applications, with 25 percent of the total application 14 days before planting and 75 percent 30 days after planting.
- Manure applications during winter months (December, January, February, and March) were moved to 14 days pre-plant or April 1, whichever occurs first. This rule allows for late March applications of manure in the warmer climates of the Arkansas-White-Red Basin. April 1 is near the period when the soils warm and become biologically active. However, this late date could begin to pressure manure storage capacities and it is recognized that this could create storage problems.

In the baseline condition, about 5 percent of the cropped acres in the Arkansas-White-Red Basin receive fertilizer applications in the fall for at least one spring-planted row crop in the rotation. The only fall application of nutrients simulated in the nutrient management treatment scenario was for fall seeded crops that received a starter fertilizer at planting time.

Specific rules for method of application

If the method of application was other than incorporation, fertilizer and manure applications in the simulations became incorporated or injected. Incorporation reduces the opportunity for nutrients on the soil surface to volatize or be carried away in soluble form or attached to eroding particles. For manure applications on no-till fields, if the manure was in liquid or slurry form and had been sprayed/broadcast applied it was changed to injected or placed under the soil surface. Manure of solid consistency was incorporated by disking without regard to the tillage management type. If the tillage type had been originally no-till, the incorporation of the manure changed the tillage type to mulch tillage.

Specific rules for the form of application

If the tillage type was no-till, commercial fertilizer was changed to a form that could be knifed or injected below the soil surface. The change in form did not change the ammonia or nitrate ratio of the fertilizer.

Specific rules for the rate of nutrients applied

Nitrogen application rates above 1.2 times the crop removal rate were reduced in the simulations to 1.2 times the crop removal rate for all crops except wheat and other small grain crops. The 1.2 ratio is in the range of rates recommended by many of the Land Grant Universities. This rate accounts for the savings in nutrients due to improved application timing and implementation of water erosion control practices and also replaces a reduced amount of environmental losses that occur during the cropping season.

For wheat and other small grain crops (barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale), nitrogen applications above 1.5 times the crop removal rate were reduced to 1.5 times the crop removal rate.

Phosphorus application rates above 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation were adjusted to be equal to 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation. Application rates for all phosphorus applications in the rotation were reduced in equal proportions.

Simulation of Irrigation Water Use Efficiency

Increases in the efficiency of irrigation water conveyances and water application were simulated in both the erosion control and the erosion control with nutrient management treatment scenarios. The volume of irrigation water used was simulated in the same manner as described for the baseline scenario in chapter 4. (Irrigation water was applied in the APEX model when a yield stress exceeded a specified threshold; the amount of irrigation water applied was determined by the amount of irrigation water required to fill the root-zone after accounting for conveyance losses.)

The treatment scenarios had four components:

1. The on-farm conveyance ditches were upgraded to pipelines.
2. Gravity systems and pressure systems were upgraded to center pivot or linear move sprinkler systems utilizing low-pressure sprinkler heads.[31]
3. Irrigation water management practices were simulated, which consisted of timing and rate of application adjustments designed to attain specified irrigation efficiencies.
4. Edge-of-field irrigation induced runoff was essentially eliminated on irrigated acres.

[31] An exception is in rice production areas where gravity systems are required to flood the fields. In these areas, gated pipe replaced ditches in the treatment simulations.

Implementation of the treatment scenario on all irrigated acres would result in an additional 1.95 million acres converted to center pivot or linear move sprinkler systems with low pressure heads.

In the Arkansas-White-Red Basin, the representation of irrigation management in the treatment scenarios increased the average Virtual Irrigation System Efficiency (VISE) from 69 percent in the baseline conservation condition to 80 percent in the treatment scenarios. (As discussed in chapter 3, irrigation efficiencies were represented in APEX simulations as a combination of three different coefficients (losses at the head of the field, percolation losses, and end-of-field runoff) combined into a single efficiency value, VISE).

If all irrigated acres were treated, VISE would be increased by—

- 1-10 percent on 3.6 million acres (60 percent of irrigated acres),
- 10-20 percent on 0.8 million acres (13 percent),
- 20-30 percent on 1.1 million acres (18 percent), and
- 30-50 percent on 0.3 million acres (5 percent).

Emerging Technologies for Reducing Nutrient Losses from Farm Fields

The nutrient management simulated to assess the potential for further gains from conservation treatment represents traditional nutrient management techniques that have been in use for several years and would be expected to be found in current NRCS conservation plans. There are, however, emerging conservation technologies that have the potential to further reduce nutrient loss from farm fields and provide even greater crop use efficiencies once the technologies become more widespread. These include—

- Innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies;
- Enhanced-efficiency nutrient application products such as slow or controlled release fertilizers, polymer coated products, nitrogen stabilizers, urease inhibitors, and nitrification inhibitors;
- Drainage water management that controls discharge of drainage water and provides treatment of contaminants, thereby reducing the levels of nitrogen and even some soluble phosphorus loss; and
- Constructed wetlands receiving surface water runoff or drainage water from farm fields prior to discharge to streams and rivers.
- Use of riparian corridors for treating drainage water.

New technologies that have the potential to increase crop yields without increasing nutrient inputs could further improve crop nutrient use efficiency and reduce offsite transport of nutrients relative to the level of crop production.

Potential for Field-Level Gains

Treatment of the 1.3 million critical under-treated acres

Average annual model output is presented in table 37 for the 1.3 million critical under-treated acres (acres with a high level of treatment need). The baseline results for these acres are contrasted to model output for the two treatment simulations in that table. According to the model simulation, treatment of these acres with erosion control practices would nearly eliminate sediment loss and reduce wind erosion to an average of 2.7 tons per acre per year for the treated acres. Nitrogen loss with surface runoff would be reduced to 1.5 pounds per acre per year on average (64-percent reduction), and phosphorus lost to surface water would be reduced to 1.0 pounds per acre per year (49-percent reduction).

However, the reduction in nitrogen loss in subsurface flows would be small—17 percent—due to the re-routing of surface water to subsurface flow pathways.

The addition of nutrient management would have little additional effect on wind erosion, sediment loss, or nitrogen loss with surface runoff, but would be effective in reducing nitrogen loss in subsurface flows and further reducing phosphorus lost to surface water (table 37). Nitrogen loss in subsurface flows for these acres would be reduced to an average of 12.4 pounds per acre per year, representing a 52-percent reduction compared to losses simulated for the baseline conservation condition. Phosphorus lost to surface water would be reduced to an average of 0.55 pound per acre per year, representing a 73 percent reduction compared to the baseline.

These results support the conclusion drawn from the assessment of the effects of conservation practices in chapter 4 that nutrient management practices need to be paired with erosion control practices to attain significant reductions in the loss of soluble nutrients from cropped fields.

Treatment of all 10.4 million under-treated acres

Average annual model output is presented in table 38 for the treatment of all 10.4 million under-treated acres (acres with a high or moderate level of treatment need). The 10.4 million under-treated acres include 9.1 million acres with a moderate need for treatment that are less vulnerable or have more conservation practice use than the critical under-treated acres and therefore the potential for gains with additional treatment is less for those acres. Thus, table 38 shows that per-acre percent reductions of sediment and nutrient loss due to additional practices would generally be less, on average, than percent reductions for only the 1.3 million under-treated acres with a high need for conservation treatment.

Nonetheless, the per-acre gains from additional treatment of these acres would be substantial. Treatment with both erosion control and nutrient management would, compared to the baseline results for these acres—

- reduce average annual sediment loss from 0.4 ton per acre for the baseline to less than 0.1 ton per acre,
- reduce average wind erosion from 3.4 tons per acre per year to 1.8 tons per acre per year,
- reduce average annual nitrogen loss with surface runoff (including waterborne sediment) from 2.3 pounds per acre to less than 1 pound per acre,
- reduce average annual nitrogen loss in subsurface flows from 16.5 pounds per acre to about 10 pounds per acre,
- reduce total nitrogen loss (all loss pathways, including wind erosion) from 35 pounds per acre per year to 21 pounds per acre per year, and
- reduce total phosphorus loss (all loss pathways, including wind erosion) from 3.0 pounds per acre per year to 1.3 pounds per acre, per year, for these acres.

Diminishing returns from additional conservation treatment

Per-acre gains from additional conservation treatment are highest for the more vulnerable and less treated acres than for the less vulnerable and more treated acres. These “diminishing returns” to additional treatment indicate that targeting treatment to the acres with the greatest need is an efficient way to reduce agricultural sources of contaminants from farm fields within the basin.

Table 39 contrasts the per-acre model simulation results for additional erosion control and nutrient management on three subsets of acres in the Arkansas-White-Red Basin—

1. the 1.3 million under-treated acres with a “high” need for additional treatment,
2. the 9.1 million under-treated acres with a “moderate” need for additional treatment, and
3. the 20.1 million acres with a “low” need for additional treatment.

Diminishing returns from additional conservation treatment is demonstrated by comparing the average annual per-acre reductions in losses among the three groups of acres.

For example, conservation treatment of the 1.3 million critical under-treated acres would reduce sediment loss by an average of 0.93 ton per acre per year on those acres. In comparison, additional treatment of the 9.1 million acres with a moderate need for treatment would reduce sediment loss by about 0.28 ton per acre per year on those acres. Treatment of the remaining 20.1 million acres would also reduce sediment loss by about 0.28 ton per acre, on average.

Conservation treatment of the 1.3 million critical under-treated acres would reduce wind erosion by an average of 2.6 tons per acre per year on those acres. In comparison, additional treatment of the 9.1 million acres with a moderate need for treatment would reduce wind erosion by about 1.5 tons per acre per year on those acres. Treatment of the remaining 20.1 million acres would reduce wind erosion by only about 0.6 ton per acre, on average.

Similarly, diminishing returns would be pronounced for nitrogen and phosphorus loss. Total nitrogen loss would be reduced by an average of 23.8 pounds per acre per year on the 1.3 million critical under-treated acres, compared to a reduction of 12.5 pounds per acre for the 9.1 million under-treated acres with a moderate need for treatment, and only 6.9 pounds per acre for the remaining 20.1 million acres.

Nitrogen loss in subsurface flows would be reduced by an average of 13.2 pounds per acre per year on the 1.3 million critical under-treated acres, compared to a reduction of 5.9 pounds per acre for the 9.1 million acres with a moderate need for treatment. The reduction from treatment of the remaining 20.1 million acres would average only 2.0 pounds per acre.

Total phosphorus loss would be reduced by an average of 5 pounds per acre per year on the 1.3 million critical under-treated acres, compared to a reduction of 1.3 pounds per acre for the 9.1 million under-treated acres with a moderate need for treatment and only 1 pound per acre for the remaining 20.1 million acres.

(This rudimentary assessment of diminishing returns ignores the cost of treatment and is focused only on reducing edge-of-field losses. If the cost of treatment for the critical under-treated acres is substantially greater than for the non-critical under-treated acres, the optimal strategy would be to treat a mix of critical and non-critical under-treated acres so as to maximize total edge-of-field savings for a given level of expenditure. If the objective of the conservation treatment was specifically to protect water quality, the relative environmental benefits of sediment and nutrient reductions would need to also be considered, as well as any edge-of-field loss thresholds that would need to be met to achieve local water quality goals.)

Table 37. Conservation practice effects for additional treatment of 1.3 million critical under-treated acres (acres with a *high* need for conservation treatment) in the Arkansas-White-Red Basin

	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
Model simulated outcome	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	2.5	1.9	23%	1.9	23%
Subsurface water flow (inches)	2.7	2.8	-2%	2.8	-2%
Erosion and sediment loss					
Wind erosion (tons/acre)	5.23	2.66	49%	2.64	50%
Sheet and rill erosion (tons/acre)	1.22	0.72	41%	0.73	40%
Sediment loss at edge of field due to water erosion (tons/acre)	1.03	0.10	90%	0.10	90%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-116	-70	--	-72	--
Nitrogen					
Nitrogen applied (pounds/acre)	115	112*	3%	78	32%
Nitrogen in crop yield removed at harvest (pounds/acre)	72.8	70.3	3%	68.0	7%
Total nitrogen loss for all loss pathways (pounds/acre)	49.7	37.6	24%	25.8	48%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	4.1	1.5	64%	1.4	66%
Nitrogen loss in subsurface flows (pounds/acre)	25.6	21.2	17%	12.4	52%
Phosphorus					
Phosphorus applied (pounds/acre)	25	25*	<1%	14	44%
Total phosphorus loss for all loss pathways (pounds/acre)	6.94	4.06	41%	1.95	72%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	1.99	1.02	49%	0.55	73%

* Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.

Note: Values reported in this table are for the 1.3 million critical under-treated acres only. Percent reductions are with respect to the baseline conservation condition.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 38. Conservation practice effects for additional treatment of all 10.4 million under-treated acres (acres with a *high* or *moderate* need for conservation treatment) in the Arkansas-White-Red Basin

Model simulated outcome	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	2.0	1.5	24%	1.5	24%
Subsurface water flow (inches)	3.2	3.3	-1%	3.3	-2%
Erosion and sediment loss					
Wind erosion (tons/acre)	3.44	1.81	47%	1.80	48%
Sheet and rill erosion (tons/acre)	0.62	0.39	36%	0.39	37%
Sediment loss at edge of field due to water erosion (tons/acre)	0.40	0.04	91%	0.04	91%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-72	-42	--	-46	--
Nitrogen					
Nitrogen applied (pounds/acre)	81	78*	3%	62	23%
Nitrogen in crop yield removed at harvest (pounds/acre)	64.2	62.4	3%	59.9	7%
Total nitrogen loss for all loss pathways (pounds/acre)	35.5	30.0	15%	21.5	39%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	2.3	0.9	61%	0.8	66%
Nitrogen loss in subsurface flows (pounds/acre)	16.5	15.9	4%	9.7	41%
Phosphorus					
Phosphorus applied (pounds/acre)	14	14*	<1%	11	24%
Total phosphorus loss for all loss pathways (pounds/acre)	3.01	1.74	42%	1.28	58%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	0.80	0.42	47%	0.28	65%

* Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.
Note: Values reported in this table are for the 10.4 million under-treated acres only. Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 39. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices for three groups of acres comprising the 30.5 million cropped acres in the Arkansas-White-Red Basin

	Additional treatment for 1.3 million critical under-treated acres*			Additional treatment for 9.1 million non-critical under-treated acres*			Additional treatment for remaining 20.1 million acres		
	Baseline	Treatment scenario		Baseline	Treatment scenario		Baseline	Treatment scenario	
	Average annual amount	Average annual amount	Reduction	Average annual amount	Average annual amount	Reduction	Average annual amount	Average annual amount	Reduction
Water flow									
Surface water runoff (inches)	2.5	1.9	0.6	1.9	1.5	0.5	2.6	2.0	0.6
Subsurface water flow (inches)	2.7	2.8	-0.1	3.3	3.4	-0.1	2.3	2.6	-0.3
Erosion and sediment loss									
Wind erosion (tons/acre)	5.23	2.64	2.59	3.18	1.67	1.50	1.51	0.95	0.57
Sheet and rill erosion (tons/acre)	1.22	0.73	0.49	0.53	0.34	0.19	0.48	0.35	0.13
Sediment loss at edge of field due to water erosion (tons/acre)	1.03	0.10	0.93	0.31	0.03	0.28	0.31	0.04	0.28
Soil organic carbon									
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-116	-72	44**	-66	-42	24**	-35	-21	14**
Nitrogen									
Nitrogen applied (pounds/acre)	115	78	37	76	60	16	69	58	11
Nitrogen in crop yield removed at harvest (pounds/acre)	72.8	68.0	5	63.0	58.7	4	62.4	58.9	4
Total nitrogen loss for all loss pathways (pounds/acre)	49.7	25.8	23.8	33.4	20.9	12.5	24.6	17.7	6.9
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	4.1	1.4	2.7	2.1	0.7	1.4	2.6	1.0	1.5
Nitrogen loss in subsurface flows (pounds/acre)	25.6	12.4	13.2	15.2	9.3	5.9	8.6	6.6	2.0
Phosphorus									
Phosphorus applied (pounds/acre)	25	14	11.03	12	10	2.28	12	10	1.99
Total phosphorus loss for all loss pathways (pounds/acre)	6.94	1.95	4.99	2.44	1.18	1.27	2.02	1.03	0.99
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	1.99	0.55	1.45	0.63	0.24	0.38	0.88	0.36	0.52

*Critical under-treated acres have a high need for additional treatment. Non-critical under-treated acres have a moderate need for additional treatment.
** Gain in soil organic carbon.

Estimates of edge-of-field sediment and nutrient savings due to use of conservation practices

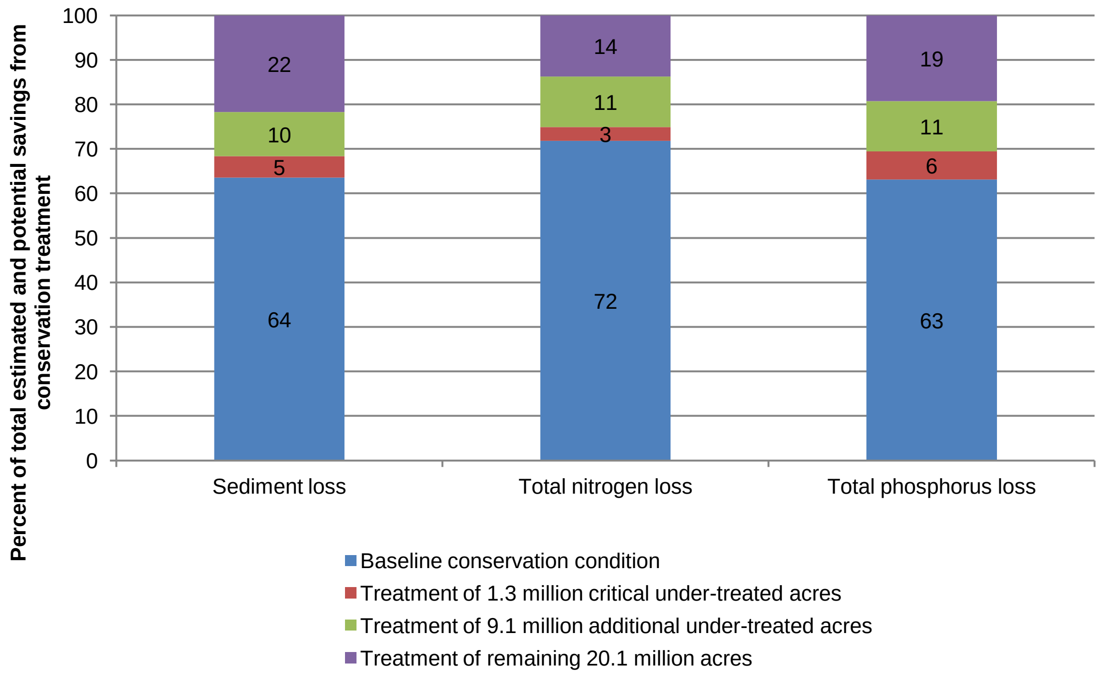
Potential sediment and nutrient savings from additional conservation treatment are contrasted to estimated savings for the conservation practices in use in 2003–06 in figure 77. The no-practice scenario represents the maximum losses that would be expected without any conservation practices in use. Treatment of *all acres* with nutrient management and erosion control practices was used to represent a "full-treatment" condition. The difference in sediment and nutrient loss between these two scenarios represents the maximum savings possible for conservation treatment, which totaled 25.4 million tons of sediment, 501,805 tons of nitrogen, and 51,276 tons of phosphorus for the Arkansas-White-Red Basin (fig. 77).

For sediment loss, about 64 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition (fig. 77). Additional treatment of the 1.3 million critical under-treated acres would account for another 5 percent of the potential sediment savings. Treatment of the 9.1 million under-treated acres with a moderate need for treatment would account for about 10 percent of the potential savings. Treatment of the 20.1 million adequately treated acres would account for the last 22 percent of potential savings.

The proportions of savings from existing practices and with additional conservation treatment are about the same for phosphorus.

The proportions of savings from existing practices for nitrogen are slightly larger—about 72 percent of the potential savings are accounted for by the conservation practices already in use (fig. 77). Additional treatment of the 1.3 million critical under-treated acres would account for another 3 percent of the potential sediment savings. Treatment of the 9.1 million under-treated acres with a moderate need for treatment would account for about 11 percent of the potential savings. Treatment of the 20.1 million adequately treated acres would account for the last 14 percent of potential savings.

Figure 77. Comparison of estimated sediment, nitrogen, and phosphorus savings (field-level) that are due to practices in use in the baseline conservation condition and potential savings with additional water erosion control *and* nutrient management treatment of cropped acres in the Arkansas-White-Red Basin



Sediment, nitrogen, and phosphorus saved or potentially saved due to conservation practices

	Estimated savings due to conservation practice use (baseline conservation condition)	Potential savings from treatment of 1.3 million critical under-treated acres*	Potential savings from treatment of 9.1 million additional under-treated acres*	Potential savings from treatment of remaining 20.1 million acres*	Total estimated and potential savings from conservation treatment
Sediment (tons)	16,171,137	1,218,590	2,526,018	5,528,206	25,443,950
Nitrogen (tons)	360,390	15,540	56,898	68,977	501,805
Phosphorus (tons)	32,370	3,252	5,753	9,901	51,276

*Treatment with erosion control practices and nutrient management practices on all cropped acres.

Note: Calculations do not include land in long-term conserving cover.

Note: Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

Expected regional results assuming all under-treated acres were treated

Even though under-treated acres represent only about one in three of the cropped acres in this region, important reductions in soil and nutrient loss from farm fields could be achieved with additional conservation treatment. Table 40 summarizes the effects that would be expected if all 10.4 million acres with a high or moderate treatment need were treated with erosion control practices alone or with erosion control and nutrient management practices under the assumptions of those two treatment scenarios. Results are presented in table 40 for the region as a whole by combining model output simulating additional treatment for the 10.4 million under-treated acres with unchanged model output for the remaining 20.1 million acres from the baseline simulation.

Compared to the baseline conservation condition, treating the 10.4 million under-treated acres (34 percent of cropped acres in the region) with soil erosion control practices *and* nutrient management practices would, for the region as a whole—

- reduce sediment loss averaged over all cropped acres in the region by 36 percent;
- reduce wind erosion averaged over all cropped acres in the region by 26 percent,
- reduce total nitrogen loss averaged over all cropped acres in the region by 17 percent:
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) averaged over all cropped acres in the region by 21 percent, and
  - reduce nitrogen loss in subsurface flows averaged over all cropped acres in the region by 21 percent; and
- reduce phosphorus lost to surface water averaged over all cropped acres in the region by 21 percent.

Nearly all of these reductions in sediment loss, wind erosion, nitrogen lost with surface water, and phosphorus lost to surface water are due to the erosion control practices, as shown in table 40. The additional nutrient management practices accounted for nearly all of the reduction in nitrogen loss in subsurface flows, reducing the annual loss from about 11 pounds per acre to 9 pounds per acre averaged over all of the 30.5 million acres in the region.

The effects of treating the 10.4 million acres for the region as a whole are graphically shown in figures 78 through 85. In these figures the model results for the baseline distribution are contrasted with the distribution of model results for additional treatment of under-treated acres with erosion control and nutrient management practices. Results for two additional scenarios are also shown for perspective: 1) the no-practice scenario, and 2) treatment of *all* acres with erosion control and nutrient management practices, including the 20.1 million acres with a "low" treatment need.

Model simulations indicate that for wind erosion the percentage of acres exceeding 4 tons per acre per year (the "acceptable level" used in chapter 5 as part of the process to identify under-treated acres) would be reduced from 17 percent in the baseline to 11 percent after treating the 10.4 million undertreated acres (fig. 78). For sediment loss (fig. 79), the percentage of acres exceeding 2 tons per acre per year would be reduced from 3 percent in the baseline to 1 percent after treating the 10.4 million undertreated acres.

Figure 80 shows that the distribution of soil organic carbon is affected little by additional soil erosion control and nutrient management practices for under-treated acres in the region. Increases in soil organic carbon were generally restricted to acres losing more than 100 pounds per acre in the baseline scenario.

The effect of additional conservation treatment for under-treated acres on nitrogen loss is low, as shown in figures 81–83. Nitrogen lost with surface runoff is low throughout the region and for both baseline and treatment scenarios. For nitrogen loss in subsurface flows, the percentage of acres with losses exceeding 25 pounds per acre per year would be reduced from 10 percent in the baseline to 8 percent (fig. 82). Reductions in total nitrogen loss, which also includes nitrogen loss with windborne sediment, nitrogen volatilization, and denitrification, would be reduced by larger amounts, as shown in figure 83.

The percentage of acres with phosphorus losses to surface water exceeding 4 pounds per acre per year would be reduced from 4 percent in the baseline to 2 percent (fig. 84) by treating the 10.4 million under-treated acres.

Figure 85 shows the effects of irrigation water use on irrigated acres in the Arkansas-White-Red Basin. The gap between the curves for the baseline conservation condition and the no-practice scenario reflects the movement away from less efficient ditches and gravity irrigation used in the past to more efficient pressure irrigation systems. Implementing the treatment scenario on all irrigated acres would reduce irrigation water use by an average of 3 inches per acre per year, compared to the baseline, on the 6 million irrigated acres.

One of the objectives in constructing the treatment scenarios was to maintain the level of regional crop production. The removal of nitrogen at harvest serves as a useful proxy for crop yields and allows for aggregation over the mix of crops. As shown in figure 86, the distribution of nitrogen removed at harvest is about the same for the curve representing the baseline scenario and the curve representing additional treatment of 10.4 million under-treated acres. A reduction in yield for the region as a whole would occur, however, if the 20.1 million acres with a "low" need for additional treatment were also treated, as shown by the curve in figure 86 representing the treatment of *all* acres.

Table 40. Conservation practice effects for the region as a whole* after additional treatment of 10.4 million under-treated acres (acres with a *high* or *moderate* need for conservation treatment) in the Arkansas-White-Red Basin

	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
Model simulated outcome	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	2.4	2.2	7%	2.2	7%
Subsurface water flow (inches)	2.6	2.7	-1%	2.7	-1%
Erosion and sediment loss					
Wind erosion (tons/acre)	2.17	1.61	26%	1.61	26%
Sheet and rill erosion (tons/acre)	0.52	0.45	15%	0.45	15%
Sediment loss at edge of field due to water erosion (tons/acre)	0.34	0.22	36%	0.22	36%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-48	-37	--	-39	--
Nitrogen					
Nitrogen applied (pounds/acre)	73	72**	1%	67	9%
Nitrogen in crop yield removed at harvest (pounds/acre)	63.0	62.4	1%	61.6	2%
Total nitrogen loss for all loss pathways (pounds/acre)	28.3	26.4	7%	23.6	17%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	2.5	2.0	19%	2.0	21%
Nitrogen loss in subsurface flows (pounds/acre)	11.3	11.1	2%	8.9	21%
Phosphorus					
Phosphorus applied (pounds/acre)	12	12**	<1%	11	9%
Total phosphorus loss for all loss pathways (pounds/acre)	2.35	1.92	18%	1.76	25%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	0.85	0.72	15%	0.67	21%

* Results presented for the region as a whole combine model output for the 10.4 million treated acres with model results from the baseline conservation condition for the remaining acres.
** Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.
Note: Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 78. Estimates of average annual wind erosion for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Arkansas-White-Red Basin

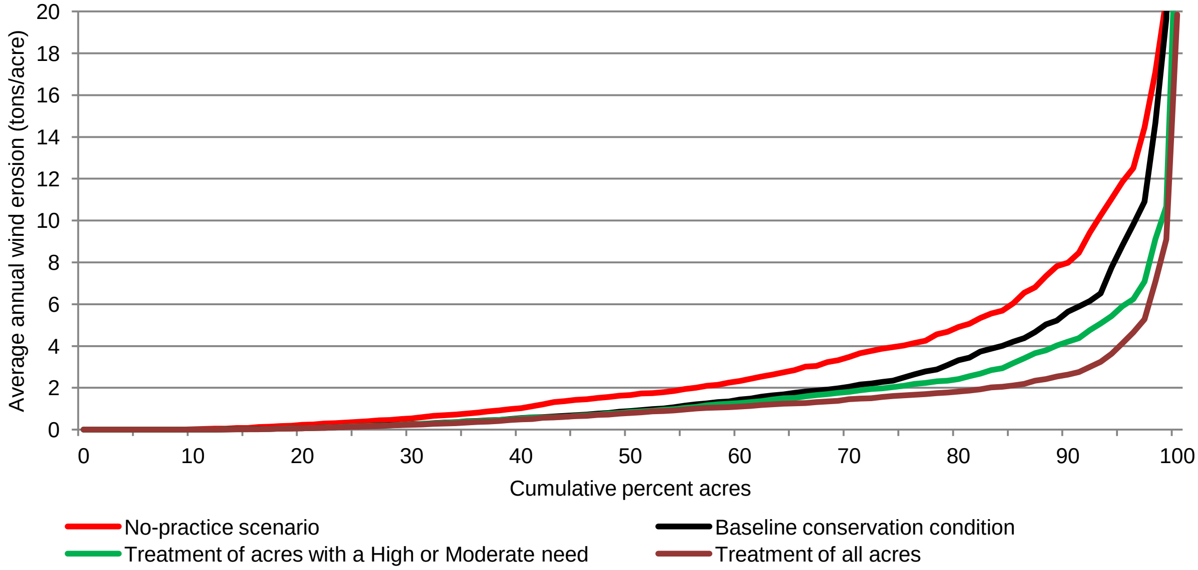


Figure 79. Estimates of average annual sediment loss for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Arkansas-White-Red Basin

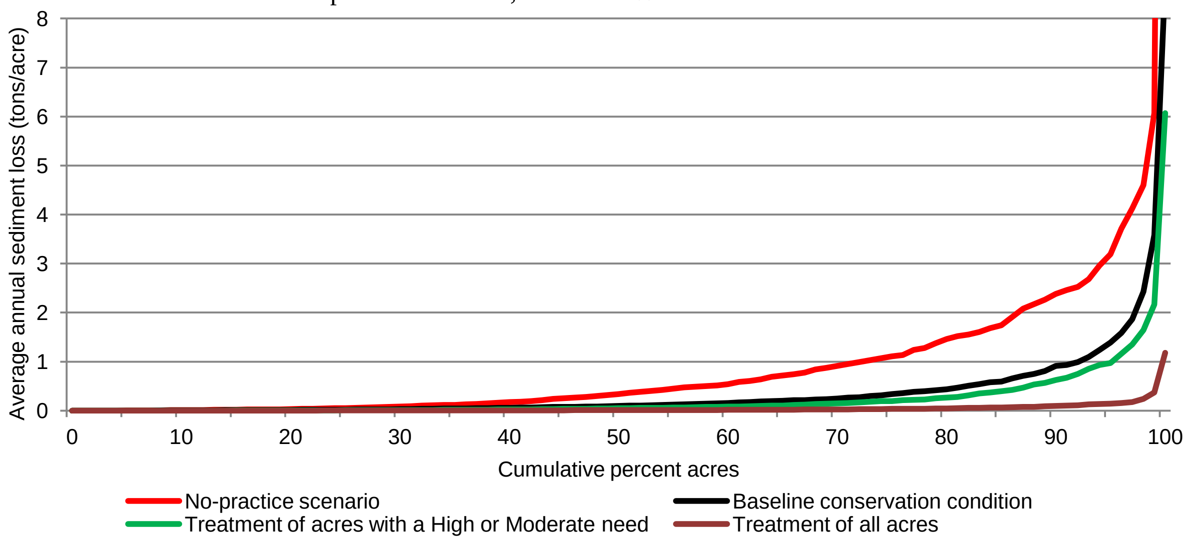


Figure 80. Estimates of average annual change in soil organic carbon for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Arkansas-White-Red Basin

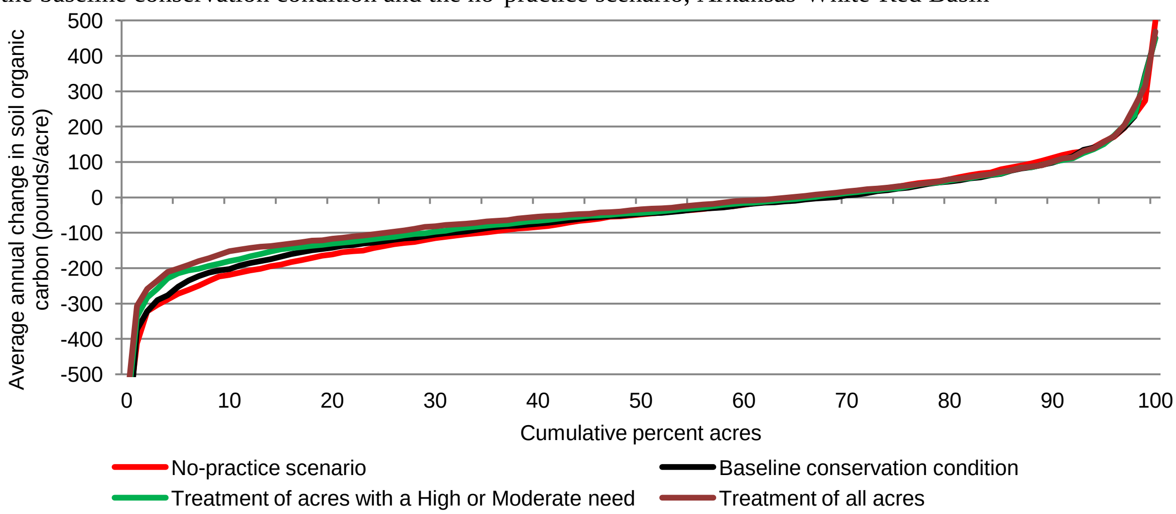


Figure 81. Estimates of average annual loss of nitrogen with surface runoff for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Arkansas-White-Red Basin

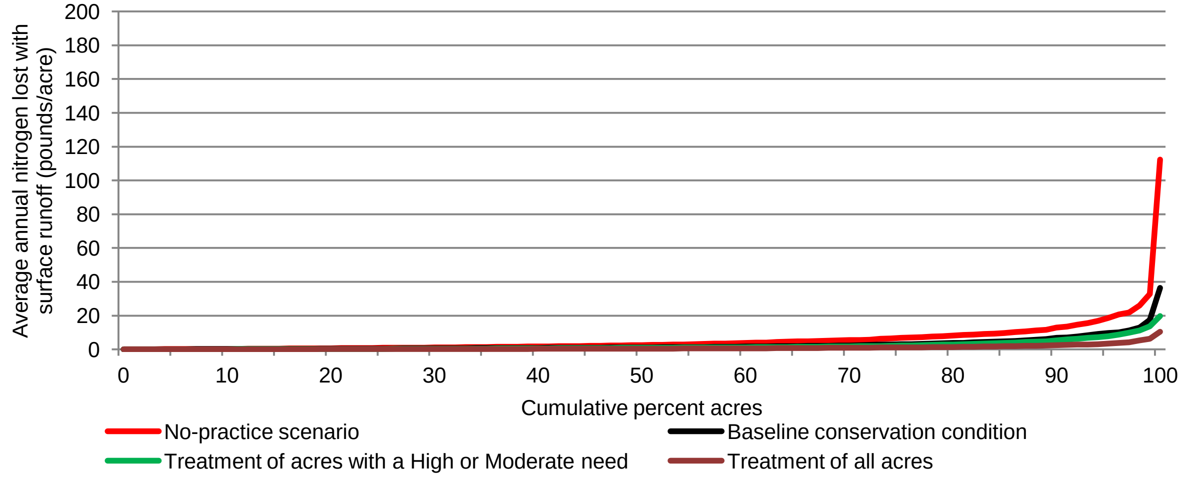


Figure 82. Estimates of average annual loss of nitrogen in subsurface flows for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Arkansas-White-Red Basin

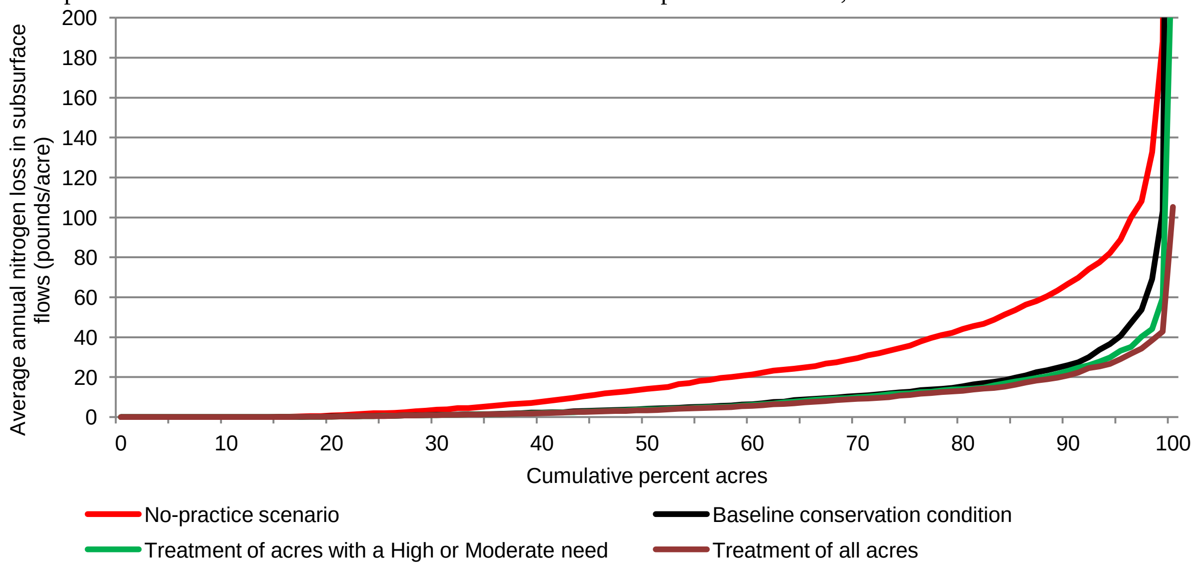


Figure 83. Estimates of average annual total nitrogen loss for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Arkansas-White-Red Basin

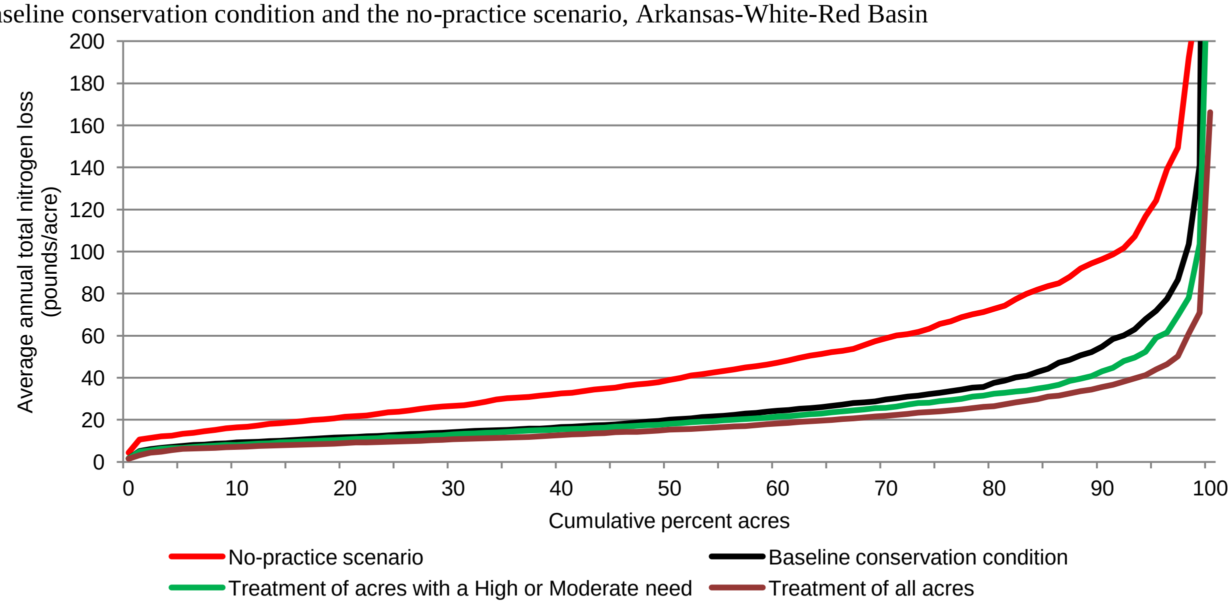
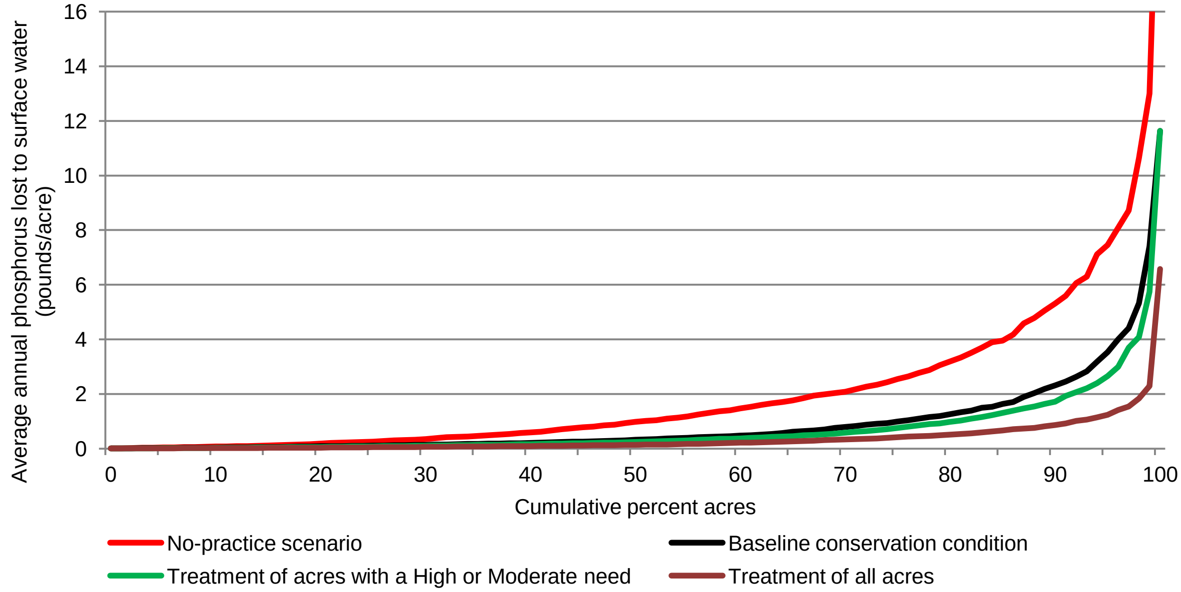


Figure 84. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Arkansas-White-Red Basin



* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

Figure 85. Estimates of average annual irrigation water application for the treatment scenarios compared to the baseline conservation condition and the no-practice scenarios, Arkansas-White-Red Basin

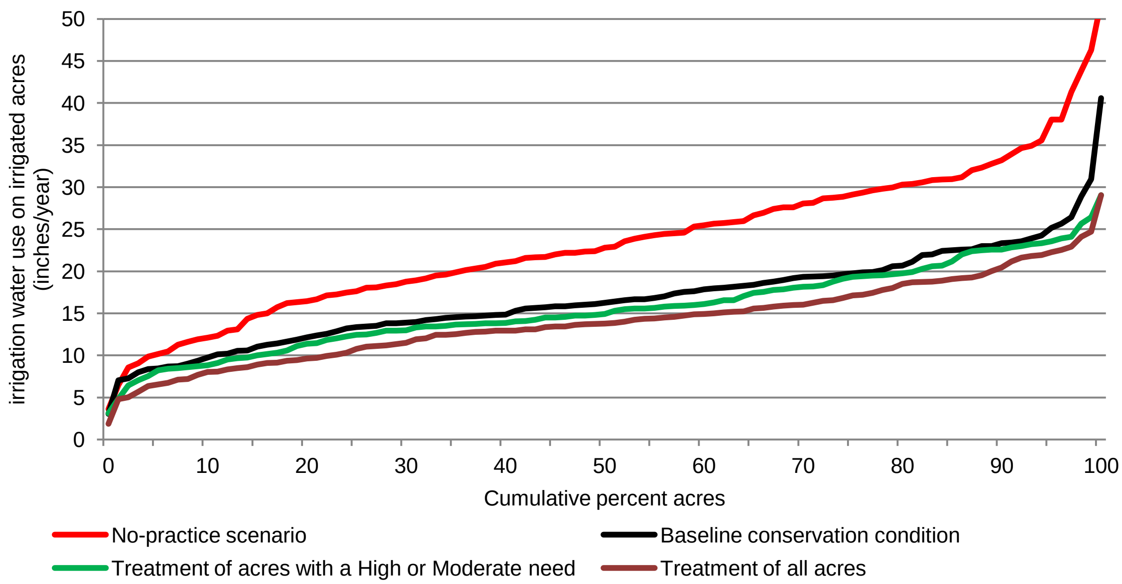
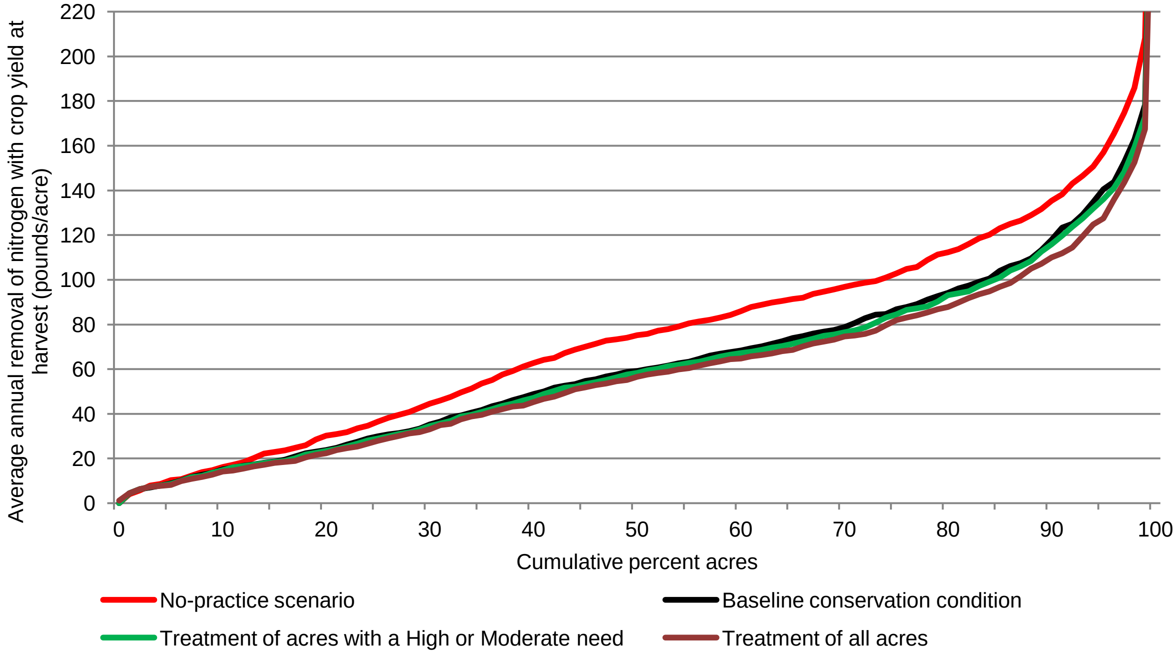


Figure 86. Estimates of average annual removal of nitrogen with crop yield at harvest for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Arkansas-White-Red Basin



Chapter 7
Offsite Water Quality Effects of Conservation Practices

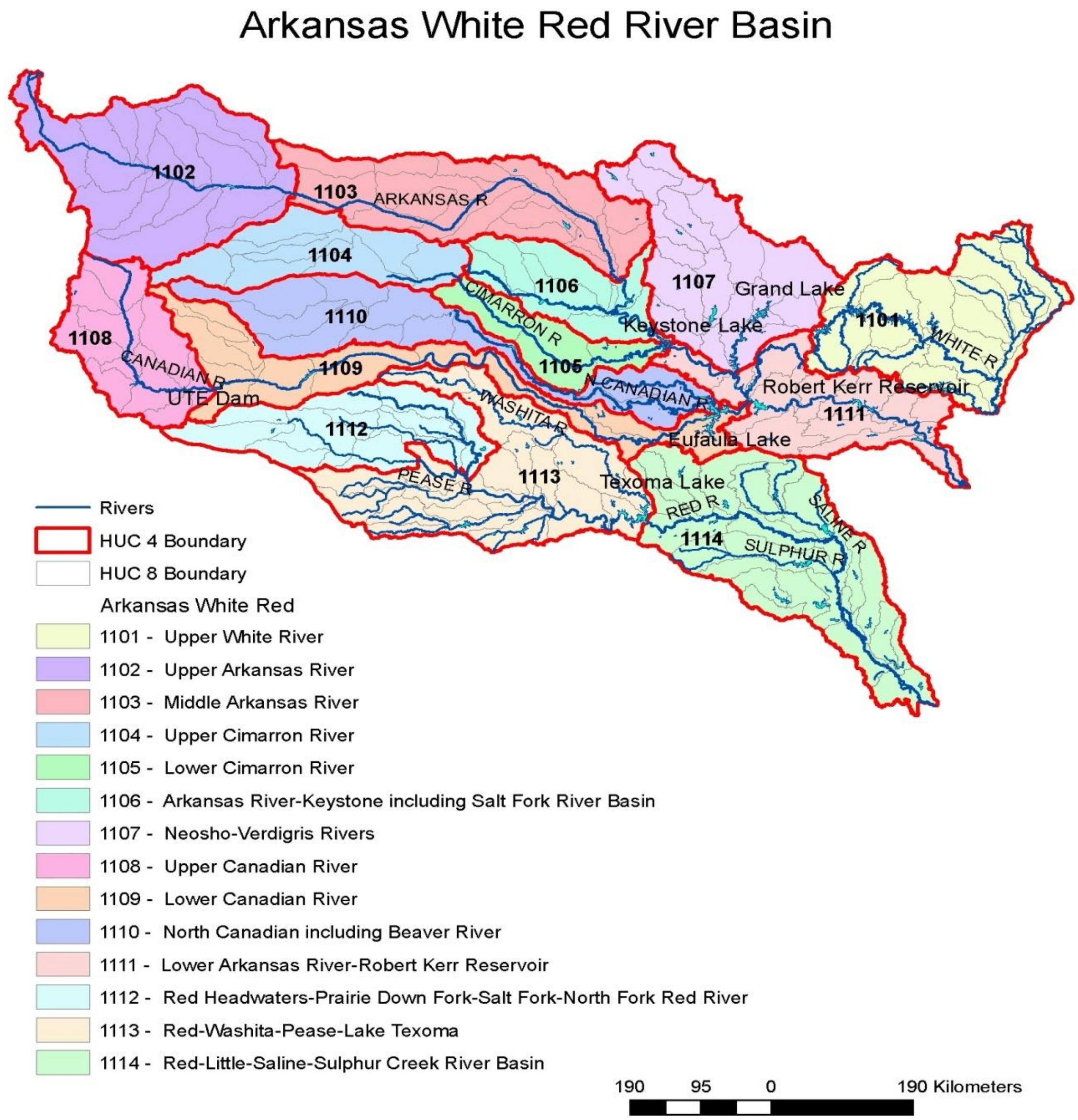
Field-level losses of sediment and nutrients estimated using APEX were integrated into a large-scale water quality model to estimate the extent to which conservation practices reduce—

- loads delivered to rivers and streams within the basin,
- instream loads at various points within the basin, and
- loads exported from the region to the Mississippi River.

Loading estimates are reported for each of the 14 subregions (4-digit hydrologic unit code) in the Arkansas-White-Red Basin, shown in figure 87, with one exception. The Upper Canadian River Basin (code 1108) has too few CEAP sample points to report results separately. Results for this subregion are therefore aggregated with the adjoining Lower Canadian River Basin (code 1109) for reporting.

Loads were not estimated for the pesticide atrazine, as was done in previous CEAP reports, because the level of atrazine use in this region was too low to reliably estimate loads at the watershed scale.

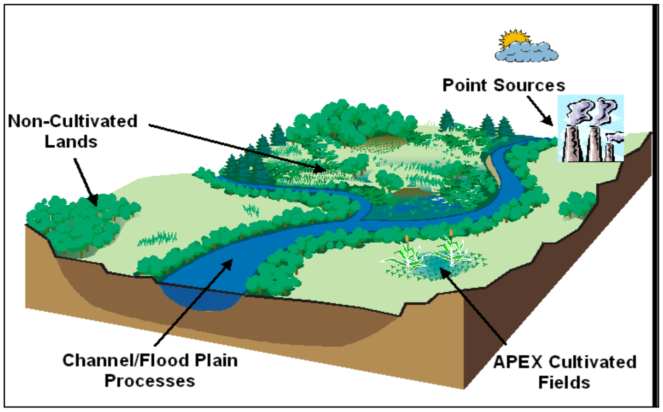
Figure 87. Subregions (4-digit HUC groupings of 8-digit HUCs) within the Arkansas-White-Red Basin



The National Water Quality Model—HUMUS/SWAT

Offsite estimates of water quality benefits were assessed using HUMUS/SWAT, a combination of the SWAT model (Soil and Water Assessment Tool) and HUMUS (Hydrologic Unit Modeling for the United States) databases required to run SWAT at the watershed scale for all watersheds in the United States (Arnold et al. 1999; Srinivasan et al. 1998). SWAT simulates the transport of water, sediment, nutrients, and pesticides from the land to receiving streams and the flow downstream to the next watershed and ultimately to estuaries and oceans (fig. 88).

Figure 88. Sources of water flows, sediment, and agricultural chemicals simulated with HUMUS/SWAT



Like APEX, SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007).[32] The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

Upland processes

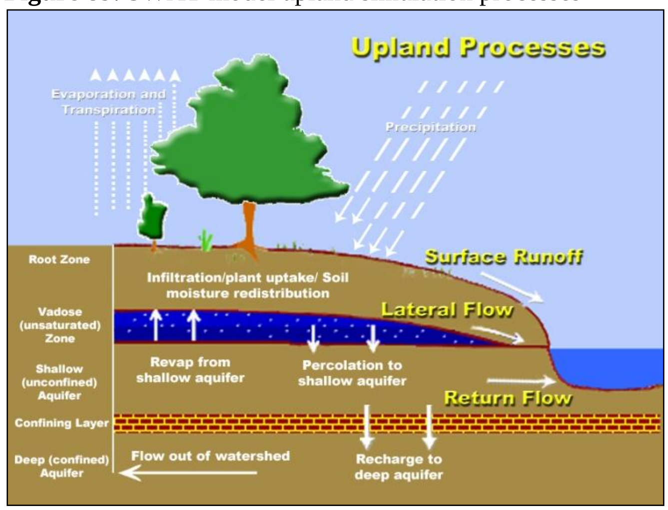
The water balance is the driving force for transport and delivery of sediment and nutrients from fields to streams and rivers. For this study, upland processes for non-cultivated cropland were modeled using SWAT, while source loads for cultivated cropland are estimated by APEX.

In SWAT, each watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, management, and slope. An HRU is not a contiguous land area, but rather represents the percentage of the watershed that has the HRU characteristics. In this study, SWAT is used to simulate the fate and transport of water, sediment, and nutrients for the following land use categories, referred to as HRUs:

- Pastureland
- Permanent hayland
- Range shrub
- Range grass
- Urban
- Mixed forest
- Deciduous forest
- Evergreen forest
- Horticultural lands
- Forested wetlands
- Non-forested wetlands

Upland processes were modeled for each of these HRUs in each watershed (8-digit HUC) (fig. 89). The model simulates surface runoff estimated from daily rainfall; percolation modeled with a layered storage routing technique combined with a subsurface flow model; lateral subsurface flow; groundwater flow to streams from shallow aquifers; potential evapotranspiration; snowmelt; transmission losses from streams; and water storage and losses from ponds.

Figure 89. SWAT model upland simulation processes



Agricultural sources

Upland processes for cultivated cropland (including land in long-term conserving cover) were modeled using APEX as described in previous chapters. The weighted average of per-acre APEX model output for surface water delivery, sediment, and nutrients was multiplied by the acres of cultivated cropland in the HUMUS database and used as SWAT model inputs for cultivated cropland for each 8-digit Hydrologic Unit Code (HUC). The acreage weights for the CEAP sample points were used to calculate the per-acre loads. (Several of the 8-digit watersheds in each region had too few CEAP sample points to reliably estimate edge-of-field per-acre loads. In these cases, the 6-digit per acre loads and sometimes the 4-digit per-acre loads were used to represent cultivated cropland.)

Various types of agricultural land management activities were modeled in SWAT for land use categories other than cultivated cropland. For permanent hayland, the following management activities were simulated:

[32] A complete description of the SWAT model can be found at http://www.brc.tamus.edu/swat/index.html.

- Hay was fertilized with nitrogen according to the crop need as determined by an auto-fertilization routine, which was set to grow the crop without undue nitrogen stress.
- Legume hay was grown in a 4-year rotation and phosphorus was applied at the time of planting (every fourth year) at a rate of 50 pounds per acre, followed by applications of 13 pounds per acre every other year.
- Recoverable manure from animal feeding operations was applied to 16 percent of the hayland acres at rates estimated from probable land application of manure using the methods described in USDA/NRCS (2003). These calculations indicated that 16 percent of hayland acres in the Arkansas-White-Red Basin could have received manure from animal feeding operations.
- Three hay cuttings were simulated per crop year for grass hay, and four hay cuttings were simulated per year for legume hay.
- For hayland acres that land-use databases indicated were irrigated, water was applied at a frequency and rate defined by an auto-irrigation routine.

For pastureland and rangeland, the following management activities were simulated:

- Continuous grazing was simulated by algorithms that determined the length of the grazing period, amount of biomass removed, and amount of biomass trampled. Grazing occurs whenever the plant biomass is above a specified minimum for grazing. The amount of biomass trampled daily is converted to residue.
- Manure nutrients from grazing animals were simulated for pastureland and rangeland according to the density of grazing livestock as reported in the 2002 Census of Agriculture. Non-recoverable manure was estimated by subtracting recoverable manure available for land application from the total manure nutrients representing all livestock populations. Non-recoverable manure nutrients include the non-recoverable portion from animal feeding operations. Estimates of manure nutrients were derived from data on livestock populations as reported in the 2002 Census of Agriculture, which were available for each 6-digit HUC and distributed among the 8-digit HUCs on a per-acre basis.
- Recoverable manure from animal feeding operations was applied to 6 percent of the pastureland acres at rates estimated from probable land application of manure using the methods described in USDA/NRCS (2003). These calculations indicated that 6 percent of pastureland acres in the Arkansas-White-Red Basin could have received manure from animal feeding operations.
- Supplemental commercial nitrogen fertilizers were applied to pastureland according to the crop need as determined by an auto-fertilization routine, which was set to grow grass without undue nitrogen stress.

Horticulture land was fertilized with 100 pounds per acre of nitrogen per year and 44 pounds per acre of phosphorus. For the irrigated horticultural acres, water was applied at a frequency and rate defined by an auto-irrigation routine.

Land application of biosolids from wastewater treatment facilities was not simulated. Manure nutrients from wildlife populations are not included in the model simulation.

A summary of the total amount of nitrogen and phosphorus applied to agricultural land in the model simulation, including nitrogen and phosphorus applied to cultivated cropland in the APEX modeling, is presented in table 41.[33]

Windborne sediment and nutrients

In areas of the country where wind erosion is a significant resource concern, as in the Arkansas-White-Red Basin, windblown sediment can be an important source of instream loads. The wind eroded material is deposited on many different landscapes and land uses including: other agricultural fields, filter or buffer areas, ditches, roadways, flood plains, and even directly into rivers and streams. In most cases windblown sediment will consist of unconsolidated material, which is easily transported into rivers and streams with surface water runoff. Because windblown material usually consists of fine and very fine soil particles, the portion that originates from cropland is usually rich in nutrients.

There are no published estimates of the magnitude of instream loads that originate from windborne sediment. Recognizing, however, that this is an important source of sediment and sediment-bound nutrients in areas prone to wind erosion, a rough estimate was calculated and incorporated into the model simulation. Windblown sediment materials were estimated conservatively by increasing the waterborne sediment loads delivered to the outlet of each 8-digit HUC by 10 percent. Nutrients carried with these windblown sediments were assumed to be in the same proportion as in the water-eroded materials. Sediment and sediment-bound nitrogen and phosphorus loads estimated using this approach are presented in table 42.

Estimates of windborne sediment and sediment-bound nutrients were not made for land uses other than cultivated cropland.

[33] For information on how manure nutrients were calculated for use in HUMUS modeling, see "Manure Loadings Used to Simulate Pastureland and Hayland in CEAP HUMUS/SWAT Modeling," available at: http://www.nrcs.usda.gov/technical/nri/ceap.

Table 41. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Arkansas-White-Red Basin

Subregion	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
Cultivated cropland						
Upper White River Basin (code 1101)	36,355	627	36,982	8,015	190	8,205
Upper Arkansas River Basin (code 1102)	18,539	9,488	28,027	1,846	3,878	5,724
Middle Arkansas River Basin (code 1103)	230,074	17,173	247,247	32,215	6,906	39,121
Upper Cimarron River Basin (code 1104)	100,152	10,984	111,136	11,267	4,354	15,620
Lower Cimarron River Basin (code 1105)	53,736	9,134	62,870	7,642	3,806	11,448
Arkansas River-Keystone incl. Salt Fork River Basin (code 1106)	82,482	8,365	90,847	13,732	3,337	17,069
Neosho-Verdigris River Basin (code 1107)	65,977	4,303	70,280	16,600	1,515	18,116
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	56,855	5,268	62,122	6,813	2,157	8,970
North Canadian including Beaver River Basin (code 1110)	98,640	11,279	109,919	11,041	4,515	15,556
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	17,103	6,338	23,441	2,592	1,892	4,484
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	81,308	17,878	99,186	7,940	6,617	14,557
Red-Washita-Pease-Lake Texoma Basin (code 1113)	107,204	14,825	122,029	17,402	6,136	23,538
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	43,659	2,065	45,724	5,271	860	6,131
Total	992,084	117,727	1,109,811	142,376	46,163	188,539
Hayland						
Upper White River Basin (code 1101)	25,616	7,462	33,077	209	3,509	3,717
Upper Arkansas River Basin (code 1102)	70	9	78	23	4	27
Middle Arkansas River Basin (code 1103)	146	163	309	391	49	440
Upper Cimarron River Basin (code 1104)	185	27	212	347	10	356
Lower Cimarron River Basin (code 1105)	597	24	621	29	10	40
Arkansas River-Keystone incl. Salt Fork River Basin (code 1106)	2,787	42	2,828	134	21	155
Neosho-Verdigris River Basin (code 1107)	40,418	5,163	45,580	412	2,405	2,817
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	8,392	186	8,578	139	104	244
North Canadian including Beaver River Basin (code 1110)	10,223	143	10,366	126	83	209
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	19,721	11,551	31,273	52	5,446	5,498
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	0	0	0	0	0	0
Red-Washita-Pease-Lake Texoma Basin (code 1113)	7,472	291	7,763	538	133	671
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	32,374	6,598	38,971	86	3,055	3,141
Total	148,000	31,657	179,657	2,487	14,828	17,315
Pastureland and rangeland						
Upper White River Basin (code 1101)	7,988	35,250	43,238	4,735	20,470	25,204
Upper Arkansas River Basin (code 1102)	3,624	14,495	18,119	1,961	7,846	9,807
Middle Arkansas River Basin (code 1103)	9,167	36,669	45,836	4,001	16,005	20,007
Upper Cimarron River Basin (code 1104)	4,653	18,614	23,267	1,779	7,115	8,894
Lower Cimarron River Basin (code 1105)	4,267	17,068	21,335	2,529	10,117	12,646
Arkansas River-Keystone incl. Salt Fork River Basin (code 1106)	4,506	18,025	22,532	2,788	11,153	13,941
Neosho-Verdigris River Basin (code 1107)	15,187	64,903	80,091	9,066	38,183	47,249
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	8,336	33,356	41,691	4,653	18,617	23,269
North Canadian including Beaver River Basin (code 1110)	9,482	37,933	47,415	4,486	17,946	22,432
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	8,512	40,498	49,010	4,965	22,888	27,853
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	8,706	34,823	43,528	3,983	15,933	19,917
Red-Washita-Pease-Lake Texoma Basin (code 1113)	12,537	50,148	62,685	7,684	30,735	38,419
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	12,950	54,998	67,948	7,741	32,432	40,173
Total	109,915	456,779	566,695	60,372	249,439	309,811

Table 41--continued. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Arkansas-White-Red Basin

Subregion	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
			Horticulture			
Upper White River Basin (code 1101)	178	0	178	78	0	78
Upper Arkansas River Basin (code 1102)	133	0	133	59	0	59
Middle Arkansas River Basin (code 1103)	0	0	0	0	0	0
Upper Cimarron River Basin (code 1104)	8	0	8	4	0	4
Lower Cimarron River Basin (code 1105)	74	0	74	33	0	33
Arkansas River-Keystone incl. Salt Fork River Basin (code 1106)	78	0	78	34	0	34
Neosho-Verdigris River Basin (code 1107)	1,554	0	1,554	684	0	684
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	313	0	313	138	0	138
North Canadian including Beaver River Basin (code 1110)	855	0	855	376	0	376
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	1,226	0	1,226	540	0	540
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	56	0	56	25	0	25
Red-Washita-Pease-Lake Texoma Basin (code 1113)	1,682	0	1,682	740	0	740
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	2,030	0	2,030	894	0	894
Total	8,188	0	8,188	3,604	0	3,604
			Total for all agricultural land			
Upper White River Basin (code 1101)	70,136	43,339	113,475	13,037	24,168	37,205
Upper Arkansas River Basin (code 1102)	22,366	23,991	46,357	3,889	11,727	15,617
Middle Arkansas River Basin (code 1103)	239,388	54,004	293,392	36,608	22,960	59,568
Upper Cimarron River Basin (code 1104)	104,999	29,624	134,623	13,396	11,479	24,874
Lower Cimarron River Basin (code 1105)	58,675	26,226	84,900	10,233	13,933	24,166
Arkansas River-Keystone incl. Salt Fork River Basin (code 1106)	89,853	26,432	116,285	16,688	14,511	31,199
Neosho-Verdigris River Basin (code 1107)	123,136	74,369	197,505	26,762	42,103	68,866
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	73,896	38,809	112,705	11,743	20,877	32,620
North Canadian including Beaver River Basin (code 1110)	119,200	49,355	168,555	16,030	22,543	38,573
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	46,563	58,387	104,949	8,148	30,227	38,375
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	90,069	52,700	142,770	11,948	22,550	34,498
Red-Washita-Pease-Lake Texoma Basin (code 1113)	128,895	65,264	194,159	26,364	37,004	63,368
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	91,012	63,661	154,674	13,993	36,347	50,340
Total	1,258,187	606,163	1,864,350	208,838	310,430	519,268

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

“Legacy Phosphorus” Not Accounted for in Modeling

“Legacy phosphorus” from cultivated cropland sources results from the over-application of phosphorus on farm fields in past years. When excessive amounts of fertilizer or manure are applied to a farm field, soil phosphorus levels increase dramatically. It may take decades for phosphorus levels to return to background levels once these practices are halted. Use of soil testing to determine the need for phosphorus applications can prevent further over-application, but there remains legacy phosphorus locked into the soil profile within the field, along the edge of the field and drainageways, and in streambeds that cannot be offset by current management activities. Legacy phosphorus can also come from sediment sources other than cultivated cropland.

The transport of sediment—and the phosphorus bound to those particles—from farm fields to rivers and streams can take many years. Eroded soil particles leaving a farm field can be deposited where runoff slows or ponding occurs before reaching a stream or river. Once the sediment has entered streams, some of the soil particles settle out and can remain in the streambed or settle on the floodplain when the water is high and slow moving. These sediments remain in place until a storm creates enough surface water runoff to re-suspend the previously eroded soil, or until streamflow cuts into streambanks made up of deposits of previously eroded soil. Windborne sediment transported into waterways can similarly be a mixture of newly eroded and previously eroded materials.

Consequently, measured phosphorus levels in rivers and streams include not only phosphorus lost from farm fields as a result of current farming activities but also “legacy phosphorus” from prior farming activities as well as prior deposits from non-farming sources. Some of this sediment-adsorbed “legacy phosphorus” can be solubilized by chemical reactions within the water body and measured as soluble phosphorus.

The simulation models used in this study do not account for these “legacy phosphorus” levels. There is recognition, however, that “legacy phosphorus” can be an important contributor to current levels of instream phosphorus loads, including soluble phosphorus loads.

Urban Sources

Urban sources include (1) loads from point sources discharged from industrial and municipal wastewater treatment plants and (2) loads from urban land runoff.

Discharges from industrial and municipal wastewater treatment plants can be major sources of nutrients and sediment in some watersheds. Point sources of water flow, total suspended sediment, total phosphorus, and Kjeldahl nitrogen were estimated using county-level data on population change to adjust 1980 estimates of point source loadings published by Resources for the Future (Gianessi and Peskin 1984) to the year 2000. The original Resources for the Future assessment covered 32,000 facilities, including industries, municipal wastewater treatment plants, and small sanitary waste facilities for the years 1977 to 1981. A GIS-based procedure was used to convert county data to the 8-digit HUC level. Point source loads are aggregated within each watershed and average annual loads input into SWAT at the watershed outlet.

Urban runoff is estimated separately for three categories of cover within an urban HRU: 1) Pervious surfaces such as lawns, golf courses, and gardens, 2) impervious surfaces hydraulically connected to drainage systems such as paved roads and paved streets draining to storm drains, and 3) impervious surfaces not hydraulically connected to drainage systems such as a house roof draining to a pervious yard that is not directly connected to drains (composite urban surface consisting of impervious roof surface and pervious yard surface).

Pervious surfaces are simulated in the same manner as other grass areas (such as pasture). Surface runoff from pervious surfaces is calculated using the NRCS Runoff Curve Number (RCN). (The RCN is an empirical parameter used in surface hydrology for predicting direct runoff or infiltration.) Nitrogen fertilizer (40 pounds per acre per year) is applied on grassed urban areas such as lawns and grassed roadsides using an auto-fertilizer routine to grow grass without undue nitrogen stress. The grass is considered irrigated as needed based on plant stress demand using an auto-irrigation routine.

For estimating surface water runoff from impervious urban areas, a runoff curve number of 98 was used for surfaces connected hydraulically to drainage systems. A composite runoff curve number was used for impervious surfaces not hydraulically connected to drainage systems. Sediment and nutrients carried with stormwater runoff to streams and rivers were estimated using the build up-wash off algorithm developed by Huber and Dickinson (1988).

The concept behind the build up-wash off algorithm is that over a period of time, dust, dirt, and other constituents are built up on street surfaces during dry periods. During a storm event the materials are washed off. The algorithms were developed from an EPA national urban water quality database that relates storm runoff loads to rainfall, drainage area, and impervious area.

Sediment produced from construction sites was also simulated in SWAT. Construction areas were assumed to represent 3 percent of urban areas. Parameters in the soil input file were modified to produce surface runoff and sediment yield that mimicked the average sediment load from published studies on construction sites.

A summary of the total amount of nitrogen and phosphorus applied to non-agricultural land in the model simulation is presented in table 42. Nutrients from septic systems were not included in the model simulations as data on locations of septic systems, populations using the septic systems, and types of septic systems were not available.

Atmospheric nitrogen deposition

Atmospheric deposition of nitrogen can be a significant component of the nitrogen balance. Nitrogen deposition data (loads and concentrations) were developed from the National Atmospheric Deposition Program/National Trends Network database (NADP 2004). When a rainfall event occurs in the model simulation, the amount of rainfall is multiplied by the average ammonium and nitrate concentrations calculated for the watershed to account for wet deposition. An additional amount of ammonium and nitrate are added on a daily basis to account for dry deposition. A summary of the total amount of nitrogen deposition included as inputs to the HUMUS/SWAT model simulation is presented in table 42.

Table 42. Summary of nutrients applied to urban land, nutrients originating from point sources, and wet and dry atmospheric deposition of nitrogen used as inputs to the HUMUS/SWAT model, Arkansas-White-Red Basin.

	Urban land	Point sources		Wet and dry atmospheric deposition
Subregion	Nitrogen fertilizer (tons/year)	Nitrogen (tons/year)	Phosphorus (tons/year)	Nitrogen (tons/year)
Upper White River Basin (code 1101)	6,739	910	215	51,050
Upper Arkansas River Basin (code 1102)	3,987	3,015	767	18,846
Middle Arkansas River Basin (code 1103)	6,391	6,830	1,004	11,193
Upper Cimarron River Basin (code 1104)	2,201	150	50	6,942
Lower Cimarron River Basin (code 1105)	2,705	251	63	7,557
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	2,777	310	75	10,090
Neosho-Verdigris River Basin (code 1107)	8,002	2,632	514	36,922
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	3,687	863	214	32,498
North Canadian including Beaver River Basin (code 1110)	5,520	830	211	18,289
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	7,245	3,695	875	35,535
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	2,842	329	68	12,146
Red-Washita-Pease-Lake Texoma Basin (code 1113)	6,476	2,029	322	27,725
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	9,786	3,553	919	55,161
Total	68,360	25,396	5,297	323,954

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

Routing and channel processes

SWAT simulates stream/channel processes including channel flood routing, channel sediment routing, nutrient routing, and transformations modified from the QUAL2E model (fig. 90).

- **Flood routing**. As water flows downstream, some may be lost due to evaporation and transmission through the channel bed. Another potential loss is removal of water from the channel for agricultural or human use. Flow may be supplemented by rainfall directly on the channel and/or addition of water from point source discharges.

- **Sediment routing—deposition, bed degradation, and streambank erosion**. Sediment transport in the stream network is a function of two processes, deposition and degradation. SWAT computes deposition and degradation simultaneously within the reach. Deposition is based on the fall velocity of the sediment particles and the travel time through each stream. Stream power is used to predict bed and bank degradation; excess stream power results in degradation. Bed degradation and streambank erosion are based on the erodibility and vegetative cover of the bed or bank and the energy available to carry sediment (a function of depth, velocity, and slope). The maximum amount of sediment that can be transported from a reach segment is a function of the peak channel velocity. Available stream power is used to re-entrain loose and deposited material until all of the material is removed.[34]

- **Nutrient routing**. Nutrient transformations in the stream are controlled by the instream water quality component of the model. The model tracks nutrients dissolved in the stream and nutrients adsorbed to the sediment. Dissolved nutrients are transported with the water, while those adsorbed to sediments are deposited with the sediment on the bed of the channel.

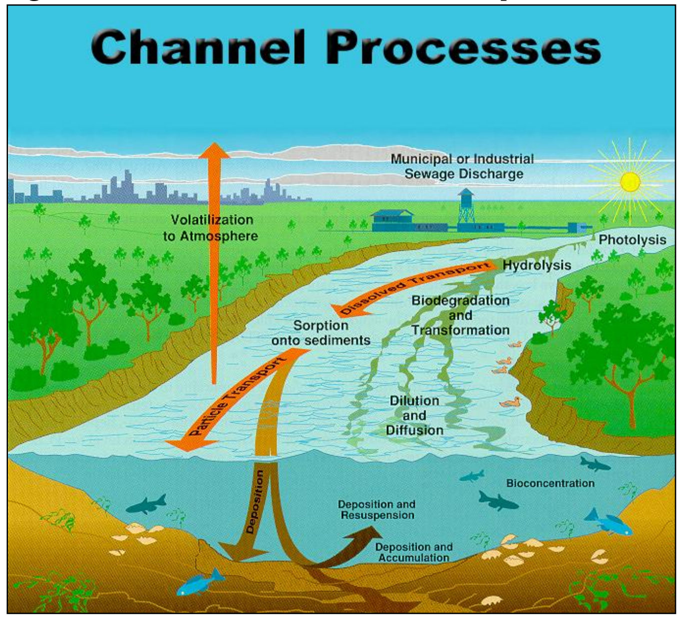
Reservoirs

Reservoirs alter the dynamics of a free-flowing river, resulting in different rates of sediment deposition and chemical transformations. SWAT includes routines for reservoirs that account for the hydrological aspects of reservoirs. Basic reservoir data such as storage capacity and surface area were obtained from the dams database.

- **Reservoir outflow**. A simple target volume approach was used in this study to simulate reservoir outflow. The algorithm attempts to keep reservoir storage near the principal spillway volume during the flood season but allow water storage to accumulate above the principal storage during the non-flood season.

[34] There are no national estimates of streambank erosion that can be uniformly used to calibrate this component of the model. Parameters governing instream sediment processes are adjusted in concert with those governing upland sediment yields such that HUMUS predictions at calibration sites mimic measured sediment data. Sediment data collected at a single stream gauging site is a combination of upland and instream sources, which cannot be proportioned by source. Collectively a network of sediment monitoring sites may be used to develop a sediment budget for a watershed which may include a stream bank component. When such studies are available for a HUMUS region they are used as ancillary data during model calibration.

Figure 90. SWAT model channel simulation processes



- **Sediment routing**. The concentration of sediment in the reservoir is estimated using a simple continuity equation based on volume and concentration of inflow, outflow, and water retained in the reservoir. Settling of sediment in the reservoir is governed by an equilibrium sediment concentration and the median sediment particle size. The amount of sediment in the reservoir outflow is the product of the volume of water flowing out of the reservoir and the suspended sediment concentration in the reservoir at the time of release.

- **Reservoir nutrients**. The model assumes that (1) the reservoir is completely mixed, (2) phosphorus is the limiting nutrient, and (3) total phosphorus is a measure of the trophic status. The phosphorus mass balance equation includes the concentration in the reservoir, inflow, outflow, and overall loss rate.

The Arkansas-White-Red River Basin contains several reservoirs which significantly affect the delivery of sediment and nutrients. Much of the sediment and nutrient load from the western and central portions of the basin is intercepted and trapped in these reservoirs on the Arkansas, Canadian, and Red Rivers. These intercepted loads are not delivered to the Mississippi River. Major reservoirs are located near the outlets of subregions 1105 and 1106 on the Arkansas River (Lake Keystone), at the outlet of 1110 on the Canadian River (Lake Eufaula), at the outlet of 1111 on the Arkansas River (Robert Kerr Reservoir), and at the outlet of 1113 on the Red River (Lake Texoma) (fig. 91). Smaller reservoirs such as Grand Lake (in subregion 1107) and Conchas/UTE dams (in subregion 1108) are also located in this region. Seventy-four reservoirs of varying size were simulated in the region in the HUMUS model. Collectively these reservoirs trapped 43 million tons of sediment annually. However reservoirs may also exacerbate downstream bank erosion, thus reducing the actual impact of the reservoir on sediment loads. These reservoirs also trap 200,000 tons of nitrogen and 25,000 tons of phosphorus each year. It is important to note that phosphorus trapped in reservoirs is not necessarily removed from these systems permanently. Reservoir sediments may become a source of soluble phosphorus under anoxic conditions common in eutrophic water-bodies and may be a contributor to “Legacy Phosphorus” issues.

Calibration

Delivery of surface water (surface runoff) and subsurface water (baseflow) simulated from upland processes (HRUs and CEAP sample points) was spatially calibrated for each 8-digit watershed. This process ensures that simulated runoff or water yield (surface runoff plus baseflow) was in agreement with long-term average runoff or water yield obtained for the Arkansas-White-Red River Basin from the USGS. Hydrologic parameters in APEX (used for simulating cultivated cropland) and SWAT (used for simulating non-cultivated land) were adjusted separately for each 8-digit watershed to minimize differences in the long-term water yield. The time series calibration of streamflow were conducted for the period from 1961–1990 at six gaging stations in this region. Predicted annual and monthly streamflow were compared against the monitored streamflow for the calibration period. Most of the flow calibration was carried out with minimal or no parameterization for the annual and monthly streamflow. [35] When necessary, the channel losses, seepage, and evaporation losses in reservoirs were adjusted to match the predicted flow time series with that of observed data. The annual and monthly observed and predicted streamflow were validated for the period from 1991–06 at the selected gaging stations.

For sediment calibration, observations were taken from USGS monitoring stations. Most of the sediment observations were grab-sample concentrations of suspended sediment. These, along with monitored daily flow data, were processed using the USGS’s Estimator software to estimate annual average sediment load. The estimated annual average sediment loads at six gaging stations in the Arkansas-White-Red Basin were used to calibrate the predicted sediment loads from HUMUS/SWAT. Upland soil erosion and sediment yields were calibrated by adjusting the soil erodibility factor and residue cover. Instream sediment loads were calibrated using parameters controlling stream power and sediment carrying capacity of channels. Delivery ratios from field to 8-digit watershed outlet and from 8-digit watershed outlet to river were adjusted to match predicted sediment load with that of observations for each gaging station. Where necessary, parameters affecting settling of sediment in reservoirs were adjusted.

Total nitrogen and total phosphorus loads were calibrated at the same six gaging stations. Nitrate-nitrogen, nitrite-nitrogen, total Kjeldahl nitrogen, and orthophophate were calibrated in stations where observed data were available. Most of the data for nutrient calibration were taken from the USGS-NASQAN data monitoring program. Nutrient loads were estimated from grab-sample concentrations using the same procedure outlined for sediment.

Upland nutrient loads were calibrated using parameters controlling nutrient uptake by plants, leaching to groundwater, and mineralization. Instream nutrient loads were calibrated using parameters affecting benthic nutrient source rates, mineralization, hydrolysis, and settling of particulate nutrients. Where necessary, parameters affecting settling of nutrients in reservoirs were also adjusted.

The “background” scenario

An additional scenario was conducted to represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by simulating with APEX a grass-and-tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.[36] All SWAT modeling remained the same for this scenario. Thus, “background” loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Source Loads and Instream Loads

All source loads are introduced into SWAT at the outlet of each watershed (8-digit hydrologic unit code [HUC]). Flows and source loads from upstream watersheds are routed through each downstream watershed, including reservoirs when present.[37]

A sediment delivery ratio was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The sediment delivery ratio used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the

[35] For a complete documentation of calibration procedures and results for the Arkansas-White-Red River Basin, see “Calibration and Validation of CEAP HUMUS” at http://www.nrcs.usda.gov/technical/nri/ceap.

[36] In a natural ecosystem, the vegetative cover would include a mix of species, which would continually change until a stable ecosystem was established. APEX allows for multiple species and simulates plant competition over time according to plant growth, canopy cover, vegetative form, and relative maturity or growth stage. The initial mix of species at the beginning of the 47-year simulation was similar to the mix of grasses and trees used to establish long-term conserving cover. Mixes included at least one grass and one legume. Over the 47-year simulation, the mix of grasses and trees shifted due to plant competition. The grass species typically dominate in the simulation until shaded out by tree cover. For further details on how the background simulation was conducted, see “Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for the CEAP National Cropland Assessment” at http://www.nrcs.usda.gov/technical/nri/ceap.

[37] For a complete documentation of HUMUS/SWAT as it was used in this study, see “The HUMUS/SWAT National Water Quality Modeling System and Databases” at http://www.nrcs.usda.gov/technical/nri/ceap.

HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU.[38]

In addition to the sediment delivery ratio, an enrichment ratio was used to simulate organic nitrogen and organic phosphorus transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen and organic phosphorus concentrations transported with sediment to the watershed outlet divided by their concentrations at the edge of the field. As sediment is transported from the edge of field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen and soluble phosphorus. In general, the proportion of soluble nutrients delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

There are four points in the modeling process at which source loads or instream loads are assessed, shown in the schematic in figure 91 for sediment.

1. Edge-of-field loads from cultivated cropland—aggregated APEX model output as reported in the previous chapter.

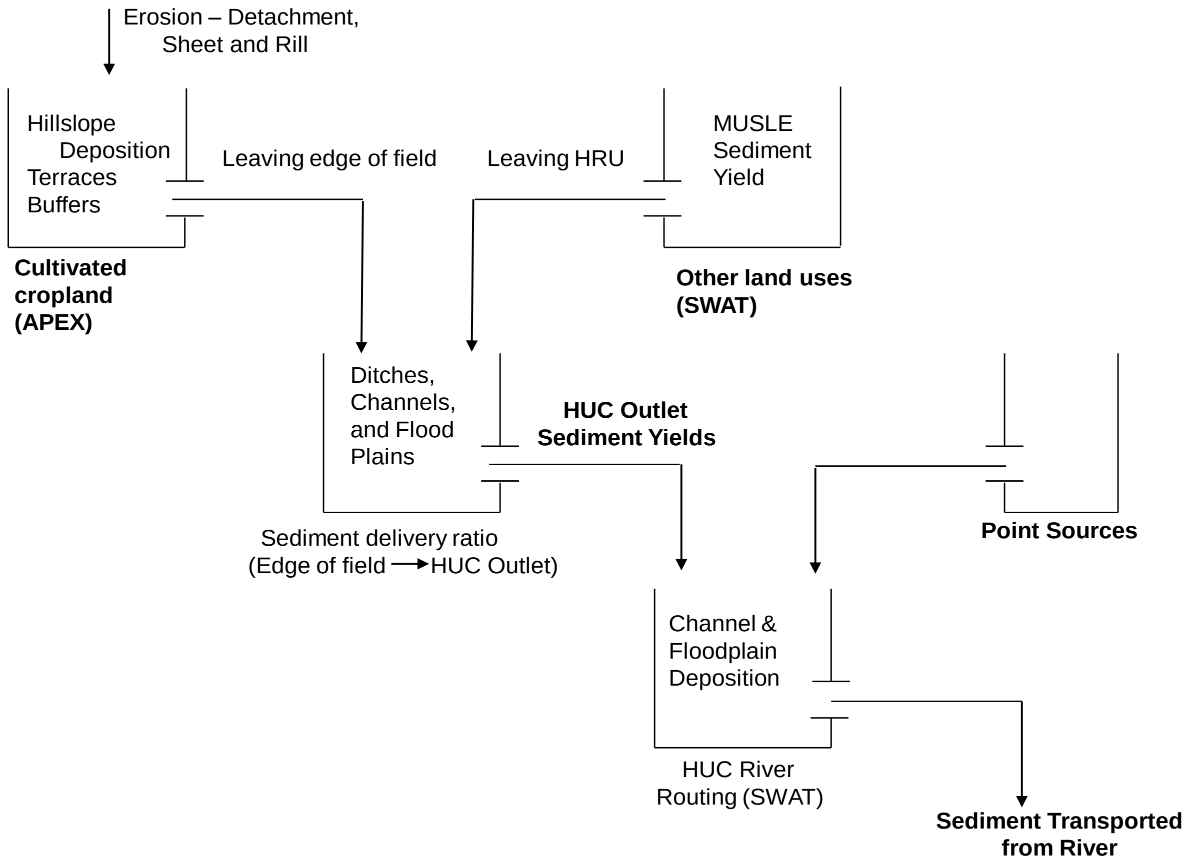
2. Delivery to the watershed outlet from cultivated cropland—aggregated edge-of-field loads after application of delivery ratios. Loadings delivered to streams and rivers differ from the amount leaving the field because of losses during transport from the field to the stream. Delivery ratios are used to make this adjustment.

3. Delivery to the watershed outlet from land uses other than cultivated cropland as simulated by SWAT, after application of delivery ratios. Point sources are included.

4. Loadings in the stream or river at a given point. Instream loads include loadings delivered to the watershed outlet from all sources as well as loads delivered from upstream watersheds, after accounting for channel and reservoir processes.

[38] For a complete documentation of delivery ratios used for the Arkansas-White-Red Basin, see “Delivery Ratios Used in CEAP Cropland Modeling” at http://www.nrcs.usda.gov/technical/nri/ceap.

Figure 91. Schematic of sediment sources and delivery as modeled with HUMUS/SWAT for the Arkansas-White-Red Basin



Modeling Land Use in the Arkansas-White-Red Basin

The USGS National Land-Cover Database for 2001 (Homer et al. 2007) was the principal source of acreage estimates for HUMUS/SWAT modeling. The 2003 National Resources Inventory (USDA/NRCS 2007) was used to adjust NLCD cropland acreage estimates to include acres in Conservation Reserve Program (CRP) General Signups, used here to represent cropland in long-term conserving cover. Consequently, cultivated cropland acres used to simulate the water quality effects of conservation practices differ slightly from the cropped acres reported in the previous chapters, which were estimated on the basis of the CEAP Cropland sample.

Estimates of the acreage by land use, exclusive of water, used in the model simulation to estimate the effects of conservation practices in this chapter are presented in table 43 and figure 92. Grazing land (rangeland and pastureland) makes up slightly less than half of the acres in the basin. Cultivated cropland and forest and other land uses each make up about 23 percent. Urban land and hayland are minor land uses in this region.

Cultivated cropland acres are distributed throughout the region but are concentrated in the central part of the basin (Kansas, Oklahoma, and northern Texas) (tables 4 and 43 and fig. 2). The Middle Arkansas River Basin (code 1103) has the most acres of cultivated cropland—25 percent of the cultivated cropland in the region. Four additional subregions account for another 44 percent: the Upper Cimarron River Basin (code 1104), the Red-Washita-Pease-Lake Texoma Basin (code 1113), the Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112), and the North Canadian including Beaver River Basin (code 1110).

The concentration of cultivated cropland within each subregion is an important indicator of the extent to which sediment and nutrient loads in rivers and streams are influenced by farming operations. Cultivated cropland accounts for about 40 percent or more of the land base in 4 of the 14 subregions (table 4 and fig. 2):

- Middle Arkansas River Basin (code 1103), with 67 percent,
- Upper Cimarron River Basin (code 1104), with 52 percent,
- Arkansas River-Keystone including Salt Fork River Basin (code 1106), with 42 percent, and
- Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112), with 40 percent.

As reported in table 4, cultivated cropland is a minor land use in four subregions, where it accounts for only a small percentage of the total area within each subregion—

- Upper White River Basin (code 1101), with 6 percent,
- Red-Little-Saline-Sulphur Creek River Basin (code 1114), with 4 percent,
- Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111), with 3 percent, and
- Upper Canadian River Basin (code 1108), with 1 percent.

The amount of land in long-term conserving cover, which represents about 17 percent of the cultivated cropland acres in this region (table 4), is also an important determinant of the extent to which sediment and nutrient loads in rivers and streams are influenced by farming operations. Subregions where land in long-term conserving cover is 20 percent or more of cultivated cropland acres are (table 4):

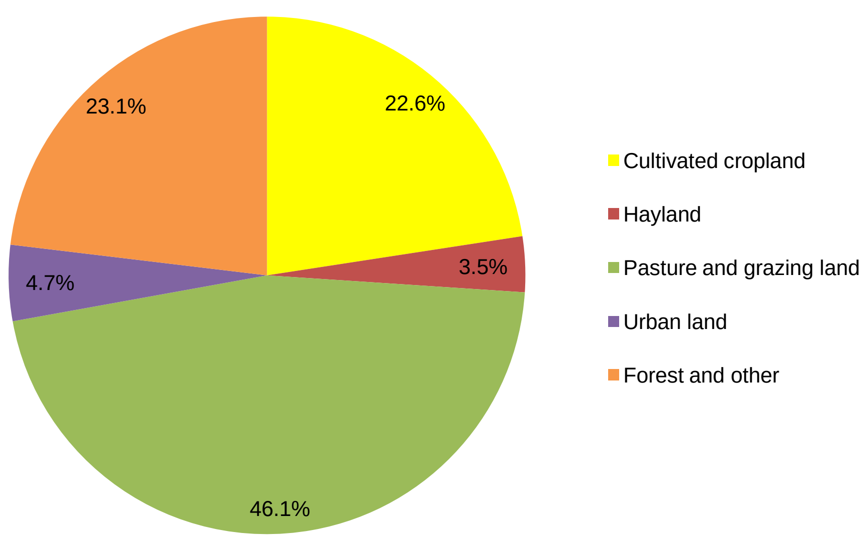
- Upper Arkansas River Basin (code 1102), with 37 percent,
- Upper Canadian River Basin (code 1108), with 32 percent,
- Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112), with 30 percent,
- North Canadian including Beaver River Basin (code 1110), with 26 percent, and
- Upper Cimarron River Basin (code 1104), with 22 percent.

Table 43. Acres by land use, exclusive of water, used in model simulations to estimate instream sediment and nutrient loads for the Arkansas-White-Red Basin

Subregions	Cultivated cropland (acres)*	Hay land not in rotation with crops (acres)	Pasture and grazing land not in rotation with crops (acres)**	Urban land (acres)	Forest and other (acres)***	Total land exclusive of water (acres)
Upper White River Basin (code 1101)	882,586	944,601	2,448,628	703,362	9,103,689	14,082,865
Upper Arkansas River Basin (code 1102)	1,802,116	7,281	10,938,556	408,880	2,736,559	15,893,392
Middle Arkansas River Basin (code 1103)	8,772,889	90,995	3,183,083	675,783	236,459	12,959,209
Upper Cimarron River Basin (code 1104)	3,986,576	85,684	3,189,577	242,287	222,643	7,726,766
Lower Cimarron River Basin (code 1105)	1,566,785	24,123	2,140,123	280,300	445,674	4,457,005
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	2,615,440	107,252	2,806,246	291,431	367,757	6,188,126
Neosho-Verdigris River Basin (code 1107)	1,828,068	1,338,864	6,717,755	839,402	2,336,068	13,060,158
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	1,476,719	270,699	13,842,716	424,323	2,796,202	18,810,659
North Canadian including Beaver River Basin (code 1110)	3,665,400	328,653	5,467,458	653,266	1,119,895	11,234,670
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	339,530	823,382	2,419,836	741,982	5,561,638	9,886,368
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	3,770,088	47	5,031,321	393,408	232,682	9,427,545
Red-Washita-Pease-Lake Texoma Basin (code 1113)	3,961,403	334,970	9,132,933	732,780	1,451,647	15,613,732
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	675,053	1,075,273	4,866,959	1,033,029	9,555,331	17,205,645
Regional total	35,342,653	5,431,823	72,185,190	7,420,233	36,166,242	156,546,141

*Acres of cultivated cropland include land in long-term conserving cover as well as hay land and pastureland in rotation with crops.
**Includes grass and brush rangeland categories.
***Includes forests (all types), wetlands, horticulture, and barren land.
Note: Estimates were obtained from HUMUS databases on land use, and thus cultivated cropland estimates do not exactly match the acreage estimates obtained from the NRI-CEAP sample.

Figure 92. Percent acres for land use/cover types in the Arkansas-White-Red Basin, exclusive of water



Conservation Practice Effects on Loadings to Waterbodies

HUMUS/SWAT accounts for the transport of water, sediment, and nutrients from the land to receiving streams and routes the flow downstream to the next watershed and ultimately to estuaries and oceans. Not all of the sediment and nutrients, that leave farm fields are delivered to streams and rivers. Some material is bound up in various parts of the landscape during transport. In addition, instream degradation processes and streambed deposition and accumulation remove or trap a portion of the sediment and nutrients after delivery to streams and rivers.

The results from the onsite APEX model simulations for cultivated cropland, including land in long-term conserving cover, were integrated into HUMUS/SWAT to assess the effects of conservation practices on instream loads of sediment, nitrogen, and phosphorus. The water quality effects of conservation practices in use during 2003–06 were assessed by comparing HUMUS/SWAT model simulation results for the baseline conservation condition to simulation results for the no-practice scenario. For the no-practice scenario, only the conditions for cultivated cropland were changed, as described previously. All other aspects of the simulations—including sediment and nutrient loads from point sources and land uses other than cultivated cropland—remained the same.

In summary, findings for the Arkansas-White-Red Basin indicate that for the baseline conservation condition—

- *Amounts of sediment and nutrient loads* ***delivered to rivers and streams from cultivated cropland sources*** *per year, on average, are:*
  - *6.9 million tons of sediment (30 percent of loads from all sources);*
  - *283 million pounds of nitrogen (43 percent of loads from all sources); and*
  - *17 million pounds of phosphorus (20 percent of loads from all sources).*

- *Instream* ***loads from all sources delivered from the region to the Lower Mississippi River Basin*** *per year, on average, are:*
  - *21 million tons of sediment (8 percent attributable to cultivated cropland sources);*
  - *224 million pounds of nitrogen (28 percent attributable to cultivated cropland sources); and*
  - *30 million pounds of phosphorus (14 percent attributable to cultivated cropland sources).*

Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have—

- *Reduced sediment and nutrient loads* ***delivered to rivers and streams from cultivated cropland sources*** *per year, on average, by:*
  - *64 percent for sediment;*
  - *59 percent for nitrogen; and*
  - *59 percent for phosphorus.*

- *Reduced instream* ***loads from all sources delivered from the region to the Lower Mississippi River Basin*** *per year, on average, by:*
  - *5 percent for sediment;*
  - *27 percent for nitrogen; and*
  - *17 percent for phosphorus.*

Sediment

Baseline condition. Model simulation results show that of the 9 million tons of sediment exported from farm fields in the Arkansas-White-Red Basin (table 44), about 6.9 million tons are delivered to rivers and streams each year (table 45), on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 0.20 ton per acre of sediment from cultivated cropland is delivered to rivers and streams per year, on average for the region (table 45).

About 59 percent of the sediment delivered to rivers and streams from cultivated cropland originates in four subregions—

- the Middle Arkansas River Basin (code 1103), with 24 percent of the total load for the region,
- the Red-Washita-Pease-Lake Texoma Basin (code 1113), with 13 percent,
- the Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112), with 12 percent, and
- the Neosho-Verdigris River Basin (code 1107), with 10 percent.

On a per-acre basis, annual sediment delivery from cultivated cropland is highest in the Red-Little-Saline-Sulphur Creek River Basin (code 1114), where it averages 0.73 ton delivered per cultivated cropland acre. Two other subregions also have relatively high per-acre sediment delivery, averaging 0.44 ton per acre for Upper White River Basin (code 1101) and 0.42 ton per acre for the Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111).

Sediment delivered to rivers and streams from cultivated cropland represents about 30 percent of the total sediment load delivered from all sources in the region (table 46, fig. 93). This percentage ranges, however, from a low of 5 percent in the Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111) to a high of 97 percent in the Middle Arkansas River Basin (code 1103).

Cultivated cropland is the dominant source of sediment delivered to rivers and streams in only 5 of the 14 subregions (table 46). In 8 of the subregions, grazing land (rangeland and pastureland) is the dominant source of sediment delivered to rivers and streams. Overall, rangeland and pastureland account for 47 percent of the sediment load delivered to rivers and streams in this region. Urban sources account for 14 percent, and other sources account for the remaining 9 percent (table 46).

Instream sediment loads delivered from all sources in the region to the Lower Mississippi River Basin, after accounting for instream deposition and transport processes, total about 21 million tons per year, averaged over the 47 years of weather as simulated in the model (table 47, fig. 94). The Red River is the source of most of this sediment load, averaging 18.6 million tons per year. The White River averages about 1.6 million tons and the Arkansas River averages about 1.2 million tons (table 47).

Of the total instream load delivered from all sources in the region to the Lower Mississippi River Basin, about 8 percent is attributed to cultivated cropland sources in the model simulation (10 percent for the White River, 14 percent for the Arkansas River, and 8 percent for the Red River). The amount attributed to cultivated cropland was determined by subtracting the instream loads in the “background” scenario (no cultivation) from the total load from all sources in the baseline conservation condition (table 47).

As noted in the previous section, the Arkansas-White-Red Basin contains several reservoirs which reduce loads delivered to the Mississippi River. Much of the sediment load from the western and central portions of the basin is intercepted and trapped in these reservoirs on the Arkansas, Canadian, and Red Rivers.

Effects of conservation practices. Sediment loads delivered to streams and rivers would have been much larger if soil erosion control practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of sediment from fields to rivers and streams by about 64 percent (table 45), on average. Reductions due to conservation practices vary throughout the region, ranging from a low of 31 percent for Red-Little-Saline-Sulphur Creek River Basin (code 1114) to a high of 88 percent for the Upper Cimarron River Basin (code 1104).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of sediment from the Arkansas-White-Red Basin to the Lower Mississippi River Basin by about 5 percent overall (table 47, fig. 94). Without conservation practices, the total amount of sediment delivered to the Lower Mississippi River Basin would be larger by 1 million tons per year.

Table 44. Average annual sediment loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Arkansas-White-Red Basin

Subregions	Baseline conservation condition: Amount (1,000 tons)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Tons delivered per cultivated cropland acre	No-practice Scenario (1,000 tons)	Reductions in loads due to conservation practices: Reduction (1,000 tons)	Reductions in loads due to conservation practices: Percent
Upper White River Basin (code 1101)	996	11	1.13	1,433	437	31
Upper Arkansas River Basin (code 1102)	64	1	0.04	375	311	83
Middle Arkansas River Basin (code 1103)	1,464	16	0.17	4,269	2,805	66
Upper Cimarron River Basin (code 1104)	175	2	0.04	2,916	2,741	94
Lower Cimarron River Basin (code 1105)	499	6	0.32	1,369	870	64
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	737	8	0.28	2,096	1,359	65
Neosho-Verdigris River Basin (code 1107)	1,671	18	0.91	4,637	2,966	64
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	117	1	0.08	716	599	84
North Canadian including Beaver River Basin (code 1110)	197	2	0.05	1,596	1,399	88
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	312	3	0.92	538	226	42
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	530	6	0.14	2,284	1,754	77
Red-Washita-Pease-Lake Texoma Basin (code 1113)	1,032	11	0.26	3,239	2,207	68
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	1,240	14	1.84	1,797	557	31
Regional total	9,034	100	0.26	27,265	18,232	67

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.

Table 45. Average annual sediment loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Arkansas-White-Red Basin

Subregions	Baseline conservation condition: Amount (1,000 tons)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Tons delivered per cultivated cropland acre	No-practice Scenario (1,000 tons)	Reductions in loads due to conservation practices: Reduction (1,000 tons)	Reductions in loads due to conservation practices: Percent
Upper White River Basin (code 1101)	389	6	0.44	578	188	33
Upper Arkansas River Basin (code 1102)	113	2	0.06	655	542	83
Middle Arkansas River Basin (code 1103)	1,691	24	0.19	3,706	2,015	54
Upper Cimarron River Basin (code 1104)	313	5	0.08	2,611	2,298	88
Lower Cimarron River Basin (code 1105)	320	5	0.20	646	326	50
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	541	8	0.21	1,068	527	49
Neosho-Verdigris River Basin (code 1107)	672	10	0.37	1,855	1,183	64
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	171	2	0.12	832	661	79
North Canadian including Beaver River Basin (code 1110)	315	5	0.09	1,837	1,522	83
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	143	2	0.42	246	103	42
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	830	12	0.22	2,525	1,695	67
Red-Washita-Pease-Lake Texoma Basin (code 1113)	919	13	0.23	1,968	1,049	53
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	494	7	0.73	718	224	31
Regional total	6,912	100	0.20	19,244	12,332	64

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 44 are due to the application of delivery ratios, which were used to simulate delivery of sediment from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.

Table 46. Average annual sediment loads ***delivered to watershed outlets*** (8-digit HUCs) in the Arkansas-White-Red Basin, baseline conservation condition, by source

Subregions	All sources	Cultivated cropland*	Hayland	Grazing land	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 tons)			
Upper White River Basin (code 1101)	1,512	390	181	214	516	2	209
Upper Arkansas River Basin (code 1102)	147	113	0	17	9	6	1
Middle Arkansas River Basin (code 1103)	1,751	1,691	<1	19	32	8	<1
Upper Cimarron River Basin (code 1104)	354	313	0	34	6	<1	<1
Lower Cimarron River Basin (code 1105)	1,139	320	1	711	88	1	19
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	1,132	541	3	515	53	1	19
Neosho-Verdigris River Basin (code 1107)	3,110	673	71	1,857	433	4	71
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	2,044	172	59	1,567	104	2	140
North Canadian including Beaver River Basin (code 1110)	966	315	7	469	162	2	12
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	2,781	145	208	1,258	757	10	404
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	1,085	830	0	219	26	<1	9
Red-Washita-Pease-Lake Texoma Basin (code 1113)	2,563	919	13	1,392	161	3	75
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	4,685	497	129	2,775	796	19	470
Regional total	23,269	6,920	671	11,048	3,143	57	1,430
				Percent of all sources			
Upper White River Basin (code 1101)	100	26	12	14	34	<1	14
Upper Arkansas River Basin (code 1102)	100	77	0	12	6	4	1
Middle Arkansas River Basin (code 1103)	100	97	<1	1	2	<1	<1
Upper Cimarron River Basin (code 1104)	100	88	0	10	2	<1	<1
Lower Cimarron River Basin (code 1105)	100	28	<1	62	8	<1	2
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	100	48	<1	46	5	<1	2
Neosho-Verdigris River Basin (code 1107)	100	22	2	60	14	<1	2
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	100	8	3	77	5	<1	7
North Canadian including Beaver River Basin (code 1110)	100	33	1	49	17	<1	1
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	100	5	7	45	27	<1	15
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	100	76	<1	20	2	<1	1
Red-Washita-Pease-Lake Texoma Basin (code 1113)	100	36	1	54	6	<1	3
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	100	11	3	59	17	<1	10
Regional total	100	30	3	47	14	<1	6

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

Figure 93. Percentage by source of average annual sediment loads delivered to rivers and streams in the Arkansas-White-Red Basin, baseline conservation condition

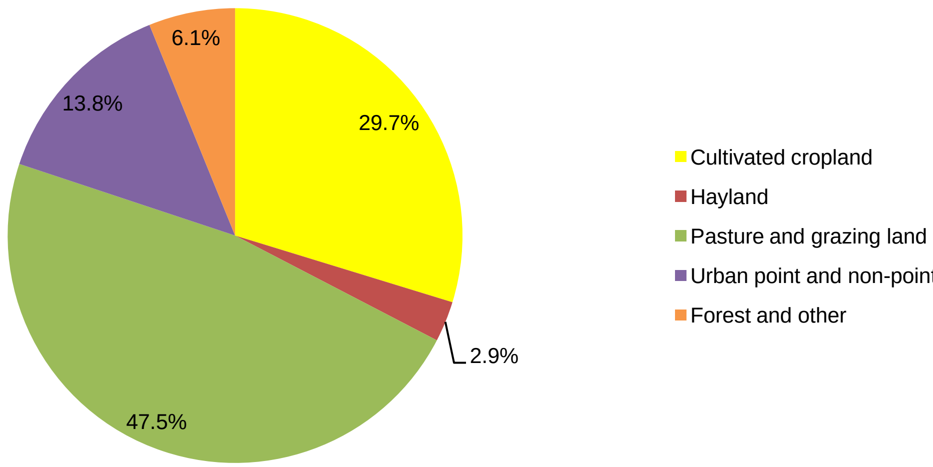


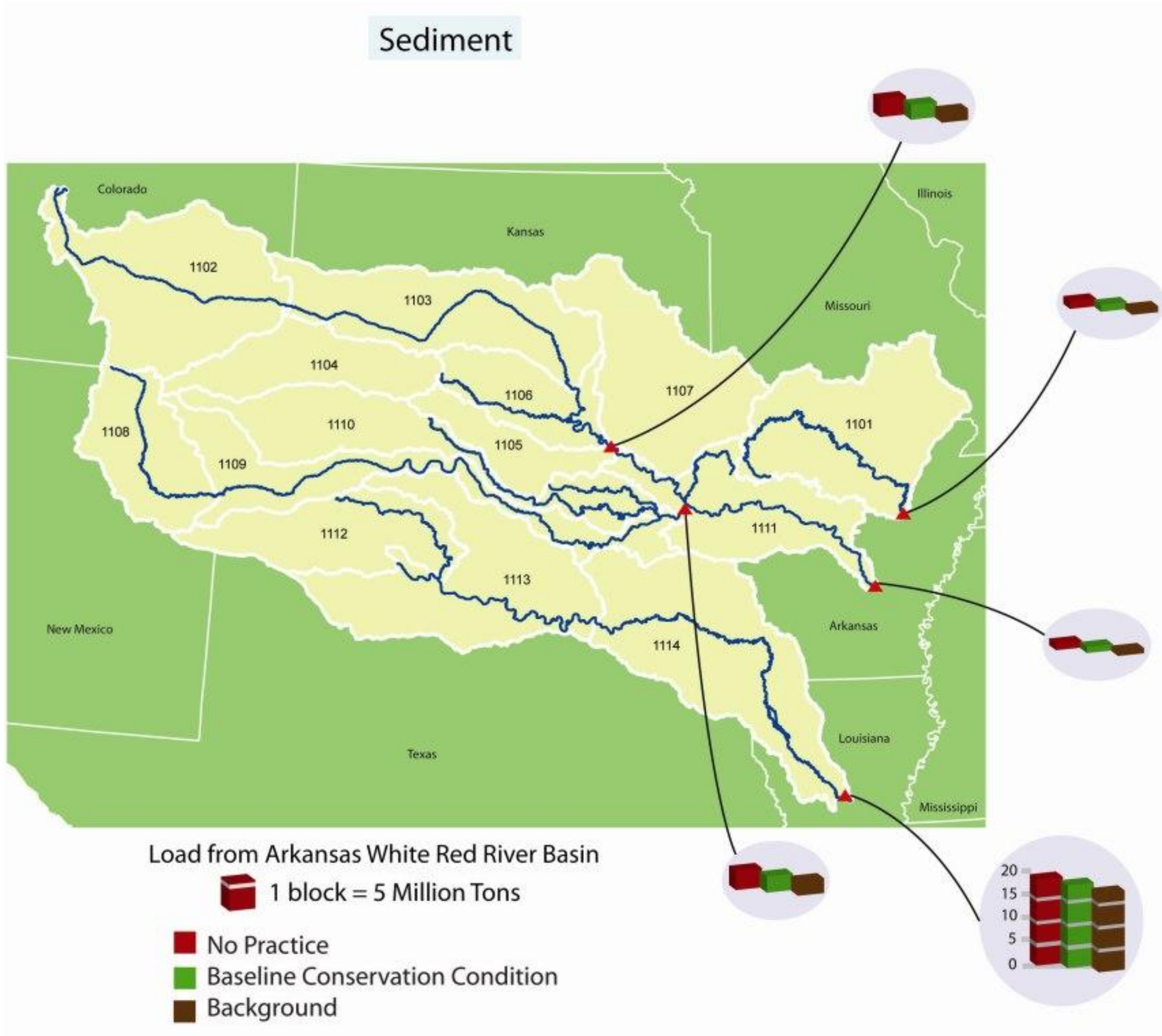
Table 47. Average annual ***instream sediment loads*** (all sources) for the Arkansas-White-Red Basin

	Baseline conservation condition				Reductions in loads due to conservation practices	
Subregions	Load from all sources (1,000 tons)	Background sources* (1,000 tons)	Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 tons)	Reduction (1,000 tons)	Percent
White River						
Load delivered from Upper White River (code 1101) to the Lower Mississippi River Basin	1,589	1,430	10	1,665	76	5
Arkansas River						
Load delivered from Cimarron River (code 11051) to Arkansas River at Lake Keystone	3,411	2,481	27	4,382	971	22
Load delivered from the Neosho-Verdigris Rivers (code 1107) to Arkansas River	2,863	2,738	4	2,875	12	<1
Load delivered from Upper and Middle Arkansas River, including Salt Fork River (code 1106), to the Lower Arkansas River at Lake Keystone	3,487	2,333	33	4,123	636	15
Load delivered from Upper and Lower Canadian River (code 1109) to Arkansas River at Lake Eufaula	3,623	3,277	10	4,234	611	14
Load delivered from the North Canadian River, including Beaver River (code 1110), to Arkansas River at Lake Eufaula	1,081	926	14	1,403	322	23
Load delivered from Lower Arkansas River (code 1111) to the Lower Mississippi River Basin at the Robert Kerr Reservoir	1,173	1,014	14	1,268	95	7
Red River						
Load delivered from the Red River and its tributaries, including the Bayou Rigolette Basin (code 1114), to the Lower Mississippi River Basin	18,580	17,110	8	19,420	840	4
Total load delivered from Arkansas-White-Red Basin to Lower Mississippi River Basin**	21,342	19,554	8	22,353	1,011	5

***** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
** Sum of loads from the White River, Arkansas River, and Red River at the outlets to the Lower Mississippi River Basin.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Figure 94. Estimates of average annual instream sediment loads for the baseline conservation condition compared to the no-practice scenario for the Arkansas-White-Red Basin*



* Instream sediment loads (all sources) are shown for selected subregions corresponding to estimates presented in table 47.

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Total Nitrogen

Baseline condition. Model simulation results show that of the 313 million pounds of nitrogen exported from farm fields in the Arkansas-White-Red Basin (table 48), about 283 million pounds are delivered to rivers and streams each year (table 49), on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 8 pounds per acre of nitrogen from cultivated cropland are delivered to rivers and streams per year, on average for the region (table 49).

The Middle Arkansas River Basin (code 1103) delivers the most nitrogen from cultivated cropland to rivers and streams within the region, accounting for 20 percent of the total load for the region. However, this load represents only about 6 pounds per cultivated cropland acre. The subregion with the greatest per-acre delivery of nitrogen from cultivated cropland is the Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111) with 33 pounds per acre per year of nitrogen delivered to rivers and streams.

Nitrogen delivered to rivers and streams from cultivated cropland represents about 43 percent of the total nitrogen load delivered from all sources in the region (table 50, fig. 95). This percentage ranges, however, from a low of 7 percent in the Red-Little-Saline-Sulphur Creek River Basin (code 1114) to a high of 93 percent in the Upper Cimarron River Basin (code 1104).

Cultivated cropland is the dominant source of nitrogen delivered to rivers and streams in all but 4 subregions. In 3 of these the dominant source of nitrogen load is rangeland and pastureland. These are (table 50)—

- the Neosho-Verdigris River Basin (code 1107),
- the Upper White River Basin (code 1101), and
- the Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111).

In the Red-Little-Saline-Sulphur Creek River Basin (code 1114), the dominant source of nitrogen was forestland and other land uses, and the amount of nitrogen delivered from urban non-point and point sources was about the same as nitrogen delivered from rangeland and pastureland, each slightly less than 25 percent of the total load.

Overall, rangeland and pastureland account for 20 percent of the nitrogen load delivered to rivers and streams in this region. Urban sources account for 18 percent, and other sources account for the remaining 19 percent (table 50).

Instream nitrogen loads delivered from all sources in the region to the Lower Mississippi River Basin, after accounting for instream deposition and transport processes, total about 224 million pounds per year, averaged over the 47 years of weather as simulated in the model (table 51, fig. 96). The Arkansas River and its tributaries are the greatest source of this nitrogen, averaging about 103 million pounds per year. The White River averages 53 million pounds per year at the outlet, and the Red River averages 68 million pounds per year at the outlet.

Of the total instream nitrogen load leaving the basin, about 28 percent is attributed to cultivated cropland sources in the model simulation (table 51). About 21 percent is attributed to cultivated cropland sources in the model simulation for the White River, 41 percent for the Arkansas River, and 14 percent for the Red River. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the “background” scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 51).

As previously noted, the Arkansas White Red Basin contains several reservoirs which reduce loads delivered to the Mississippi River. Some of the nitrogen load from the western and central portions of the basin is intercepted and trapped in these reservoirs on the Arkansas, Canadian, and Red Rivers.

Effects of conservation practices. Nitrogen loads delivered to rivers and streams would have been much larger if soil erosion control practices and nutrient management practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of nitrogen from fields to rivers and streams by about 59 percent (table 49), on average. Reductions due to conservation practices vary throughout the region, ranging from a low of 12 percent for the Upper Arkansas River Basin (code 1102) to 70 percent for two subregions:

- the Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112), and
- the North Canadian including Beaver River Basin (code 1110).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of nitrogen from the Arkansas-White-Red Basin to the Lower Mississippi River Basin by about 27 percent overall (table 51, fig. 96). Without conservation practices, the total amount of nitrogen delivered to the Lower Mississippi River Basin would be larger by 84 million pounds per year—65 million tons from the Arkansas River, 13 million tons from the Red river, and 6 million tons from the White River.

Table 48. Average annual nitrogen loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Arkansas-White-Red Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Upper White River Basin (code 1101)	15,220	5	17.24	22,050	6,830	31
Upper Arkansas River Basin (code 1102)	24,720	8	13.72	26,810	2,090	8
Middle Arkansas River Basin (code 1103)	63,030	20	7.18	152,400	89,370	59
Upper Cimarron River Basin (code 1104)	21,720	7	5.45	64,360	42,640	66
Lower Cimarron River Basin (code 1105)	20,300	6	12.96	58,780	38,480	65
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	27,850	9	10.65	83,370	55,520	67
Neosho-Verdigris River Basin (code 1107)	27,570	9	15.08	50,430	22,860	45
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	13,567	4	9.19	43,679	30,112	69
North Canadian including Beaver River Basin (code 1110)	16,550	5	4.52	57,650	41,100	71
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	11,620	4	34.22	18,730	7,110	38
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	18,830	6	4.99	70,700	51,870	73
Red-Washita-Pease-Lake Texoma Basin (code 1113)	38,870	12	9.81	118,100	79,230	67
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	12,720	4	18.84	19,700	6,980	35
Regional total	312,567	100	8.84	786,759	474,192	60

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.

Table 49. Average annual nitrogen loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Arkansas-White-Red Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Upper White River Basin (code 1101)	13,280	5	15.05	19,760	6,480	33
Upper Arkansas River Basin (code 1102)	19,770	7	10.97	22,430	2,660	12
Middle Arkansas River Basin (code 1103)	56,850	20	6.48	126,700	69,850	55
Upper Cimarron River Basin (code 1104)	24,670	9	6.19	67,050	42,380	63
Lower Cimarron River Basin (code 1105)	20,240	7	12.92	58,610	38,370	65
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	28,180	10	10.77	83,080	54,900	66
Neosho-Verdigris River Basin (code 1107)	21,410	8	11.71	39,240	17,830	45
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	11,642	4	7.88	36,012	24,370	68
North Canadian including Beaver River Basin (code 1110)	18,820	7	5.13	62,180	43,360	70
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	11,200	4	32.99	18,280	7,080	39
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	17,550	6	4.66	58,580	41,030	70
Red-Washita-Pease-Lake Texoma Basin (code 1113)	31,330	11	7.91	90,470	59,140	65
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	8,260	3	12.24	13,180	4,920	37
Regional total	283,202	100	8.01	695,572	412,370	59

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 48 are due to the application of delivery ratios, which were used to simulate delivery of nitrogen from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.

Table 50. Average annual nitrogen loads ***delivered to watershed outlets*** (8-digit HUCs) in the Arkansas-White-Red Basin, baseline conservation condition, by source

Subregions	All sources	Cultivated cropland*	Hayland	Grazing land	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 pounds)			
Upper White River Basin (code 1101)	68,768	13,289	7,014	23,590	11,379	1,024	12,472
Upper Arkansas River Basin (code 1102)	26,685	19,770	0	1,360	1,362	3,392	800
Middle Arkansas River Basin (code 1103)	67,057	56,850	5	462	2,030	7,682	28
Upper Cimarron River Basin (code 1104)	26,579	24,672	0	165	1,561	168	12
Lower Cimarron River Basin (code 1105)	31,771	20,237	142	5,135	4,874	282	1,101
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	37,527	28,182	315	4,369	3,130	349	1,182
Neosho-Verdigris River Basin (code 1107)	80,726	21,421	8,115	30,605	14,057	2,960	3,568
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	25,804	11,649	840	5,124	3,615	970	3,606
North Canadian including Beaver River Basin (code 1110)	33,331	18,819	975	4,095	6,301	933	2,208
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	75,437	11,211	8,650	20,216	12,452	4,156	18,752
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	19,485	17,550	0	1,061	461	370	42
Red-Washita-Pease-Lake Texoma Basin (code 1113)	51,248	31,328	1,020	6,770	6,833	2,283	3,014
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	118,084	8,271	7,759	26,658	25,580	3,997	45,819
Regional total	662,501	283,248	34,835	129,611	93,635	28,565	92,606
				Percent of all sources			
Upper White River Basin (code 1101)	100	19	10	34	17	1	18
Upper Arkansas River Basin (code 1102)	100	74	0	5	5	13	3
Middle Arkansas River Basin (code 1103)	100	85	0	1	3	11	0
Upper Cimarron River Basin (code 1104)	100	93	0	1	6	1	0
Lower Cimarron River Basin (code 1105)	100	64	0	16	15	1	3
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	100	75	1	12	8	1	3
Neosho-Verdigris River Basin (code 1107)	100	27	10	38	17	4	4
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	100	45	3	20	14	4	14
North Canadian including Beaver River Basin (code 1110)	100	56	3	12	19	3	7
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	100	15	11	27	17	6	25
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	100	90	0	5	2	2	0
Red-Washita-Pease-Lake Texoma Basin (code 1113)	100	61	2	13	13	4	6
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	100	7	7	23	22	3	39
Regional total	100	43	5	20	14	4	14

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

Figure 95. Percentage by source of average annual nitrogen loads delivered to rivers and streams in the Arkansas-White-Red Basin, baseline conservation condition

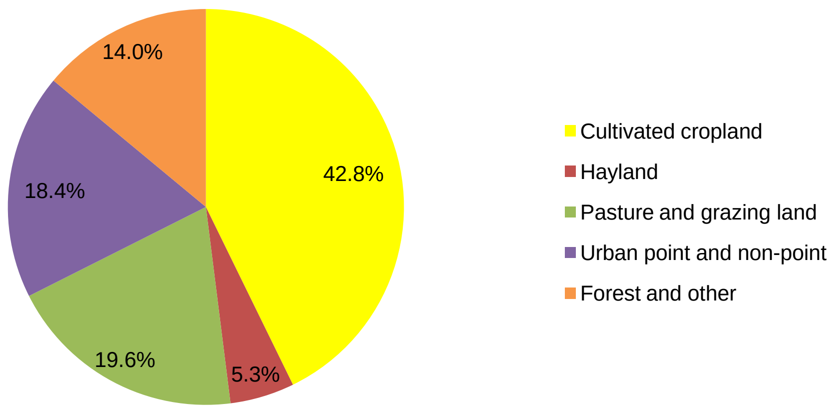


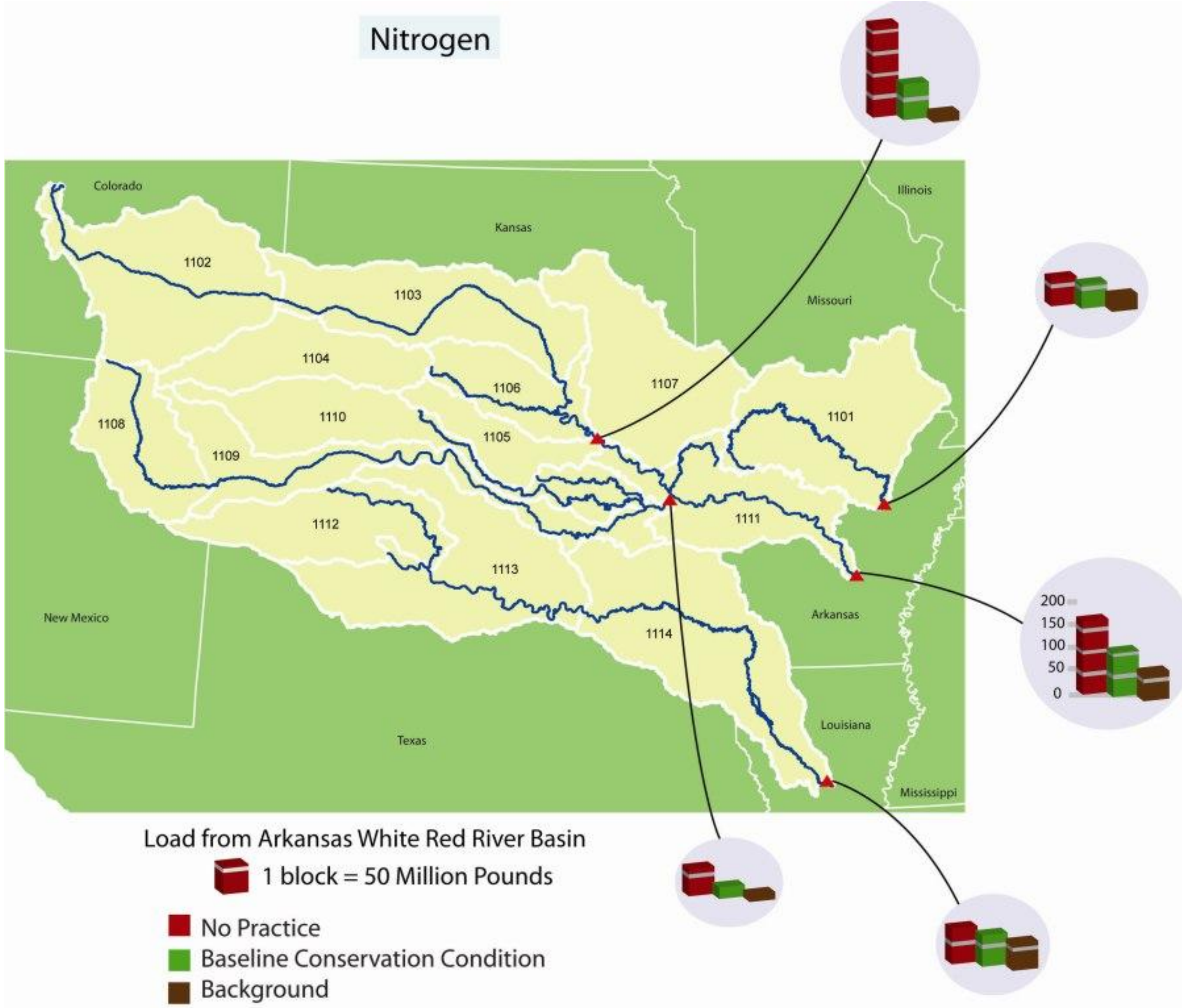
Table 51. Average annual ***instream nitrogen loads*** (all sources) for the Arkansas-White-Red Basin

Subregions	Baseline conservation condition: Load from all sources (1,000 pounds)	Baseline conservation condition: Background sources* (1,000 pounds)	Baseline conservation condition: Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 pounds	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
White River						
Load delivered from Upper White River (code 1101) to the Lower Mississippi River Basin	52,900	41,900	21	58,760	5,860	10
Arkansas River						
Load delivered from Cimarron River (code 11051) to Arkansas River at Lake Keystone	64,580	16,720	74	133,300	68,720	52
Load delivered from the Neosho-Verdigris Rivers (code 1107) to Arkansas River	37,340	28,230	24	44,610	7,270	16
Load delivered from Upper and Middle Arkansas River, including Salt Fork River (code 1106), to the Lower Arkansas River at Lake Keystone	87,910	20,260	77	209,700	121,790	58
Load delivered from Upper and Lower Canadian River (code 1109) to Arkansas River at Lake Eufaula	25,080	13,480	46	59,990	34,910	58
Load delivered from the North Canadian River, including Beaver River (code 1110), to Arkansas River at Lake Eufaula	18,900	9,243	51	49,850	30,950	62
Load delivered from Lower Arkansas River (code 1111) to the Lower Mississippi River Basin at the Robert Kerr Reservoir	102,600	60,230	41	167,700	65,100	39
Red River						
Load delivered from the Red River and its tributaries, including the Bayou Rigolette Basin (code 1114), to the Lower Mississippi River Basin	68,060	58,690	14	81,060	13,000	16
Total load delivered from Arkansas-White-Red Basin to Lower Mississippi River Basin**	223,560	160,820	28	307,520	83,960	27

***** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
** Sum of loads from the White River, Arkansas River, and Red River at the outlets to the Lower Mississippi River Basin.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Figure 96. Estimates of average annual instream nitrogen loads for the baseline conservation condition compared to the no-practice scenario for the Arkansas-White-Red Basin*



* Instream sediment loads (all sources) are shown for selected subregions corresponding to estimates presented in table 51.

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Total Phosphorus

Baseline condition. Model simulation results show that about 23.1 million pounds of phosphorus are lost from farm fields (edge-of-field) per year within the Arkansas-White-Red Basin (table 52) under conditions represented by the baseline conservation condition, which includes farming activities and conservation practices in use during the period 2003 to 2006. Of this, about 16.9 million pounds are delivered into rivers and streams per year, on average (table 53). About 0.48 pound per acre of phosphorus from cultivated cropland is delivered to rivers and streams per year, on average for the region (table 53).

The Middle Arkansas River Basin (code 1103) and the Neosho-Verdigris River Basin (code 1107) deliver the most nitrogen to rivers and streams within the region, averaging about 3 million pounds per year for each subregion, together accounting for over one-third of the load.

On a per-acre basis, phosphorus delivery to rivers and streams from cultivated cropland is highest for the Neosho-Verdigris River Basin (code 1107), averaging 1.69 pounds per acre (table 53). Per acre phosphorus delivery is lowest in the Upper Arkansas River Basin (code 1102), with 0.11 pound per acre.

Phosphorus delivered to rivers and streams from cultivated cropland represents about 20 percent of the total phosphorus load delivered from all sources in the region (table 54, fig. 97). This percentage ranges, however, from a low of 3 percent in the Red-Little-Saline-Sulphur Creek River Basin (code 1114) and the Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111) to a high of 75 percent in the Upper Cimarron River Basin (code 1104).

Cultivated cropland is the dominant source of phosphorus delivered to rivers and streams in four subregions—

- the Upper Cimarron River Basin (code 1104), where cultivated cropland is the source for 75 percent of the load delivered to rivers and streams,
- the Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112), where cultivated cropland is the source for 63 percent,
- the Middle Arkansas River Basin (code 1103), where cultivated cropland is the source for 59 percent, and
- the Arkansas River-Keystone including Salt Fork River Basin (code 1106), where cultivated cropland is the source for 49 percent.

In 9 of the subregions, grazing land (rangeland and pastureland) is the dominant source of phosphorus delivered to rivers and streams. Point sources are the dominant source of phosphorus in the Upper Arkansas River Basin (code 1102). Overall, rangeland and pastureland account for 55 percent of the phosphorus load delivered to rivers and streams in this region. Urban sources account for 18 percent, and other sources account for the remaining 7 percent (table 54).

Instream phosphorus loads delivered from all sources in the region to the Mississippi River, after accounting for instream deposition and transport processes, total about 30 million pounds per year, averaged over the 47 years of weather as simulated in the model (table 55, fig. 98). The Red River and tributaries are the source of most of this phosphorus, averaging about 15.7 million pounds per year. The White River averages 3.4 million pounds per year at the outlet, and the Arkansas River averages 11.1 million pounds per year at the outlet.

Of the total instream phosphorus load leaving the basin, about 14 percent is attributed to cultivated cropland sources in the model simulation (table 55). About 26 percent is attributed to cultivated cropland sources in the model simulation for the White River, 17 percent for the Arkansas River, and 9 percent for the Red River. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the “background” scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 55).

As previously noted, the Arkansas White Red Basin contains several reservoirs which reduce loads delivered to the Mississippi River. Some of the phosphorus load from the western and central portions of the basin is intercepted and trapped in these reservoirs on the Arkansas, Canadian, and Red Rivers.

Effects of conservation practices. Phosphorus loads delivered to streams and rivers would have been larger if soil erosion control and nutrient management practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of phosphorus from fields to rivers and streams by about 59 percent (table 53), on average. Reductions due to conservation practices vary throughout the region, ranging from a low of 36 percent for the Arkansas River-Keystone including Salt Fork River Basin (code 1106) to a high of 84 percent for the Upper Arkansas River Basin (code 1102).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of phosphorus from the Arkansas-White-Red Basin to the Lower Mississippi River Basin by about 17 percent overall (table 55, fig. 98). Without conservation practices, the total amount of phosphorus delivered to the Lower Mississippi River Basin would be larger by 6.1 million pounds per year—2.2 million pounds from the Arkansas River, 2.0 million pounds from the Red River, and 1.9 million pounds from the White River.

Table 52. Average annual phosphorus loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Arkansas-White-Red Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Upper White River Basin (code 1101)	1,763	8	2.00	4,456	2,693	60
Upper Arkansas River Basin (code 1102)	163	1	0.09	1,115	952	85
Middle Arkansas River Basin (code 1103)	3,429	15	0.39	9,178	5,749	63
Upper Cimarron River Basin (code 1104)	475	2	0.12	3,787	3,312	87
Lower Cimarron River Basin (code 1105)	1,578	7	1.01	3,137	1,559	50
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	2,614	11	1.00	4,991	2,377	48
Neosho-Verdigris River Basin (code 1107)	5,458	24	2.99	12,950	7,492	58
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	445	2	0.30	1,451	1,007	69
North Canadian including Beaver River Basin (code 1110)	576	2	0.16	2,778	2,202	79
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	628	3	1.85	1,576	948	60
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	1,251	5	0.33	4,738	3,487	74
Red-Washita-Pease-Lake Texoma Basin (code 1113)	3,504	15	0.88	7,620	4,116	54
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	1,206	5	1.79	2,852	1,646	58
Regional total	23,090	100	0.65	60,629	37,539	62

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.

Table 53. Average annual phosphorus loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Arkansas-White-Red Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Upper White River Basin (code 1101)	1,025	6	1.16	3,138	2,113	67
Upper Arkansas River Basin (code 1102)	196	1	0.11	1,258	1,062	84
Middle Arkansas River Basin (code 1103)	3,018	18	0.34	6,488	3,470	53
Upper Cimarron River Basin (code 1104)	586	3	0.15	3,084	2,498	81
Lower Cimarron River Basin (code 1105)	1,127	7	0.72	2,008	881	44
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	2,092	12	0.80	3,288	1,196	36
Neosho-Verdigris River Basin (code 1107)	3,084	18	1.69	7,162	4,078	57
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	413	2	0.28	1,182	769	65
North Canadian including Beaver River Basin (code 1110)	608	4	0.17	2,495	1,887	76
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	368	2	1.08	1,063	695	65
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	1,191	7	0.32	3,697	2,506	68
Red-Washita-Pease-Lake Texoma Basin (code 1113)	2,653	16	0.67	4,849	2,196	45
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	570	3	0.84	1,749	1,179	67
Regional total	16,931	100	0.48	41,461	24,530	59

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 52 are due to the application of delivery ratios, which were used to simulate delivery of phosphorus from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.

Table 54. Average annual phosphorus loads ***delivered to watershed outlets*** (8-digit HUCs***)*** in the Arkansas-White-Red Basin, baseline conservation condition, by source

Subregions	All sources	Cultivated cropland*	Hayland	Grazing land	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 pounds)			
Upper White River Basin (code 1101)	4,604	1,026	429	1,973	322	403	450
Upper Arkansas River Basin (code 1102)	1,675	196	0	29	10	1,438	2
Middle Arkansas River Basin (code 1103)	5,076	3,018	0	134	42	1,882	0
Upper Cimarron River Basin (code 1104)	783	586	0	88	16	93	0
Lower Cimarron River Basin (code 1105)	4,241	1,127	1	2,832	147	119	15
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	4,310	2,092	1	1,969	91	140	16
Neosho-Verdigris River Basin (code 1107)	14,827	3,085	386	9,391	749	963	254
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	3,339	413	117	2,245	89	402	72
North Canadian including Beaver River Basin (code 1110)	3,330	608	19	1,958	291	395	59
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	11,895	369	1,076	6,756	1,205	1,641	848
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	1,900	1,191	0	558	20	127	4
Red-Washita-Pease-Lake Texoma Basin (code 1113)	8,287	2,653	30	4,726	208	604	67
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	19,777	572	759	13,165	1,647	1,723	1,911
Regional total	84,044	16,937	2,819	45,823	4,837	9,930	3,699
				Percent of all sources			
Upper White River Basin (code 1101)	100	22	9	43	7	9	10
Upper Arkansas River Basin (code 1102)	100	12	0	2	1	86	0
Middle Arkansas River Basin (code 1103)	100	59	0	3	1	37	0
Upper Cimarron River Basin (code 1104)	100	75	0	11	2	12	0
Lower Cimarron River Basin (code 1105)	100	27	0	67	3	3	0
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	100	49	0	46	2	3	0
Neosho-Verdigris River Basin (code 1107)	100	21	3	63	5	6	2
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	100	12	3	67	3	12	2
North Canadian including Beaver River Basin (code 1110)	100	18	1	59	9	12	2
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	100	3	9	57	10	14	7
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	100	63	0	29	1	7	0
Red-Washita-Pease-Lake Texoma Basin (code 1113)	100	32	0	57	3	7	1
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	100	3	4	67	8	9	10
Regional total	100	20	3	55	6	12	4

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

Figure 97. Percentage by source of average annual phosphorus loads delivered to rivers and streams in the Arkansas-White-Red Basin, baseline conservation condition

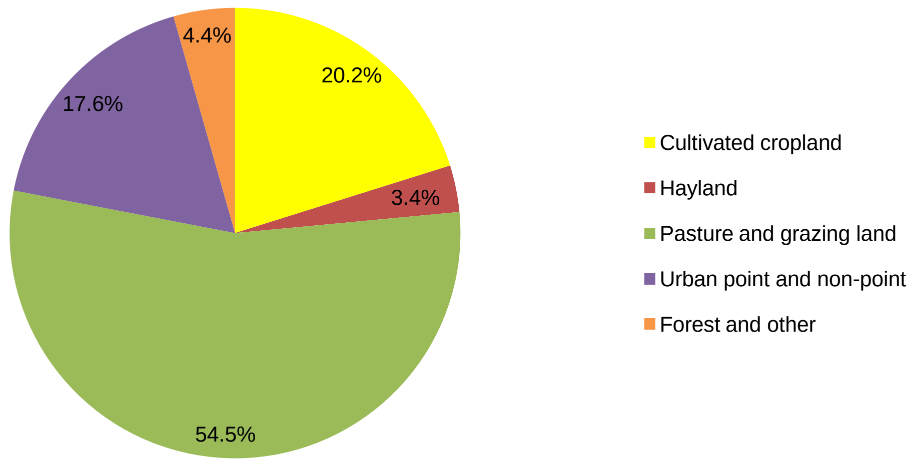


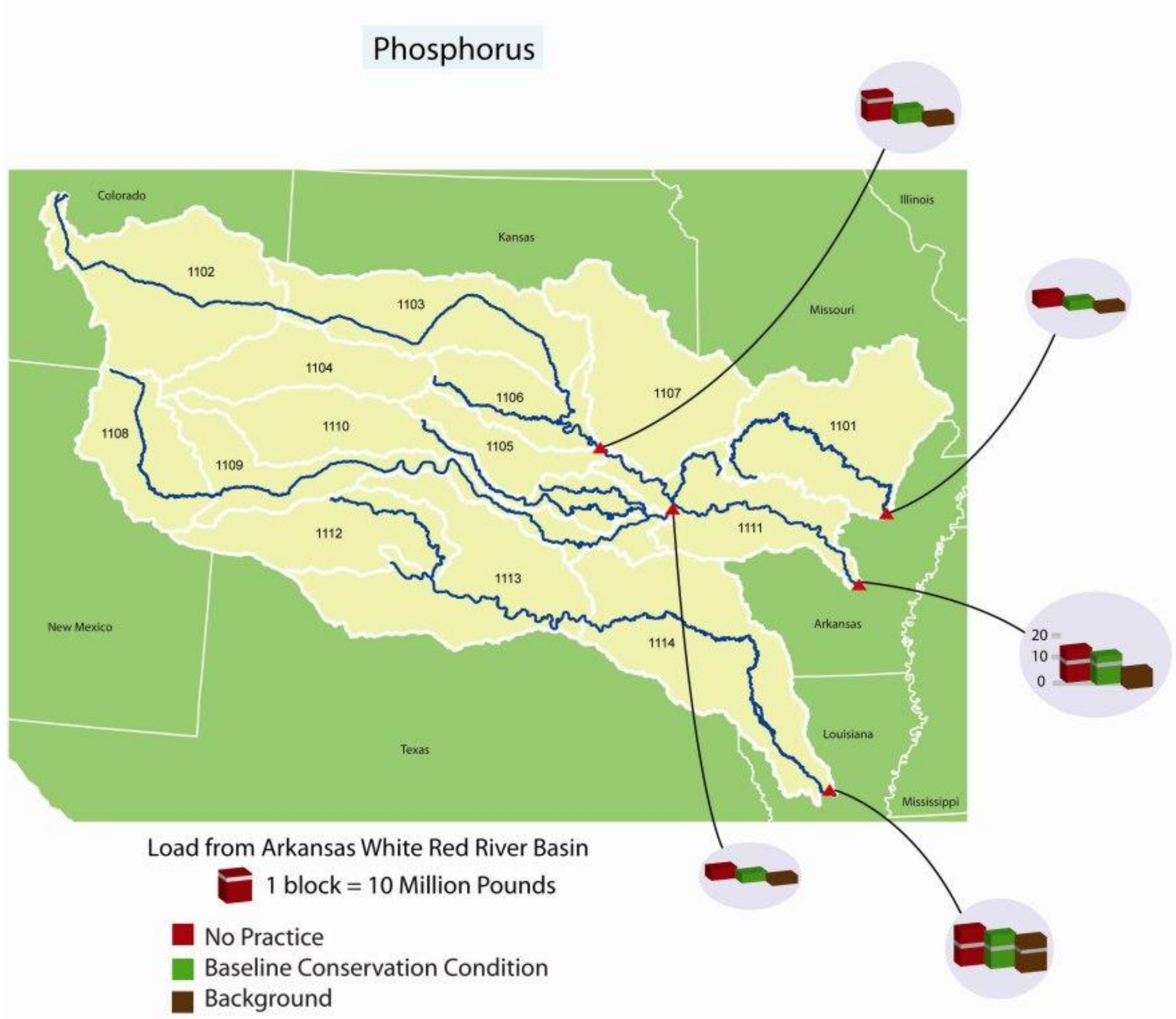
Table 55. Average annual ***instream phosphorus loads*** (all sources) for the Arkansas-White-Red Basin

Subregions	Baseline conservation condition: Load from all sources (1,000 pounds)	Baseline conservation condition: Background sources* (1,000 pounds)	Baseline conservation condition: Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
White River						
Load delivered from Upper White River (code 1101) to the Lower Mississippi River Basin	3,416	2,532	26	5,329	1,913	36
Arkansas River						
Load delivered from Cimarron River (code 11051) to Arkansas River at Lake Keystone	4,908	3,469	29	7,345	2,437	33
Load delivered from the Neosho-Verdigris Rivers (code 1107) to Arkansas River	6,300	5,220	17	7,528	1,228	16
Load delivered from Upper and Middle Arkansas River, including Salt Fork River (code 1106), to the Lower Arkansas River at Lake Keystone	7,429	4,057	45	10,580	3,151	30
Load delivered from Upper and Lower Canadian River (code 1109) to Arkansas River at Lake Eufaula	3,054	2,610	15	4,013	959	24
Load delivered from the North Canadian River, including Beaver River (code 1110), to Arkansas River at Lake Eufaula	1,752	1,504	14	2,566	814	32
Load delivered from Lower Arkansas River (code 1111) to the Lower Mississippi River Basin at the Robert Kerr Reservoir	11,080	9,199	17	13,230	2,150	16
Red River						
Load delivered from the Red River and its tributaries, including the Bayou Rigolette Basin (code 1114), to the Lower Mississippi River Basin	15,730	14,300	9	17,770	2,040	11
Total load delivered from Arkansas-White-Red Basin to Lower Mississippi River Basin**	30,226	26,031	14	36,329	6,103	17

***** “Background sources” represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
** Sum of loads from the White River, Arkansas River, and Red River at the outlets to the Lower Mississippi River Basin.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Figure 98. Estimates of average annual instream phosphorus loads for the baseline conservation condition compared to the no-practice scenario for the Arkansas-White-Red Basin*



* Instream sediment loads (all sources) are shown for selected subregions corresponding to estimates presented in table 55.

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Assessment of Potential Water Quality Gains from Further Conservation Treatment

The field-level model results for the scenarios with additional erosion control practices and nutrient management (chapter 6) were used with the HUMUS/SWAT model to determine the potential for further reductions in loads delivered from cultivated cropland to rivers and streams and instream loads throughout the region with additional conservation treatment.

Percent reductions relative to the baseline conservation condition were estimated for each of two scenarios—

1. Treatment of the 1.3 million critical undertreated acres, which have a high need for additional treatment for one or more resource concerns (4 percent of cropped acres in the region), and
2. Treatment of the 10.4 million acres with a high or moderate need for additional treatment for one or more resource concerns, including the 1.3 million critical undertreated acres (34 percent of cropped acres in the region).

Acres not receiving treatment in the simulation retained baseline values. Thus, the distribution of undertreated acres within the region influences the extent to which individual subregions benefit from additional treatment, since additional treatment was simulated only for the undertreated acres. The distribution of undertreated acres within the Arkansas-White-Red Basin is shown in chapter 5, tables 26–30.

Model simulations showed that if the 1.3 million **critical** undertreated acres were fully treated with the appropriate soil erosion control and nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the Arkansas-White-Red Basin would be reduced by, relative to the baseline conservation condition (tables 56, 58, and 60)—

- 3 percent for sediment,
- 7 percent for nitrogen, and
- 2 percent for phosphorus.

Percent reductions were usually highest in subregions with the highest proportion of critical undertreated acres within the subregion.

Model simulations further showed that if **all** of the undertreated acres (an additional 9.1 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the watershed would be reduced, relative to the baseline conservation condition (tables 56, 58, and 60)—

- 25 percent for sediment,
- 21 percent for nitrogen, and
- 13 percent for phosphorus.

These reductions in loads delivered to rivers and streams from cultivated cropland would reduce the total loads delivered from the region to the Lower Mississippi River Basin, although reductions would be small in subregions with few cultivated cropland acres and where other land uses were the dominant source of sediment and nutrients.

For example, treatment of only the 1.3 million critically under-treated acres (acres with a high need for additional treatment) would result in neglible reductions in the total instream sediment and nutrient loads in this region (tables 57, 59, and 61).

If **all** the undertreated acres (10.4 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, total loads delivered to the Lower Mississippi River Basin from all sources would be reduced, relative to the baseline conservation condition (tables 57, 59, and 61)—

- 1 percent for sediment,
- 5 percent for nitrogen, and
- 2 percent for phosphorus.

As shown in table 57, sediment loads delivered from the region to the Lower Mississippi River Basin would be close to "background" levels after additional conservation treatment of the undertreated acres, indicating that sediment contributions from cultivated cropland would be nearly negligible. The background scenario represents loads that would be expected if no acres in the watershed were cultivated. Background sediment loads delivered to the Lower Mississippi River Basin total 19.6 million tons (table 57) compared to 21.3 million tons delivered from all sources after treating all undertreated cropped acres with appropriate conservation treatment, leaving only about 1.7 million tons originating from cultivated cropland.

Using similar calculations, if all undertreated acres were fully treated throughout the region, instream nutrient loads originating from cultivated cropland delivered to the Lower Mississippi River Basin would be reduced to about 63 million pounds for nitrogen and 4.2 million pounds for phosphorus (tables 59 and 61).

To reduce loads further would require additional conservation treatment of the remaining 20.1 million cropped acres with a low level of conservation treatment need, which would have a low per-acre benefit as shown in table 39.

Table 56. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **sediment source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Arkansas-White-Red Basin

	Baseline conservation condition	Treatment of 1.3 million critical undertreated acres		Treatment of all 10.4 million undertreated acres	
Subregion	Average annual load (1,000 tons)	Average annual load (1,000 tons)	Percent reduction	Average annual load (1,000 tons)	Percent reduction
Upper White River Basin (code 1101)	389	389	0	274	30
Upper Arkansas River Basin (code 1102)	113	41	64	28	76
Middle Arkansas River Basin (code 1103)	1,691	1,669	1	1,430	15
Upper Cimarron River Basin (code 1104)	313	306	2	185	41
Lower Cimarron River Basin (code 1105)	320	320	0	252	21
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	541	541	0	502	7
Neosho-Verdigris River Basin (code 1107)	672	672	0	568	16
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	171	170	1	139	19
North Canadian including Beaver River Basin (code 1110)	315	310	2	270	14
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	143	143	0	88	39
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	830	794	4	413	50
Red-Washita-Pease-Lake Texoma Basin (code 1113)	919	881	4	637	31
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	494	494	0	430	13
Regional total	6,912	6,731	3	5,215	25

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Table 57. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream sediment loads*** from all sources delivered to the Mississippi River from the Arkansas-White-Red Basin

	Baseline conservation condition		Treatment of 1.3 million critical undertreated acres		Treatment of all 10.4 million undertreated acres	
Subregions	Average annual load from all sources (1,000 tons)	Average annual load from background sources* (1,000 tons)	Average annual load (1,000 tons)	Percent reduction	Average annual load (1,000 tons)	Percent reduction
White River						
Load delivered from Upper White River (code 1101) to the Lower Mississippi River Basin	1,589	1,430	1,589	0	1,535	4
Arkansas River						
Load delivered from Cimarron River (code 11051) to Arkansas River at Lake Keystone	3,411	2,481	3,392	1	3,363	1
Load delivered from the Neosho-Verdigris Rivers (code 1107) to Arkansas River	2,863	2,738	2,863	0	2,860	0
Load delivered from Upper and Middle Arkansas River, including Salt Fork River (code 1106), to the Lower Arkansas River at Lake Keystone	3,487	2,333	3,481	0	3,466	1
Load delivered from Upper and Lower Canadian River (code 1109) to Arkansas River at Lake Eufaula	3,623	3,277	3,621	0	3,613	0
Load delivered from the North Canadian River, including Beaver River (code 1110), to Arkansas River at Lake Eufaula	1,081	926	1,080	0	1,077	0
Load delivered from Lower Arkansas River (code 1111) to the Lower Mississippi River Basin at the Robert Kerr Reservoir	1,173	1,014	1,171	0	1,150	2
Red River						
Load delivered from the Red River and its tributaries, including the Bayou Rigolette Basin (code 1114), to the Lower Mississippi River Basin	18,580	17,110	18,580	0	18,450	1
Total load delivered from Arkansas-White-Red Basin to Lower Mississippi River Basin**	21,342	19,554	21,340	0	21,135	1

* "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

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Table 58. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **nitrogen source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Arkansas-White-Red Basin

	Baseline conservation condition	Treatment of 1.3 million critical undertreated acres		Treatment of all 10.4 million undertreated acres	
Subregion	Average annual load (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Upper White River Basin (code 1101)	13,280	13,280	0	11,990	10
Upper Arkansas River Basin (code 1102)	19,770	3,451	83	3,497	82
Middle Arkansas River Basin (code 1103)	56,850	56,550	1	49,330	13
Upper Cimarron River Basin (code 1104)	24,670	23,460	5	18,430	25
Lower Cimarron River Basin (code 1105)	20,240	20,240	0	18,650	8
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	28,180	28,180	0	23,750	16
Neosho-Verdigris River Basin (code 1107)	21,410	21,410	0	19,070	11
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	11,642	11,322	3	9,786	16
North Canadian including Beaver River Basin (code 1110)	18,820	18,230	3	13,460	28
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	11,200	11,200	0	5,536	51
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	17,550	17,330	1	14,340	18
Red-Washita-Pease-Lake Texoma Basin (code 1113)	31,330	30,940	1	28,050	10
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	8,260	8,260	0	7,946	4
Regional total	283,202	263,853	7	223,835	21

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Table 59. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream nitrogen loads*** from all sources delivered to the Mississippi River from the Arkansas-White-Red Basin

	Baseline conservation condition		Treatment of 1.3 million critical undertreated acres		Treatment of all 10.4 million undertreated acres	
Subregions	Average annual load from all sources (1,000 pounds)	Average annual load from background sources* (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
White River						
Load delivered from Upper White River (code 1101) to the Lower Mississippi River Basin	52,900	41,900	52,900	0	51,740	2
Arkansas River						
Load delivered from Cimarron River (code 11051) to Arkansas River at Lake Keystone	64,580	16,720	64,360	0	57,340	13
Load delivered from the Neosho-Verdigris Rivers (code 1107) to Arkansas River	37,340	28,230	37,340	0	36,290	3
Load delivered from Upper and Middle Arkansas River, including Salt Fork River (code 1106), to the Lower Arkansas River at Lake Keystone	87,910	20,260	87,580	0	78,050	13
Load delivered from Upper and Lower Canadian River (code 1109) to Arkansas River at Lake Eufaula	25,080	13,480	24,790	1	22,500	11
Load delivered from the North Canadian River, including Beaver River (code 1110), to Arkansas River at Lake Eufaula	18,900	9,243	18,580	2	16,190	17
Load delivered from Lower Arkansas River (code 1111) to the Lower Mississippi River Basin at the Robert Kerr Reservoir	102,600	60,230	102,300	0	93,180	10
Red River						
Load delivered from the Red River and its tributaries, including the Bayou Rigolette Basin (code 1114), to the Lower Mississippi River Basin	68,060	58,690	68,030	0	67,340	1
Total load delivered from Arkansas-White-Red Basin to Lower Mississippi River Basin**	223,560	160,820	223,230	0	212,260	5

* "Background sources" represent loads that would be expected if no acres in the watershed were cultivated.

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Table 60. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **phosphorus source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Arkansas-White-Red Basin

	Baseline conservation condition	Treatment of 1.3 million critical undertreated acres		Treatment of all 10.4 million undertreated acres	
Subregion	Average annual load (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Upper White River Basin (code 1101)	1,025	1,025	0	916	11
Upper Arkansas River Basin (code 1102)	196	55	72	50	74
Middle Arkansas River Basin (code 1103)	3,018	2,987	1	2,677	11
Upper Cimarron River Basin (code 1104)	586	565	4	424	28
Lower Cimarron River Basin (code 1105)	1,127	1,127	0	1,073	5
Arkansas River-Keystone including Salt Fork River Basin (code 1106)	2,092	2,092	0	1,935	8
Neosho-Verdigris River Basin (code 1107)	3,084	3,084	0	2,719	12
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)	413	412	0	376	9
North Canadian including Beaver River Basin (code 1110)	608	600	1	575	5
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)	368	368	0	221	40
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)	1,191	1,163	2	946	21
Red-Washita-Pease-Lake Texoma Basin (code 1113)	2,653	2,556	4	2,185	18
Red-Little-Saline-Sulphur Creek River Basin (code 1114)	570	570	0	570	0
Regional total	16,931	16,604	2	14,668	13

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Table 61. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream phosphorus loads*** from all sources delivered to the Mississippi River from the Arkansas-White-Red Basin

	Baseline conservation condition		Treatment of 1.3 million critical undertreated acres		Treatment of all 10.4 million undertreated acres	
Subregions	Average annual load from all sources (1,000 pounds)	Average annual load from background sources* (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
White River						
Load delivered from Upper White River (code 1101) to the Lower Mississippi River Basin	3,416	2,532	3,416	0	3,315	3
Arkansas River						
Load delivered from Cimarron River (code 11051) to Arkansas River at Lake Keystone	4,908	3,469	4,906	0	4,745	3
Load delivered from the Neosho-Verdigris Rivers (code 1107) to Arkansas River	6,300	5,220	6,300	0	6,157	2
Load delivered from Upper and Middle Arkansas River, including Salt Fork River (code 1106), to the Lower Arkansas River at Lake Keystone	7,429	4,057	7,420	0	7,202	3
Load delivered from Upper and Lower Canadian River (code 1109) to Arkansas River at Lake Eufaula	3,054	2,610	3,051	0	3,023	1
Load delivered from the North Canadian River, including Beaver River (code 1110), to Arkansas River at Lake Eufaula	1,752	1,504	1,749	0	1,738	1
Load delivered from Lower Arkansas River (code 1111) to the Lower Mississippi River Basin at the Robert Kerr Reservoir	11,080	9,199	11,080	0	10,840	2
Red River						
Load delivered from the Red River and its tributaries, including the Bayou Rigolette Basin (code 1114), to the Lower Mississippi River Basin	15,730	14,300	15,720	0	15,560	1
Total load delivered from Arkansas-White-Red Basin to Lower Mississippi River Basin**	30,226	26,031	30,216	0	29,715	2

* "Background sources" represent loads that would be expected if no acres in the watershed were cultivated..

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Chapter 8
Summary of Findings

Field Level Assessment

The Baseline Conservation Condition

The baseline conservation condition represents model simulations of erosion, changes in soil organic carbon, and losses from farm fields of nitrogen, phosphorus, and pesticides through various loss pathways. Wind erosion accounts for most of the soil and nutrient losses from farm fields in this region. While conservation practices in use during 2003–06 have been modestly effective in reducing wind erosion, model simulations show that rates can exceed 4 tons per acre for up to 23 percent of cropped acres in the region, and exceed 2 tons per acre for up to 35 percent of the acres. About 63 percent of total phosphorus lost from fields and 23 percent of total nitrogen loss is with windborne sediment.

Wind erosion is much higher in the western portion of the basin, averaging 2.8 tons per acre per year. About 82 percent of phosphorus and 32 percent of nitrogen in this portion of the basin are lost from farm fields with windborne sediment. Wind erosion in the eastern portion of the region averages 1.0 ton per acre, which is still high enough to be of concern in some years; 60 percent of total phosphorus loss from farm fields and 11 percent of total nitrogen loss in this portion of the basin are with windborne sediment.

Losses of sediment, nutrients, and pesticides with water are also important for some acres in the region, mostly in the eastern portion of the basin.

Evaluation of Practices in Use

The first Federal conservation efforts on cropland were focused primarily on water management and soil erosion control. Structural practices such as waterways, terraces, and diversions were installed along with supporting practices such as contour farming and stripcropping. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres—highly erodible land. This legislation created the Conservation Reserve Program as a mechanism for establishing long-term conserving cover on the most erodible cropland through multi-year contracts with landowners. More recently, the focus has shifted from soil conservation and sustainability to a broader goal of reducing all pollution impacts associated with agricultural production. Prominent among new concerns are the environmental effects of nutrient and pesticide export from farm fields.

Given the long history of conservation in the Arkansas-White-Red Basin, it is not surprising to find that most cropped acres in the region have evidence of some kind of conservation practice, especially erosion control practices. The conservation practice information collected during the study was used to assess the extent of conservation practice use. Key findings are the following.

- Structural practices for controlling water erosion are in use on 46 percent of cropped acres, distributed equally among highly erodible and non-highly erodible acres. Structural practice use is more prevalent in the eastern portion of the basin, where 59 percent of cropped acres, including 66 percent of highly erodible land, have one or more structural conservation practices in use.
- Fifty-eight percent of the cropped acres meet criteria for either no-till (14 percent) or mulch till (44 percent). Two-thirds of cropped acres had evidence of some kind of reduced tillage on at least one crop.
- About 31 percent of cropped acres are gaining soil organic carbon, including 29 percent of cropped acres in the eastern portion of the region and 32 percent in the western portion.
- Producers use either residue and tillage management practices or structural practices, or both, on 87 percent of the acres.
- Nutrient management practices are widely used on cropped acres in the Arkansas-White-Red Basin.
    - 78 percent of cropped acres meet criteria for timing of nitrogen applications on all crops and 65 percent of cropped acres meet criteria for timing of phosphorus applications on all crops.
    - 62 percent of cropped acres meet criteria for method of nitrogen application on all crops and 59 percent meet criteria for method of phosphorus application on all crops.
    - 59 percent of cropped acres meet criteria for nitrogen application rate on all crops and 40 percent meet criteria for phosphorus application rates for the full crop rotation.
- Although most cropped acres meet nutrient management criteria for rate, timing, or method, fewer acres meet criteria for all three:
    - 33 percent of cropped acres meet all criteria for nitrogen applications, including acres with no nitrogen applied,
    - 29 percent of cropped acres meet all criteria for phosphorus applications, including acres with no phosphorus applied, and
    - 25 percent of cropped acres meet criteria for *both* phosphorus and nitrogen.
- During the 2003–06 period of data collection cover crops were used on less than 1 percent of the acres in the region.
- An Integrated Pest Management (IPM) indicator showed that only about 5 percent of the acres were being managed at a relatively high level of IPM.
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of about 6 million acres in the region, of which 49 percent is highly erodible land.

Effects of Conservation Practices

Model simulation results show that, for cropped acres in the region, *on average* conservation practices have—

- Reduced surface water runoff in the region by about 0.8 inch per year averaged over all acres, representing a 26-percent reduction;
- Reduced surface water runoff by 3.4 inches per year, on average, for irrigated acres and 0.2 inch per year for non-irrigated acres;
- Reduced wind erosion by 1.37 ton per acre in the western portion of the basin and 0.27 ton per acre in the eastern portion, representing a 31-percent reduction for the entire region;
- Reduced average sediment loss from water erosion in the eastern portion of the basin by an average of 0.73 ton per acre per year, representing a 51-percent reduction, and by an average of 0.42 ton per acre per year in the western portion of the basin, representing a 76-percent reduction;
- Reduced total nitrogen loss (volatilization, denitrification, windborne sediment, surface runoff, and subsurface flow losses) by an average of 23.7 pounds per acre per year, representing a 46-percent reduction;
  - Reduced nitrogen lost with windborne sediment in the western portion of the basin by an average of 3.3 pounds per acre per year, representing an average reduction of 28 percent, and by 0.9 pound per acre per year in the eastern portion, representing a 22-percent reduction.
  - Reduced nitrogen loss in subsurface flows by an average of 12.4 pounds per acre (54-percent reduction) in the western portion of the basin and by an average of 19 pounds per acre in the eastern portion (60-percent reduction);
  - Reduced nitrogen lost with surface runoff by 3.4 pounds per acre per year in the eastern portion of the basin, representing a 42-percent reduction, and reduced nitrogen lost with surface runoff in the western portion by 2.1 pounds per acre, representing a 65-percent reduction;
- Reduced total phosphorus loss by an average of 2.1 pounds per acre per year, representing a 47-percent reduction;
  - Reduced phosphorus lost with windborne sediment in the western portion of the basin by an average of 1.24 pounds per acre per year, representing an average reduction of 42 percent, and by an average of 0.5 pound per acre per year in the eastern portion, representing an average reduction of 33 percent;
  - Reduced phosphorus lost to surface water in the eastern portion of the basin by an average of 1.95 pounds per acre per year, representing an average reduction of 54 percent, and by an average of 0.67 pound per acre per year in the western portion, representing an average reduction of 64 percent; and
- Reduced pesticide loss from fields to surface water by 44 percent, resulting in:
  - a 35-percent reduction in the edge-of-field surface water pesticide risk indicator (all pesticides combined) for aquatic ecosystems;
  - a 38-percent reduction in the edge-of-field surface water pesticide risk indicator for humans, and
  - a 49-percent reduction in the edge-of-field groundwater pesticide risk indicator for humans.

Use of improved irrigation systems in the Arkansas-White-Red Basin increases irrigation efficiency from 54 percent in the no-practice scenario to 69 percent in the baseline scenario. This change in efficiency represents an annual decreased need for irrigation water of 6.7 inches per year where irrigation is used.

At 6 million acres, land in long-term conserving cover is an important part of the agricultural landscape in the Arkansas-White-Red Basin. The benefits of this conservation "practice" were estimated by simulating crop production on these acres without use of conservation practices. Model simulation results show that soil erosion and sediment loss have been almost completely eliminated for land in long-term conserving cover. Compared to a cropped condition without conservation practices, total nitrogen loss has been reduced by 79 percent, total phosphorus loss has been reduced by 98 percent, and soil organic carbon has been increased by an average of 81 pounds per acre per year.

Conservation Treatment Needs

The adequacy of conservation practices in use in the Arkansas-White-Red Basin for the time period 2003–06 was evaluated to identify conservation treatment needs for five resource concerns:

- wind erosion,
- sediment loss with water erosion,
- nitrogen lost with surface runoff (attached to sediment and in solution),
- nitrogen loss in subsurface flows, and
- phosphorus lost to surface water (includes soluble phosphorus in lateral flow, soluble phosphorus in surface water runoff, and phosphorus lost with waterborne sediment).

Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres to reduce field-level losses to acceptable levels. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Under-treated acres were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Three levels of treatment need were identified:

- Acres with a "high" level of need for conservation treatment consist of the most critical under-treated acres in the region. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients.

- Acres with a "moderate" level of need for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability and/or have more conservation practice use than acres with a high level of need. The treatment level required is not necessarily less, although it can be, but rather the sediment and nutrient losses are lower and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment.
- Acres with a "low" level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. While gains can be obtained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

Findings for the Arkansas-White-Red Basin indicate that—

- 4 percent of cropped acres (1.3 million acres) have a **high** level of need for additional conservation treatment,
- 30 percent of cropped acres (9.1 million acres) have a **moderate** level of need for additional conservation treatment, and
- 66 percent of cropped acres (20.1 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.

About two-thirds of the under-treated acres (acres with a "high" or "moderate" need for additional treatment) are in the western portion of the region.

The 1.3 million acres with a "high" level of need for conservation treatment lose (per acre per year, on average): 1 ton of sediment by water erosion; 6.9 pounds of phosphorus; and 50 pounds of nitrogen. Wind erosion averages 5.2 tons per acre per year for these acres.

The 9.1 million acres with a "moderate" level of need for conservation treatment lose (per acre per year, on average): 0.3 ton of sediment by water erosion; 2.4 pounds of phosphorus; and 33 pounds of nitrogen. Wind erosion averages 3.2 tons per acre per year for these acres.

Losses for the 20.1 million acres with a "low" level of need are small on a per-acre basis. These acres lose (per acre per year, on average): 0.3 ton of sediment by water erosion; 2.0 pounds of phosphorus; and 25 pounds of nitrogen. Wind erosion averages 1.5 tons per acre per year for these acres.

The most pervasive concern in the region is excessive rates of wind erosion during dry periods, including windborne losses of nitrogen and phosphorus. The percentage of cropped acres in the Arkansas-White-Red Basin with a high or moderate need for additional conservation treatment was determined to be—

- 2.5 percent for sediment loss (none with a high need for treatment),
- none for nitrogen loss with surface runoff,
- 1.6 percent for phosphorus lost to surface water (all with a high need for treatment),
- 9.2 percent for nitrogen loss in subsurface flows (0.2 percent with a high need for treatment), most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow, and
- 22.7 percent for wind erosion (2.5 percent with a high need for treatment).

Nearly all of the under-treated acres for wind erosion are in the western portion of the basin. Nearly all of the under-treated acres for nutrient and sediment loss with water are in the eastern portion of the basin.

Nearly 92 percent of the under-treated acres are under-treated for wind erosion (65.7 percent), nitrogen loss in subsurface flows (25.2 percent), or both (1.0 percent).

Under-treated acres in the Arkansas-White-Red Basin are distributed throughout all of the subregions, but are most concentrated in two subregions—

- the Upper Arkansas River Basin (code 1102), where 63 percent of cropped acres are under-treated, and
- the Red-Little-Saline-Sulphur Creek River Basin (code 1114), where 52 percent of cropped acres are under-treated.

Simulation of Additional Conservation Treatment

Model simulations were used to evaluate the potential gains from further conservation treatment in the Arkansas-White-Red Basin.

Three sets of additional conservation practices were simulated:

1. Additional wind and water erosion control practices consisting of four types of structural practices—overland flow practices, concentrated flow practices, edge-of-field mitigation—and wind erosion control practices.
2. Application of nitrogen and phosphorus using appropriate rate, timing, and method.
3. Increases in the efficiency of irrigation water application.

Model simulation was used to estimate the gains that could be attained when additional soil erosion control practices, nutrient management practices, and increased irrigation efficiencies are applied in this region:

- Conservation treatment of the 1.3 million acres with a high need for treatment would reduce sediment loss by an average of 0.93 ton per acre per year on those acres. In comparison, additional treatment of the 9.1 million acres with a moderate need for treatment would reduce sediment loss by about 0.28 ton per acre per year on those acres. Treatment of the remaining 20.1 million acres would also reduce sediment loss on those acres by about 0.28 ton per acre, on average.
- Conservation treatment of the 1.3 million critical under-treated acres would reduce wind erosion by an average of 2.6 tons per acre per year on those acres. In comparison, additional treatment of the 9.1 million acres with a moderate need for treatment would reduce wind erosion by about 1.5 tons per acre per year on those acres. Treatment of the remaining 20.1 million acres would

reduce wind erosion by only about 0.6 ton per acre, on average.

- Total nitrogen loss would be reduced by an average of 23.8 pounds per acre per year on the 1.3 million critical under-treated acres, compared to a reduction of 12.5 pounds per acre for the 9.1 million under-treated acres with a moderate need for treatment, and only 6.9 pounds per acre for the remaining 20.1 million acres.
- Nitrogen loss in subsurface flows would be reduced by an average of 13.2 pounds per acre per year on the 1.3 million critical under-treated acres, compared to a reduction of 5.9 pounds per acre for the 9.1 million acres with a moderate need for treatment. The reduction from treatment of the remaining 20.1 million acres would average only 2.0 pounds per acre.
- Total phosphorus loss would be reduced by an average of 5 pounds per acre per year on the 1.3 million critical under-treated acres, compared to a reduction of 1.3 pounds per acre for the 9.1 million under-treated acres with a moderate need for treatment and only 1 pound per acre for the remaining 20.1 million acres.

Compared to the baseline conservation condition, treating the 10.4 million under-treated acres (34 percent of cropped acres in the region) with soil erosion control practices *and* nutrient management practices would, for the region as a whole—

- reduce sediment loss averaged over all cropped acres in the region by 36 percent;
- reduce wind erosion averaged over all cropped acres in the region by 26 percent,
- reduce total nitrogen loss averaged over all cropped acres in the region by 17 percent:
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) averaged over all cropped acres in the region by 21 percent, and
  - reduce nitrogen loss in subsurface flows averaged over all cropped acres in the region by 21 percent; and
- reduce phosphorus lost to surface water averaged over all cropped acres in the region by 21 percent.

The bulk of the potential field-level savings from conservation treatment, relative to losses simulated for the no-practice scenario, have been achieved in this region. The percent of potential savings represented by practices in use in 2003–06 are: 64 percent for sediment, 72 percent for nitrogen, and 63 percent for phosphorus. By treating all 10.4 million under-treated acres in the region with additional erosion control and nutrient management practices, an additional 15 percent in savings would be attained for sediment, 14 percent for nitrogen, and 17 percent for phosphorus. To achieve 100 percent of potential savings (i.e., an additional 22 percent for sediment, 19 percent for phosphorus, and 14 percent for nitrogen), additional conservation treatment for the remaining 20.1 million acres with a low need for additional treatment would be required, which would result in very small conservation gains on a per-acre basis.

Conservation Practice Effects on Water Quality

Reductions in field-level losses due to conservation practices, including land in long-term conserving cover, translate into reductions in loadings to streams and rivers in the region. Transport of sediment, nutrients, and pesticides from farm fields to streams and rivers involves a variety of processes and time-lags, and not all of the potential pollutants leaving fields contribute to instream loads.

Cultivated cropland represents about 23 percent of the land base (excluding water) in the Arkansas-White-Red Basin. At the 2003–06 level of conservation practice use, cultivated cropland delivered a disproportionate amount of sediment and nitrogen to rivers and streams and ultimately to the Lower Mississippi River Basin. Of the total loads delivered to rivers and streams from all sources, cultivated cropland is the source for 30 percent of the sediment and 43 percent of the nitrogen. Cultivated cropland is the source for 20 percent of the phosphorus delivered to rivers and streams, about equal to the land base proportion.

Figures 99, 100, and 101 summarize the extent to which conservation practices on cultivated cropland acres have reduced, and can further reduce, sediment, nitrogen, and phosphorus loads in the Arkansas-White-Red Basin, on the basis of the model simulations.

In each figure, the top map shows delivery from cultivated cropland to rivers and streams within the basin and the bottom map shows delivery from all sources to the Lower Mississippi River Basin after accounting for losses and gains through instream processes during transport through the Arkansas-White-Red Basin.

The effects of practices in use during 2003–06 are seen by contrasting loads for the baseline conservation condition to loads for the no-practice scenario.

The effects of additional conservation treatment on loads are seen by contrasting the loads for the baseline condition to either—

1. loads for treatment of acres with a “high” level of treatment need (critical under-treated acres, 1.3 million acres), or
2. loads for treatment of all undertreated acres (10.4 million acres with either a “high” or “moderate” level of treatment need).

Background levels, representing loads that would be expected if no acres in the watershed were cultivated, are also shown in the bar charts. These estimates simulate a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. Background loads also include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

Sediment loss

In figure 99, the top map shows that the use of conservation practices has reduced ***sediment loads delivered from cropland to rivers and streams*** within the basin by 64 percent from conditions that would be expected without conservation practices. Application of additional conservation practices on acres with a "high" level of treatment need (critical under-treated acres) would reduce baseline sediment loads delivered to rivers and streams by 3 percent. Treating ALL undertreated acres (acres with either a "high" or "moderate" need for treatment) would reduce baseline sediment loads delivered to rivers and streams within the basin by 25 percent.

The bottom map shows that the use of conservation practices on cropland in the Arkansas-White-Red Basin has reduced ***sediment loads delivered to the Lower Mississippi River Basin from all sources*** by 5 percent from conditions that would be expected without conservation practices. Treating ALL undertreated acres (acres with either a "high" or "moderate" need for treatment) would reduce baseline sediment loads delivered to the Lower Mississippi River Basin by 1 percent.

Total nitrogen loss

In figure 100, the top map shows that the use of conservation practices has reduced ***total nitrogen loads delivered from cropland to rivers and streams*** within the basin by 59 percent from conditions that would be expected without conservation practices. Application of additional conservation practices on acres with a "high" level of treatment need would reduce baseline total nitrogen loads delivered to rivers and streams within the basin by 7 percent. Treating ALL undertreated acres (acres with either a "high" or "moderate" need for treatment) would reduce baseline nitrogen loads delivered to rivers and streams within the basin by 21 percent.

The bottom map shows that the use of conservation practices on cropland in the Arkansas-White-Red Basin has reduced ***total nitrogen loads delivered to the Lower Mississippi River Basin from all sources*** by 27 percent from conditions that would be expected without conservation practices. Treating ALL undertreated acres (acres with either a "high" or "moderate" need for treatment) would reduce baseline nitrogen loads delivered to the Lower Mississippi River Basin by 5 percent.

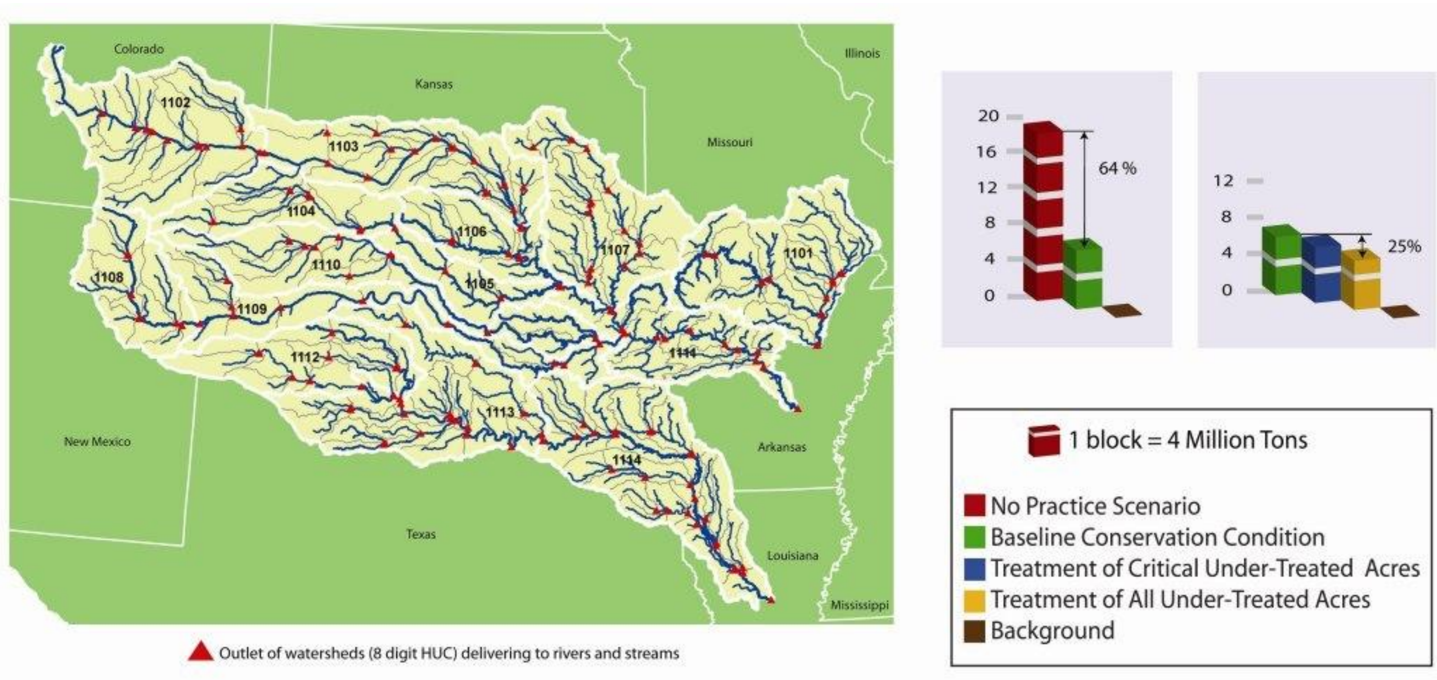
Total phosphorus loss

In figure 101, the top map shows that the use of conservation practices has reduced ***total phosphorus loads delivered from cropland to rivers and streams*** within the basin by 59 percent from conditions that would be expected without conservation practices. Application of additional conservation practices on acres with a "high" level of treatment need would reduce baseline total phosphorus loads delivered to rivers and streams by 3 percent. Treating ALL undertreated acres (acres with either a "high" or "moderate" need for treatment) would reduce baseline phosphorus loads delivered to rivers and streams within the basin by 13 percent.

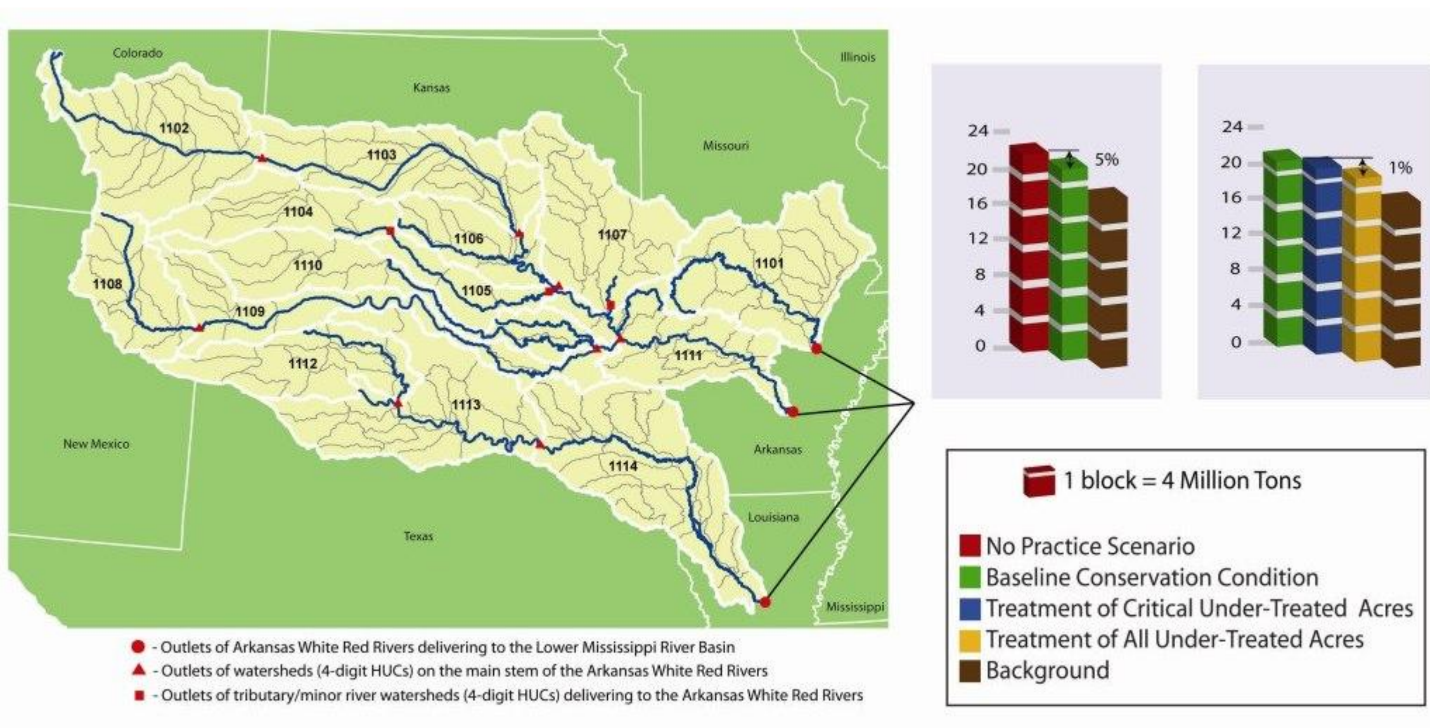
The bottom map shows that the use of conservation practices on cropland in the Arkansas-White-Red Basin has reduced ***total phosphorus loads delivered to the Lower Mississippi River Basin from all sources*** by 17 percent from conditions that would be expected without conservation practices. Treating ALL undertreated acres (acres with either a "high" or "moderate" need for treatment) would reduce baseline phosphorus loads delivered to the Lower Mississippi River Basin by 2 percent.

Figure 99. Summary of the effects of conservation practices on sediment loads in the Arkansas-White-Red Basin

Sediment delivered from cultivated cropland to rivers and streams in the Arkansas-White-Red Basin



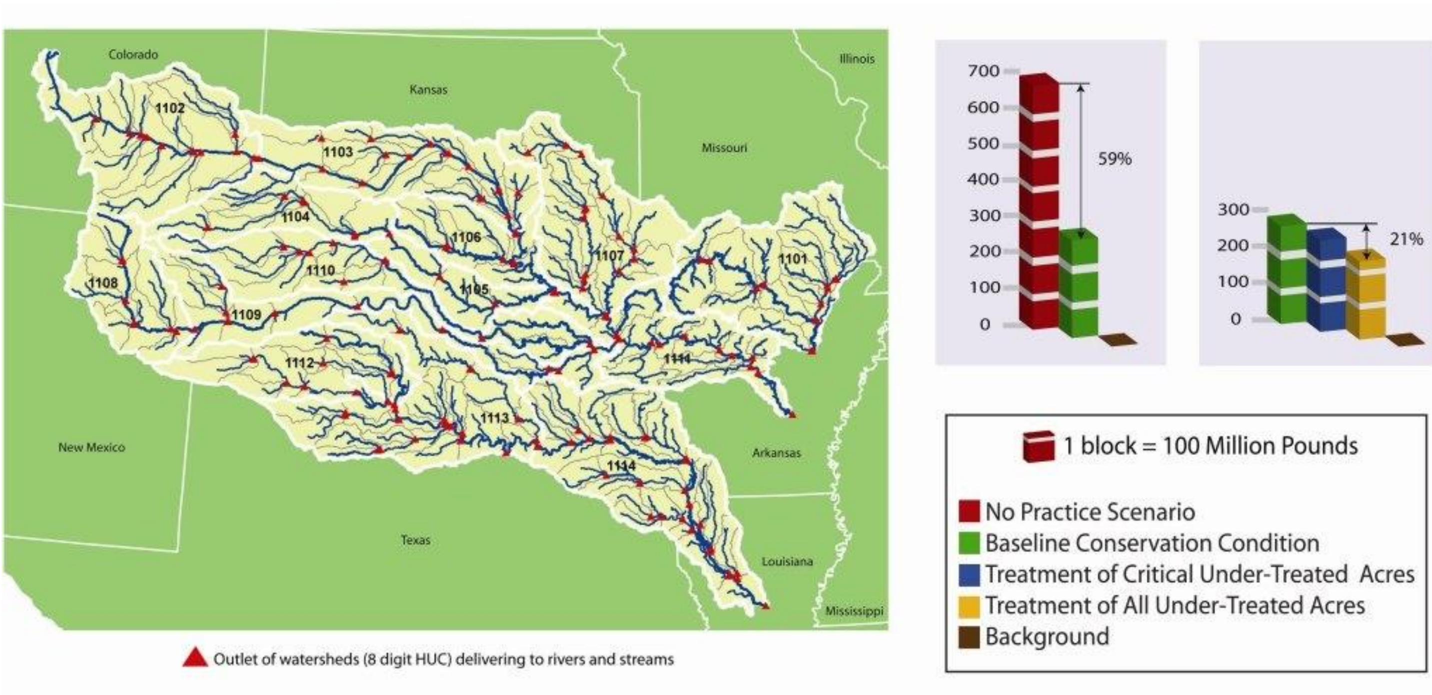
Sediment delivered to the Lower Mississippi River Basin from the Arkansas-White-Red Basin (all sources—instream loads)



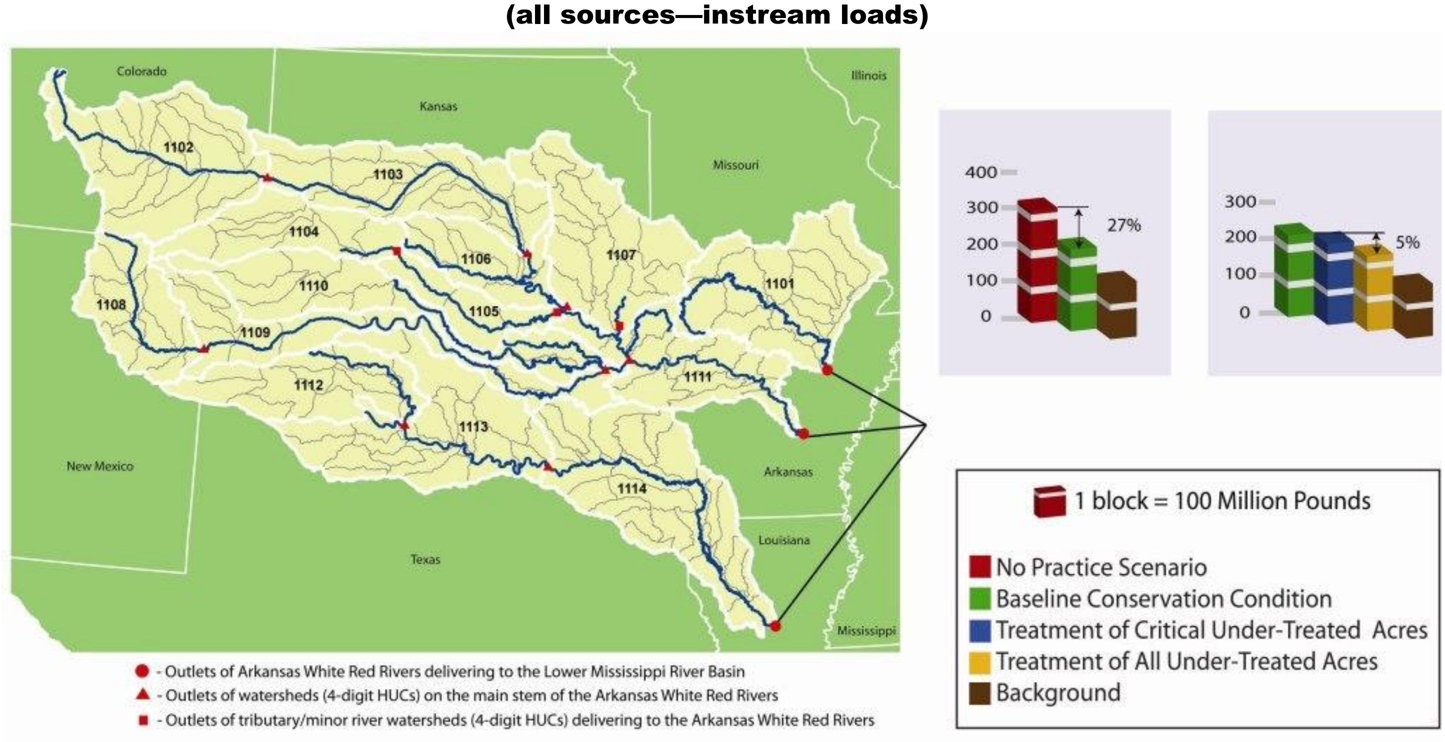
Note: Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Figure 100. Summary of the effects of conservation practices on total nitrogen loads in the Arkansas-White-Red Basin

Nitrogen delivered from cultivated cropland to rivers and streams in the Arkansas-White-Red Basin

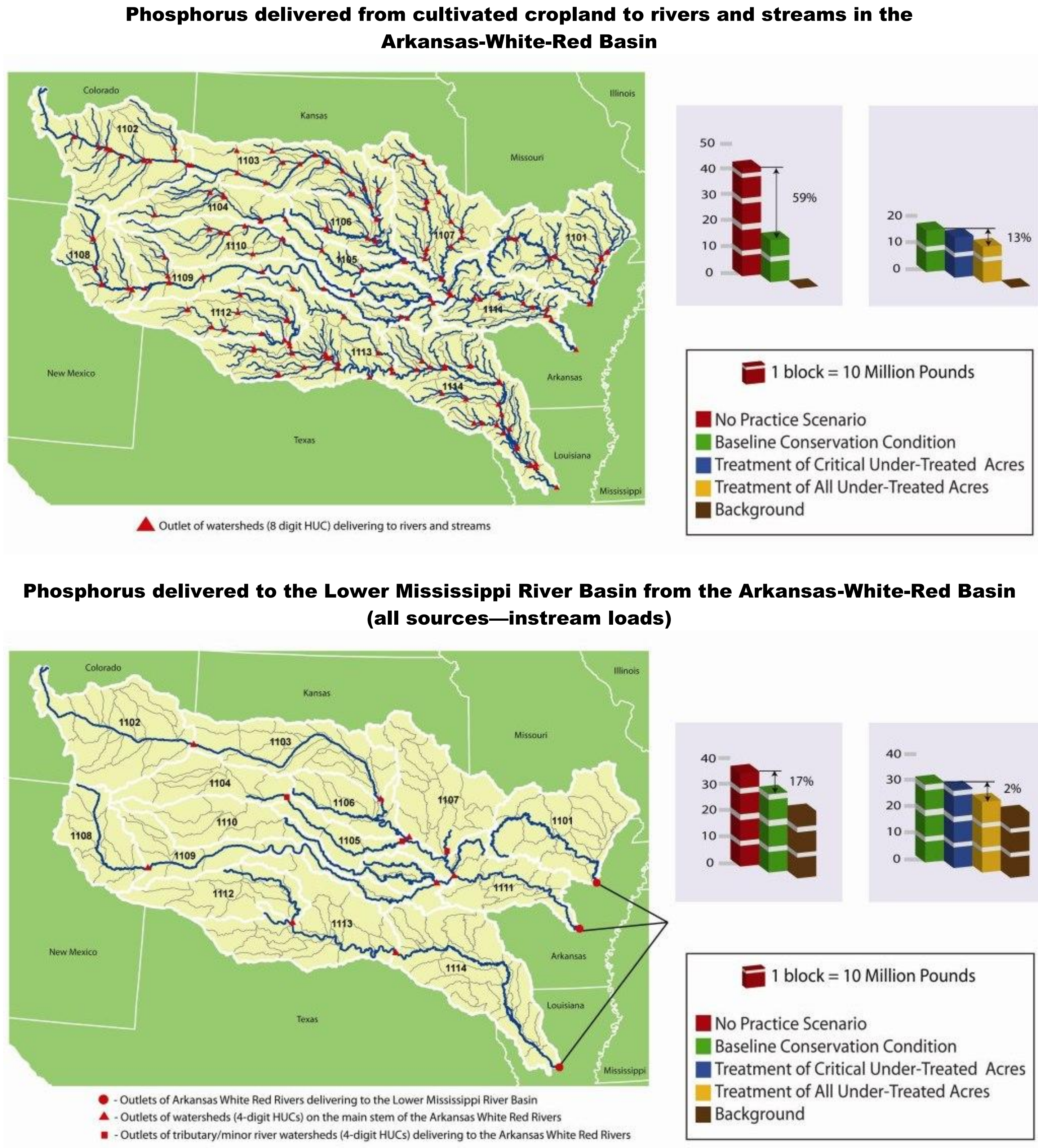


Nitrogen delivered to the Lower Mississippi River Basin from the Arkansas-White-Red Basin (all sources—instream loads)



Note: Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Figure 101. Summary of the effects of conservation practices on total phosphorus loads in the Arkansas-White-Red Basin



Note: Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Comparison of Findings to Other Regions

Sediment and nutrients from farm fields are exported from four major river basins to the Lower Mississippi River Basin. Tables 62 through 65 compare basin characteristics for the Arkansas-White-Red Basin to the other three river basins—the Ohio-Tennessee River Basin, the Upper Mississippi River Basin, and the Missouri River Basin.

The Arkansas-White-Red Basin is relatively large in size, second only to the Missouri River Basin, but the cultivated cropland is much different in kind and extent than in any of the other three basins. Most importantly, the cropping systems in the Arkansas-White-Red Basin are dominated by wheat and other close-grown crops and hay in rotation with other crops, whereas corn and soybean rotations are the dominant cropping system throughout the Ohio-Tennessee and Upper Mississippi River Basins and a very important cropping system in the Missouri River Basin. The Arkansas-White-Red Basin also has the highest percentage of irrigated land (20 percent of cropped acres), the highest percentage of land enrolled in long-term conserving cover (17 percent of cultivated cropland), and the smallest percentage of land with manure applied (4 percent of cropped acres). As in the Missouri River Basin, rangeland/pastureland is the dominant land use for most of the subregions within the Arkansas-White-Red Basin.

The vulnerability profile of the Arkansas-White-Red Basin benefits by having a lower propensity for soil and nutrient losses with surface water runoff. Precipitation in the eastern portion of the basin, averaging 35 inches per year, is similar to the average in the Upper Mississippi River Basin. The western portion of the region is, however, very dry, with annual precipitation averaging only 21 inches per year, similar to precipitation in the western portion of the Missouri River Basin. Because of the low precipitation in the Arkansas-White-Red Basin, soils there are prone to wind erosion, especially in the western part of the region. Wind erosion is not a serious resource concern in most parts of the Upper Mississippi and Ohio-Tennessee River Basins.

Except for the use of no-till, soil erosion control practices are about equally represented among the four regions. Mulch till is relatively widespread (41–63 percent of cropped acres) in all four regions, but use of no-till in the Arkansas-White-Red Basin is much lower than the other regions—only 14 percent of cropped acres compared to 28–52 percent in the other three basins (table 62). The lower use of no-till in the region occurs because more cotton is grown and more acres are irrigated, both of which usually require a greater tillage intensity, and because of a lower proportion of medium-textured soils in the region. Use of structural practices is about the same in all four regions, with wind erosion practices more common in the Arkansas-White-Red and Missouri River Basins.

A relatively high percentage of cropped acres in the Arkansas-White-Red Basin have high or moderately high levels of nutrient management, similar to that for the Missouri River Basin. The higher level of nutrient management is in part because close-grown crops dominate the cropping systems, which are less intensely fertilized with lower application rates.

Model simulations for cropped acres show that the average per-acre waterborne sediment and nutrient losses from farm fields are similar to those for the Missouri River Basin and much lower than in the Upper Mississippi and Ohio-Tennessee River Basins (table 63). In contrast, the average wind erosion rate for the Arkansas-White-Red Basin is higher than in all other regions, averaging 2.17 tons per acre per year. This rate is nearly twice as high as the average annual wind erosion rate in the Missouri River Basin. Nitrogen lost with windborne sediment averages 6.5 pounds per acre per year in the Arkansas-White-Red Basin, compared to 5.8 pounds per acre for the Missouri River Basin, 2.1 pounds per acre for the Upper Mississippi River Basin, and 0.2 pound per acre for the Ohio-Tennessee River Basin. Windborne phosphorus losses are also highest in the Arkansas-White-Red Basin.

In terms of percent reductions, practices in use in 2003–06 in the Arkansas-White-Red Basin were generally about as effective in reducing sediment and nutrient losses due to water erosion as in the Missouri River Basin, and tended to be higher than in the other two regions (table 63). Percent reductions for wind erosion and windborne nitrogen and phosphorus due to conservation practices, however, are much lower in the Arkansas-White-Red Basin than in other regions. For example, the percent reduction in average annual wind erosion due to conservation practice use was only 31 percent for the Arkansas-White-Red Basin, compared to 58–64 percent in the other three reigons.

The most critical conservation concern related to cropland differs among the regions (table 64):

- Wind erosion is the dominant need for conservation treatment in both the Arkansas-White-Red Basin and the Missouri River Basin. About 23 percent of cropped acres in the Arkansas-White-Red Basin are undertreated for wind erosion, and 12 percent of cropped acres in the Missouri River Basin are under-treated for wind erosion, compared to zero percent of cropped acres in the Upper Mississippi and Ohio-Tennessee River Basins.
- Nitrogen loss in subsurface flows is the major need for additional conservation treatment in the Upper Mississippi River Basin, where 47 percent of cropped acres have a high or moderate need for treatment for this concern (compared to 17 percent of cropped acres in the Ohio-Tennessee River Basin, 2 percent of cropped acres in the Missouri River Basin, and 9 percent of cropped acres in the Arkansas-White-Red Basin).
- Phosphorus lost to surface water is the major need for additional conservation treatment in the Ohio-Tennessee River Basin, where 63 percent of cropped acres have a high or moderate need for treatment for this concern (compared to 22 percent of cropped acres in the Upper Mississippi River Basin, 2 percent in the Arkansas-White-Red Basin, and 1 percent of cropped acres in the Missouri River Basin).
- Sediment loss and nitrogen lost with surface runoff were significant concerns only in the Ohio-Tennessee and Upper Mississippi River Basins.

Table 62. Comparison of land use, vulnerability, and conservation practice use among four of the five water resource regions that make up the Mississippi River drainage system

	Arkansas-White-Red Basin	Missouri River Basin	Upper Mississippi River Basin	Ohio-Tennessee River Basin
Total acres in basin (million acres excluding water)	156.5	322.2	118.2	128.5
Total acres of cultivated cropland (million acres)	35.3	95.1	62.9	26.8
Land use (percent of total acres excluding water)				
Cultivated cropland	23	30	53	21
Hayland	3	3	5	6
Pasture and rangeland	46	53	7	12
Urban land	5	3	8	9
Forest and other	23	11	26	52
Cultivated cropland (percent of cropped acres)				
Crop rotations with corn and soybean only	2	32	74	69
Crop rotations with wheat or other close-grown crops only	52	30	<1	<1
Crop rotations with hay and other crops	5	5	6	4
Irrigated	20	14	2	1
Manure applied	4	5	16	9
Vulnerability factors				
Average annual precipitation (inches)	27	23	34	42
Slopes greater than 2% (percent of cropped acres)	15	48	42	33
Highly Erodible Land (percent of cropped acres)	32	40	18	27
High soil runoff potential (percent of cropped acres)	<1	12	13	9
High or moderately high soil leaching potential (percent of cropped acres)	13	11	10	8
High or moderately high soil wind erosion potential (percent of cropped acres)	14	28	1	0
Conservation practice use				
No-till (percent of cropped acres)	14	46	28	52
Mulch till (percent of cropped acres)	44	47	63	41
Structural practices for water erosion control (percent of cropped acres)	46	41	45	40
Structural practices for wind erosion control (percent of cropped acres)	7	10	3	2
High tillage and residue management level (percent of cropped acres)	18	52	63	59
High or moderately high nitrogen management level (percent of cropped acres)	63	65	41	42
High or moderately high phosphorus management level (percent of cropped acres)	62	63	54	43
Land in long-term conserving cover (acres enrolled in CRP General Sign-Up) as a percent of cultivated cropland acres	17	12	5	4

Table 63. Comparison of field level losses and the effects of conservation practices among four of the five water resource regions that make up the Mississippi River drainage system

	Arkansas-White-Red Basin	Missouri River Basin	Upper Mississippi River Basin	Ohio-Tennessee River Basin
Average annual change in soil organic carbon, baseline conservation condition	-48	52	71	27
Average annual wind erosion and edge-of-field sediment and nutrient loss, baseline conservation condition				
Wind erosion (tons/acre)	2.17	1.13	0.23	0.02
Sediment loss (tons/acre)	0.34	0.26	0.89	1.59
Total nitrogen loss (pounds/acre)	28.3	23.4	39.0	42.6
Nitrogen lost with windborne sediment (pounds/acre)	6.5	5.8	2.1	0.2
Nitrogen loss with surface runoff (pounds/acre)	2.5	2.6	8.8	13.2
Nitrogen loss in subsurface flows (pounds/acre)	11.3	6.9	18.7	19.2
Total phosphorus loss (pounds/acre)	2.4	1.7	3.2	4.6
Phosphorus lost with windborne sediment (pounds/acre)	1.5	1.0	0.4	0.0
Phosphorus lost to surface water, sediment attached and soluble (pounds/acre)	0.8	0.7	2.7	4.5
Percent reduction in average annual wind erosion and edge-of-field sediment and nutrient loss due to conservation practice use (2003–06)				
Wind erosion	31	58	64	60
Sediment loss	61	73	61	52
Total nitrogen loss	46	39	20	17
Nitrogen lost with windborne sediment	27	46	37	47
Nitrogen loss with surface runoff	51	58	45	35
Nitrogen loss in subsurface flows	57	45	9	11
Total phosphorus loss	47	58	44	33
Phosphorus lost with windborne sediment	40	58	55	63
Phosphorus lost to surface water, sediment attached and soluble	57	59	42	33

Table 64. Comparison of conservation treatment needs among four of the five water resource regions that make up the Mississippi River drainage system

	Arkansas-White-Red Basin	Missouri River Basin	Upper Mississippi River Basin	Ohio-Tennessee River Basin
Conservation treatment needs (percent of cropped acres)				
Sediment loss				
High level of treatment need	0	<1	10	14
Moderate level of treatment need	2.5	3	0	12
Undertreated (high or moderate level of treatment need)	2.5	3	10	25
Nitrogen lost with runoff				
High level of treatment need	0	<1	11	12
Moderate level of treatment need	0	3	12	16
Undertreated (high or moderate level of treatment need)	0	4	24	29
Nitrogen loss in subsurface flows				
High level of treatment need	<1	<1	3	2
Moderate level of treatment need	9	2	45	16
Undertreated (high or moderate level of treatment need)	9	2	47	17
Phosphorus lost to surface water				
High level of treatment need	2	<1	5	20
Moderate level of treatment need	0	<1	18	44
Undertreated (high or moderate level of treatment need)	2	1	22	63
Wind erosion				
High level of treatment need	2	<1	0	0
Moderate level of treatment need	20	12	0	0
Undertreated (high or moderate level of treatment need)	23	12	0	0
One or more resource concern				
High level of treatment need	4	1	15	24
Moderate level of treatment need	30	17	45	46
Undertreated (high or moderate level of treatment need)	34	18	60	70
Conservation treatment needs for one or more resource concerns (million acres)				
High level of treatment need	1.304	1.127	8.980	6.012
Moderate level of treatment need	9.093	14.179	26.218	11.506
Undertreated (high or moderate level of treatment need)	10.397	15.306	35.198	17.518

Overall, the Arkansas-White-Red Basin has the least amount of under-treated acres at about 10 million acres and the Upper Mississippi River Basin has the most at about 35 million acres. The Missouri River Basin (15.3 million undertreated acres) and the Ohio-Tennessee River Basin (17.5 million undertreated acres) have about the same amount of under-treated acres (table 64).

Table 65 shows that average per-acre sediment and nutrient loads delivered to rivers and streams from cultivated cropland are highest in the Ohio-Tennessee River and the Upper Mississippi River Basins and lowest in the Arkansas-White-Red and Missouri River Basins. Cultivated cropland was the source of a much smaller proportion of sediment and nutrients delivered to rivers and streams within the basin than in the other regions. For example, 20 percent of the phosphorus loads delivered to rivers and streams in the Arkansas-White-Red Basin originated from cultivated cropland, compared to 46–62 percent in the other three regions.

Percent reductions in the sediment loads delivered to rivers and streams due to conservation practice use were about the same among the regions for sediment but higher for nutrients in the Arkansas-White-Red and Missouri River Basins (table 65). Potential percent reductions due to additional conservation treatment of undertreated acres are much lower in the Arkansas-White-Red and Missouri River Basins than in the other two regions because the proportion of acres needing additional treatment is much smaller in these two basins.

Table 65. Comparison of loads delivered from cultivated cropland to rivers and streams and instream loads (all sources) among four of the five water resource regions that make up the Mississippi River drainage system

	Arkansas-White-Red Basin	Missouri River Basin	Upper Mississippi River Basin	Ohio-Tennessee River Basin
Loads delivered to rivers and streams from cultivated cropland				
Average annual amount per cultivated cropland acre, baseline conservation condition				
Sediment (tons/acre/year)	0.20	0.15	0.29	0.6
Nitrogen (pounds/acre/year)	8	5	16.5	19
Phosphorus (pounds/acre/year)	0.5	0.3	1.3	2.0
Percent of total loads delivered from all sources, baseline conservation condition				
Sediment	30	72	71	53
Nitrogen	43	68	71	49
Phosphorus	20	46	62	48
Percent reduction due to 2003–06 conservation practices				
Sediment	64	76	65	55
Nitrogen	59	54	26	26
Phosphorus	59	60	41	32
Percent reduction due to additional conservation treatment of cropped acres with a high or moderate treatment need				
Sediment	25	28	74	81
Nitrogen	21	13	49	41
Phosphorus	13	12	41	58
Instream loads from all sources at the outlets of the basin				
Baseline conservation condition				
Sediment (average annual 1,000 tons)	21,342	44,010	40,490	26,300
Nitrogen (average annual 1,000 pounds)	223,560	511,300	1,068,700	897,082
Phosphorus (average annual 1,000 pounds)	30,226	54,650	69,350	87,800
Percent of total loads attributed to cultivated cropland sources, baseline conservation condition				
Sediment	8	22	22	20
Nitrogen	28	67	71	49
Phosphorus	14	32	61	51
Percent reduction in total loads due to 2003–06 conservation practice use on cultivated cropland acres				
Sediment	5	4	14	16
Nitrogen	17	19	36	15
Phosphorus	27	26	28	21
Percent reduction in total loads due to additional conservation treatment of cropped acres with a high or moderate treatment need				
Sediment	1	8	1	15
Nitrogen	5	33	6	20
Phosphorus	2	26	4	31

Instream loads from ***all sources*** delivered from the Arkansas-White-Red Basin to the Lower Mississippi River Basin are lower than loads delivered from each of the other three basins (table 65). Instream loads include sediment and nutrients from all sources, including point sources and cultivated cropland. As shown in table 65 for the baseline conservation condition, the largest average annual sediment loads originate from the Missouri River Basin (44 million tons), the largest average annual total nitrogen loads originate from the Upper Mississippi River basin (1.1 billion pounds), and the largest average annual total phosphorus loads (88 million pounds) originate from the Ohio-Tennessee River Basin.

On a percentage basis, instream sediment and nutrient loads delivered to the Lower Mississippi that are attributable to cultivated cropland sources are lowest for the Arkansas-White-Red Basin.

Percent reductions in instream loads (all sources) due to 2003–06 conservation practice use and due to additional conservation treatment are also contrasted among the four regions in table 65. These percentages are heavily influenced by the extent to which cultivated cropland is the source of contaminants in each basin, as well as the extent of conservation treatment within each basin.

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Appendix A: Estimates of Margins of Error for Selected Acre Estimates

The CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA/NRCS 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample. (Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap.)
The sample for cropped acres consists of 1,280 sample points in the Arkansas-White-Red Basin. Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with statistical sampling.

Statistics derived from the CEAP database are based upon data collected at sample sites located across all parts of the region. This means that estimates of acreage are statistical estimates and contain some amount of statistical uncertainty. Since the NRI employs recognized statistical methodology, it is possible to quantify this statistical uncertainty.

Margins of error are provided in table A1 for selected acres estimates found elsewhere in the report. The margin of error is a commonly used measure of statistical uncertainty and can be used to construct a 95-percent confidence interval for an estimate. The lower bound of the confidence interval is obtained by subtracting the margin of error from the estimate; adding the margin of error to the estimate forms the upper bound. Measures of uncertainty (e.g., margins of error, standard errors, confidence intervals, coefficients of variation) should be taken into consideration when using CEAP acreage estimates. The margin of error is calculated by multiplying the standard error by the factor 1.96; a coefficient of variation is the relative standard for an estimate, usually in terms of percentages, and is calculated by taking 100 times the standard error and then dividing by the estimate.

The precision of CEAP acres estimates depends upon the number of samples within the region of interest, the distribution of the resource characteristics across the region, the sampling procedure, and the estimation procedure. Characteristics that are common and spread fairly uniformly over an area can be estimated more precisely than characteristics that are rare or unevenly distributed.

For reporting, results for some subregions were combined because of small sample sizes.

Table A1. Margins of error for acre estimates based on the CEAP sample, Arkansas-White-Red Basin

	Estimated acres	Margin of error
Cropping Systems (table 6)		
Wheat only	15,188,400	1,164,151
Sorghum-wheat and sorghum only	3,995,962	590,272
Hay-crop mix	1,641,531	582,198
Corn and close grown crops	1,611,836	623,429
Soybean with or without wheat	1,505,532	446,333
Corn-soybean with or without close grown crops	1,171,005	343,779
Corn only	947,444	337,486
Soybean and sorghum with or without other crops	744,943	320,827
Rice with other crops	655,957	308,301
Cotton only	533,281	223,552
Remaining mix of row crops	560,750	304,849
Remaining mix of close-grown crops	185,868	126,522
Remaining mix of row and close-grown crops	1,734,192	595,287
Use of structural practices (table 7)		
Overland flow control practices	12,936,889	1,198,705
Concentrated flow control practices	6,899,808	1,164,569
Edge-of-field buffering and filtering practices	566,063	203,083
One or more water erosion control practices	14,114,296	1,303,010
Wind erosion control practices	1,987,847	504,292
Use of cover crops	105,039	83,724

Table A1—continued.

	Estimated acres	Margin of error
Use of residue and tillage management (table 8)		
Average annual tillage intensity for crop rotation meets criteria for no-till	4,274,958	778,542
Average annual tillage intensity for crop rotation meets criteria for mulch till	13,453,433	1,376,531
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	2,478,141	566,400
Continuous conventional tillage in every year of crop rotation	10,270,168	1,049,167
Conservation treatment levels for structural practices (fig. 9)		
High level of treatment	365,476	168,614
Moderately high level of treatment	5,935,940	1,001,911
Moderate level of treatment	7,812,880	995,413
Low level of treatment	16,362,404	1,344,803
Conservation treatment levels for residue and tillage management (fig. 10)		
High level of treatment	5,564,585	613,136
Moderately high level of treatment	1,250,812	459,363
Moderate level of treatment	15,550,442	1,223,280
Low level of treatment	8,110,861	785,895
Conservation treatment levels for nitrogen management (fig. 11)		
High level of treatment	10,405,527	1,132,989
Moderately high level of treatment	8,724,340	1,141,139
Moderate level of treatment	9,887,276	944,469
Low level of treatment	1,459,557	479,580
Conservation treatment levels for phosphorus management (fig. 12)		
High level of treatment	15,176,431	1,357,459
Moderately high level of treatment	3,559,382	593,322
Moderate level of treatment	6,603,196	912,935
Low level of treatment	5,137,692	999,437
Conservation treatment levels for IPM (fig. 13)		
High level of treatment	1,595,941	437,308
Moderate level of treatment	13,329,517	1,032,767
Low level of treatment	15,551,242	1,398,793
Conservation treatment levels for water erosion control practices (fig. 64)		
High level of treatment	5,035,273	639,721
Moderately high level of treatment	1,364,145	492,612
Moderate level of treatment	16,009,609	1,295,494
Low level of treatment	8,067,672	902,934
Conservation treatment levels for nitrogen runoff control (fig. 65)		
High level of treatment	1,090,235	296,697
Moderately high level of treatment	8,903,101	1,136,992
Moderate level of treatment	18,193,311	1,496,694
Low level of treatment	2,290,053	451,883
Conservation treatment levels for phosphorus runoff control (fig. 66)		
High level of treatment	2,103,805	490,330
Moderately high level of treatment	10,533,100	1,190,296
Moderate level of treatment	12,050,020	1,163,768
Low level of treatment	5,789,775	1,075,851
Conservation treatment levels for wind erosion control (fig. 67)		
High level of treatment	562,136	239,203
Moderately high level of treatment	5,381,584	841,511
Moderate level of treatment	13,013,402	1,310,917
Low level of treatment	11,519,578	1,119,101

Table A1—continued.

	Estimated acres	Margin of error
Soil runoff potential (fig. 68)		
High	193,770	140,042
Moderately high	3,640,704	662,778
Moderate	5,048,300	791,805
Low	21,593,926	1,247,556
Soil leaching potential (fig. 70)		
High	2,971,042	614,637
Moderately high	1,025,021	492,506
Moderate	20,127,116	1,096,149
Low	6,353,521	716,222
Soil wind erosion potential (fig. 72)		
High	575,465	290,422
Moderately high	3,577,585	622,417
Moderate	13,576,465	1,192,990
Low	12,747,186	1,071,984
Level of conservation treatment need by resource concern		
Sediment loss (table 26)		
High (critical under-treated)	0	NA
Moderate (non-critical under-treated)	760,557	372,768
Low (adequately treated)	29,716,143	1,269,514
Nitrogen loss with surface runoff (sediment attached and soluble) (table 27)		
High (critical under-treated)	0	NA
Moderate (non-critical under-treated)	0	NA
Low (adequately treated)	30,476,700	1,175,700
Nitrogen loss in subsurface flows (table 28)		
High (critical under-treated)	63,000	72,364
Moderate (non-critical under-treated)	2,726,111	633,800
Low (adequately treated)	27,687,589	1,195,557
Phosphorus lost to surface water (table 29)		
High (critical under-treated)	489,995	300,747
Moderate (non-critical under-treated)	0	NA
Low (adequately treated)	29,986,705	1,262,686
Wind erosion (table 30)		
High (critical under-treated)	750,829	274,078
Moderate (non-critical under-treated)	6,180,849	848,628
Low (adequately treated)	23,545,023	1,254,405
Level of conservation treatment need for one or more resource concerns (table 35)		
Arkansas-White-Red Basin		
High (critical under-treated)	1,303,824	338,924
Moderate (non-critical under-treated)	9,092,858	837,368
Low (adequately treated)	20,080,018	1,163,985
Upper White River Basin (code 1101)		
High (critical under-treated)	0	NA
Moderate (non-critical under-treated)	338,786	234,047
Low (adequately treated)	578,014	246,925
Upper Arkansas River Basin (code 1102)		
High (critical under-treated)	147,661	100,158
Moderate (non-critical under-treated)	500,463	313,889
Low (adequately treated)	376,675	323,866

Table A1—continued.

	Estimated acres	Margin of error
Level of conservation treatment need for one or more resource concerns--continued		
Middle Arkansas River Basin (code 1103)		
High (critical under-treated)	175,425	149,180
Moderate (non-critical under-treated)	2,127,182	476,152
Low (adequately treated)	5,605,893	903,351
Upper Cimarron River Basin (code 1104)		
High (critical under-treated)	81,466	90,337
Moderate (non-critical under-treated)	945,039	330,059
Low (adequately treated)	1,835,995	518,520
Lower Cimarron River Basin (code 1105)		
High (critical under-treated)	65,196	72,217
Moderate (non-critical under-treated)	470,115	211,409
Low (adequately treated)	971,189	281,270
Arkansas River-Keystone including Salt Fork River Basin (code 1106)		
High (critical under-treated)	117,569	105,922
Moderate (non-critical under-treated)	484,164	219,546
Low (adequately treated)	1,851,867	289,629
Neosho-Verdigris River Basin (code 1107)		
High (critical under-treated)	136,304	111,064
Moderate (non-critical under-treated)	396,635	186,132
Low (adequately treated)	1,547,261	291,226
Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)		
High (critical under-treated)	91,161	125,277
Moderate (non-critical under-treated)	463,546	248,830
Low (adequately treated)	746,292	324,366
North Canadian including Beaver River Basin (code 1110)		
High (critical under-treated)	131,328	161,780
Moderate (non-critical under-treated)	940,795	329,545
Low (adequately treated)	2,011,977	395,331
Lower Arkansas River-Robert Kerr Reservoir Basin (code 1111)		
High (critical under-treated)	0	NA
Moderate (non-critical under-treated)	208,595	236,664
Low (adequately treated)	263,205	300,925
Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin (code 1112)		
High (critical under-treated)	114,920	86,624
Moderate (non-critical under-treated)	923,447	283,507
Low (adequately treated)	1,676,233	341,580
Red-Washita-Pease-Lake Texoma Basin (code 1113)		
High (critical under-treated)	148,134	128,710
Moderate (non-critical under-treated)	948,319	257,874
Low (adequately treated)	2,203,746	389,170
Red-Little-Saline-Sulphur Creek River Basin (code 1114)		
High (critical under-treated)	94,658	213,044
Moderate (non-critical under-treated)	345,771	323,698
Low (adequately treated)	411,671	295,299

Appendix B: Model Simulation Results for the Baseline Conservation Condition for Subregions in the Arkansas-White-Red Basin

Model simulation results presented in Chapter 4 for the baseline conservation condition are presented in tables B1–B5 for the subregions in the Arkansas-White-Red Basin. For reporting, results for some subregions were combined because of small sample sizes. The column headings refer to the 4-digit Hydrologic Unit Codes (HUC), as shown below:

Subregion code	Subregion name
1101	Upper White River Basin
1102	Upper Arkansas River Basin
1103	Middle Arkansas River Basin
1104	Upper Cimarron River Basin
1105	Lower Cimarron River Basin
1106	Arkansas River-Keystone including Salt Fork River Basin
1107	Neosho-Verdigris River Basin
1108 and 1109	Upper Canadian River Basin (code 1108) and Lower Canadian River Basin (code 1109)
1110	North Canadian including Beaver River Basin
1111	Lower Arkansas River-Robert Kerr Reservoir Basin
1112	Red Headwaters-Prairie Down Fork-Salt Fork-North Fork Red River Basin
1113	Red-Washita-Pease-Lake Texoma Basin
1114	Red-Little-Saline-Sulphur Creek River Basin

Table B1. Basin characteristics and average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subregion, in the Arkansas-White-Red Basin

Model simulated outcome	Arkansas-White-Red Basin	1101	1102	1103	1104	1105	1106
CEAP sample size for estimating cropped acres	1,280	46	38	258	120	71	85
Cropped acres (million acres)	30.477	0.917	1.025	7.908	2.862	1.506	2.454
Percent of acres in region	100	3	3	26	9	5	8
Percent of acres highly erodible	32	4	74	30	41	36	20
Percent of acres irrigated	20	80	18	15	31	0	1
Percent of acres receiving manure	4	12	6	5	4	0	1
Water sources (average annual inches)							
Non-irrigated acres							
Precipitation	27.18	46.65	14.1	25.13	18.79	29.68	30.87
Irrigated acres							
Precipitation	24.23	46.16	13.03	21.89	18.71	NA	26.18
Irrigation water applied	16.66	18.7	18.31	16.28	19.5	NA	16.04
Water loss pathways (average annual inches)							
Evapotranspiration	24.6	37.5	15.8	23.5	22.5	24.3	25.9
Surface water runoff	2.4	10.7	0.1	1.4	0.5	2.3	2.5
Subsurface water flow	2.6	11.0	0.5	2.0	1.0	3.3	2.8
Erosion and sediment loss (average annual tons/acre)							
Wind erosion	2.17	0.04	6.49	1.72	3.64	1.00	1.14
Sheet and rill erosion	0.52	0.48	0.08	0.52	0.14	0.50	0.57
Sediment loss at edge of field due to water erosion	0.34	1.13	0.06	0.25	0.06	0.34	0.30
Soil organic carbon (average annual pounds/acre)							
Loss of soil organic carbon with wind and water erosion	123	109	154	110	208	64	76
Change in soil organic carbon, including loss of carbon with wind and water erosion	-48	13	-143	-47	-37	-52	-81

Table B1. Basin characteristics and average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subregion, in the Arkansas-White-Red Basin**--continued**

Model simulated outcome	1107	1108 and 1109	1110	1111	1112	1113	1114
CEAP sample size for estimating cropped acres	122	63	141	16	135	156	29
Cropped acres (million acres)	2.080	1.301	3.084	0.472	2.715	3.300	0.852
Percent of acres in region	7	4	10	2	9	11	3
Percent of acres highly erodible	33	42	36	15	22	30	30
Percent of acres irrigated	4	40	34	36	31	9	6
Percent of acres receiving manure	4	3	4	12	5	1	<1
Water sources (average annual inches)							
Non-irrigated acres							
Precipitation	38.62	25.12	21.2	46.26	22.81	28.22	46.17
Irrigated acres							
Precipitation	42.26	17.42	18.34	48.27	20.28	24.28	48.81
Irrigation water applied	12.03	14.97	15.23	13.59	15.47	18.67	13.34
Water loss pathways (average annual inches)							
Evapotranspiration	28.8	24.3	22.6	34.1	23.0	24.7	31.1
Surface water runoff	6.9	1.0	0.9	7.4	1.5	2.2	7.9
Subsurface water flow	3.8	1.9	1.2	9.8	1.7	2.8	8.3
Erosion and sediment loss (average annual tons/acre)							
Wind erosion	0.25	2.96	2.30	0.07	4.83	1.88	0.28
Sheet and rill erosion	1.14	0.17	0.15	1.18	0.46	0.59	2.35
Sediment loss at edge of field due to water erosion	0.88	0.09	0.07	0.91	0.22	0.30	1.98
Soil organic carbon (average annual pounds/acre)							
Loss of soil organic carbon with wind and water erosion	156	161	119	93	150	84	142
Change in soil organic carbon, including loss of carbon with wind and water erosion	-6	-27	-23	-39	-59	-76	-26

Table B2. Average annual estimates of nitrogen loss for the baseline conservation condition for cropped acres, by subregion, in the Arkansas-White-Red Basin

Model simulated outcome	Arkansas-White-Red Basin	1101	1102	1103	1104	1105	1106
Nitrogen (average annual pounds/acre)							
Nitrogen sources							
Atmospheric deposition	5.1	8.1	2.7	5.2	4.3	5.5	5.7
Bio-fixation by legumes	9.7	70.7	4.6	7.4	0.3	0.2	4.2
Nitrogen applied as commercial fertilizer and manure	72.9	80.7	54.7	62.5	77.7	83.7	74.0
All nitrogen sources	87.7	159.4	62.0	75.2	82.3	89.4	83.9
Nitrogen in crop yield removed at harvest	63.1	112.9	15.6	55.9	52.2	67.6	68.9
Nitrogen loss pathways							
Nitrogen loss by volatilization	5.9	4.0	4.1	4.9	5.9	8.2	6.4
Nitrogen loss through denitrification	2.2	24.5	1.1	0.3	0.1	1.1	1.8
Nitrogen lost with windborne sediment	6.5	0.1	13.9	6.1	14.2	2.7	3.4
Nitrogen loss with surface runoff , including waterborne sediment	2.5	6.1	0.3	2.1	0.8	2.1	2.4
Nitrogen loss in subsurface flow pathways	11.3	12.2	16.6	9.7	10.9	16.2	11.2
Total nitrogen loss for all loss pathways	28.3	46.8	36.0	23.2	32.0	30.4	25.2
Change in soil nitrogen	-4.2	-0.9	9.8	-4.6	-2.6	-9.0	-10.7

Table B2. Average annual estimates of nitrogen loss for the baseline conservation condition for cropped acres, by subregion, in the Arkansas-White-Red Basin**--continued**

Model simulated outcome	1107	1108 and 1109	1110	1111	1112	1113	1114
Nitrogen (average annual pounds/acre)							
Nitrogen sources							
Atmospheric deposition	6.7	4.4	4.6	7.9	4.4	4.8	6.3
Bio-fixation by legumes	48.3	1.1	0.8	43.5	0.9	1.9	25.1
Nitrogen applied as commercial fertilizer and manure	67.6	95.6	71.4	99.4	73.5	74.1	108.1
All nitrogen sources	122.7	101.0	76.7	150.8	78.7	80.8	139.6
Nitrogen in crop yield removed at harvest	97.8	67.6	52.4	102.1	54.4	63.8	93.8
Nitrogen loss pathways							
Nitrogen loss by volatilization	6.1	9.0	5.9	4.6	6.4	6.2	5.5
Nitrogen loss through denitrification	1.7	0.2	0.4	5.2	1.2	2.2	18.3
Nitrogen lost with windborne sediment	1.2	10.4	7.6	0.2	10.0	4.5	0.8
Nitrogen loss with surface runoff , including waterborne sediment	8.0	1.1	0.9	5.8	1.3	1.9	9.5
Nitrogen loss in subsurface flow pathways	10.2	15.0	7.7	36.3	9.2	11.3	13.7
Total nitrogen loss for all loss pathways	27.2	35.7	22.5	52.1	28.2	26.1	47.8
Change in soil nitrogen	-3.1	-2.8	1.1	-3.9	-4.2	-9.5	-2.3

Table B3. Average annual estimates of phosphorus loss and pesticide loss for the baseline conservation condition for cropped acres, by subregion, in the Arkansas-White-Red Basin

Model simulated outcome	Arkansas-White-Red Basin	1101	1102	1103	1104	1105	1106
Phosphorus (average annual pounds/acre)							
Phosphorus applied as commercial fertilizer and manure	12.4	17.9	11.2	9.9	10.9	15.3	13.9
Phosphorus in crop yield removed at harvest	9.0	15.7	2.1	8.3	8.7	8.9	9.5
Phosphorus loss pathways							
Phosphorus lost with windborne sediment	1.5	0.0	5.4	1.5	2.2	0.9	1.2
Phosphorus lost to surface water, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage tiles and ditches and natural seeps	0.9	2.0	0.1	0.6	0.2	1.1	1.1
Soluble phosphorus loss to groundwater	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total phosphorus loss for all loss pathways	2.4	2.1	5.5	2.2	2.4	2.0	2.3
Change in soil phosphorus	1.0	0.1	3.5	-0.6	-0.2	4.3	2.1
Pesticides							
Average annual amount of pesticides applied (grams of active ingredient/hectare)	558	1,637	574	537	861	44	231
Pesticide loss							
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	2.8	16.7	0.3	2.1	1.0	0.3	1.1
Edge-of-field pesticide risk indicator							
Average annual surface water pesticide risk indicator for aquatic ecosystem	1.67	0.48	4.85	1.73	2.09	2.26	0.71
Average annual surface water pesticide risk indicator for humans	0.32	0.25	1.02	0.41	0.43	0.09	0.11
Average annual groundwater pesticide risk indicator for humans	0.07	1.01	<0.01	0.07	0.05	<0.01	<0.01

Table B3. Average annual estimates of phosphorus loss and pesticide loss for the baseline conservation condition for cropped acres, by subregion, in the Arkansas-White-Red Basin**--continued**

Model simulated outcome	1107	1108 and 1109	1110	1111	1112	1113	1114
Phosphorus (average annual pounds/acre)							
Phosphorus applied as commercial fertilizer and manure	17.4	13.8	10.1	19.0	10.9	14.3	14.7
Phosphorus in crop yield removed at harvest	13.9	9.6	7.8	14.4	7.5	8.3	13.5
Phosphorus loss pathways							
Phosphorus lost with windborne sediment	0.3	2.1	1.1	0.1	2.2	1.3	0.1
Phosphorus lost to surface water, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage tiles and ditches and natural seeps	2.9	0.4	0.2	1.8	0.5	0.9	1.9
Soluble phosphorus loss to groundwater	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total phosphorus loss for all loss pathways	3.3	2.5	1.3	1.9	2.7	2.3	2.1
Change in soil phosphorus	0.2	1.5	0.9	2.6	0.7	3.7	-0.9
Pesticides							
Average annual amount of pesticides applied (grams of active ingredient/hectare)	851	389	413	1,066	490	380	1,118
Pesticide loss							
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	13.5	0.4	0.4	7.5	1.1	1.4	7.7
Edge-of-field pesticide risk indicator							
Average annual surface water pesticide risk indicator for aquatic ecosystem	4.30	0.89	0.72	1.08	1.00	1.39	0.87
Average annual surface water pesticide risk indicator for humans	1.06	0.13	0.08	0.31	0.22	0.04	0.27
Average annual groundwater pesticide risk indicator for humans	0.02	0.04	0.02	0.12	0.11	<0.01	0.05

Table B4. Percent of cropped acres for conservation treatment levels and soil vulnerability potentials, by subregion, in the Arkansas-White-Red Basin

Category	1101	1102	1103	1104	1105	1106	1107
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 9)							
High conservation treatment level	0	2	1	0	1	1	6
Moderately-high conservation treatment level	6	0	15	3	53	49	31
Moderate conservation treatment level	13	40	26	10	27	29	29
Low conservation treatment level	80	59	58	87	19	22	34
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 10)							
High conservation treatment level	45	9	17	19	10	14	36
Moderately-high conservation treatment level	7	2	8	6	0	0	3
Moderate conservation treatment level	35	84	52	65	39	25	53
Low conservation treatment level	14	6	24	9	51	61	8
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 11)							
High conservation treatment level	14	34	29	31	43	43	27
Moderately-high conservation treatment level	7	5	30	17	43	38	39
Moderate conservation treatment level	62	55	36	44	13	14	27
Low conservation treatment level	16	6	5	8	0	5	6
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 12)							
High conservation treatment level	28	69	49	56	50	41	44
Moderately-high conservation treatment level	34	2	12	11	7	7	14
Moderate conservation treatment level	15	17	24	18	24	28	22
Low conservation treatment level	23	13	15	15	19	23	20
Percent of cropped acres within subregion at four levels of soil runoff potential (see figure 68)							
High soil vulnerability potential	0	0	1	1	4	0	1
Moderately high soil vulnerability potential	1	18	7	1	21	14	34
Moderate soil vulnerability potential	52	7	8	2	12	15	35
Low soil vulnerability potential	47	75	85	96	63	71	30
Percent of cropped acres within subregion at four levels of soil leaching potential (see figure 70)							
High soil vulnerability potential	0	5	15	19	18	5	0
Moderately high soil vulnerability potential	0	7	3	1	2	2	4
Moderate soil vulnerability potential	51	87	73	79	57	75	45
Low soil vulnerability potential	49	1	10	0	23	19	51
Percent of cropped acres within subregion at four levels of soil wind potential (see figure 72)							
High soil vulnerability potential	0	0	0	7	0	0	0
Moderately high soil vulnerability potential	0	99	9	26	0	0	0
Moderate soil vulnerability potential	0	1	58	66	21	6	0
Low soil vulnerability potential	100	0	32	0	79	94	100

Note: Percents may not add to 100 within categories due to rounding.

Table B4. Percent of cropped acres for conservation treatment levels and soil vulnerability potentials, by subregion, in the Arkansas-White-Red Basin**--continued**

Category	1108 and 1109	1110	1111	1112	1113	1114
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 9)						
High conservation treatment level	0	1	0	0	3	0
Moderately-high conservation treatment level	23	11	15	10	24	24
Moderate conservation treatment level	10	15	11	33	45	28
Low conservation treatment level	67	73	74	57	28	49
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 10)						
High conservation treatment level	23	22	13	21	7	14
Moderately-high conservation treatment level	1	5	3	5	0	0
Moderate conservation treatment level	52	62	77	42	43	67
Low conservation treatment level	24	11	7	32	50	19
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 11)						
High conservation treatment level	36	38	14	39	48	17
Moderately-high conservation treatment level	31	19	33	26	36	36
Moderate conservation treatment level	30	38	40	34	14	47
Low conservation treatment level	3	5	13	1	2	0
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 12)						
High conservation treatment level	43	54	23	66	45	52
Moderately-high conservation treatment level	18	13	43	8	9	5
Moderate conservation treatment level	24	21	19	12	23	29
Low conservation treatment level	14	12	15	15	24	13
Percent of cropped acres within subregion at four levels of soil runoff potential (see figure 68)						
High soil vulnerability potential	0	0	0	0	2	0
Moderately high soil vulnerability potential	5	5	0	9	21	41
Moderate soil vulnerability potential	11	37	42	17	15	14
Low soil vulnerability potential	85	58	58	74	62	46
Percent of cropped acres within subregion at four levels of soil leaching potential (see figure 70)						
High soil vulnerability potential	18	9	0	5	5	0
Moderately high soil vulnerability potential	9	1	14	1	3	20
Moderate soil vulnerability potential	61	52	44	77	61	49
Low soil vulnerability potential	12	38	42	17	30	31
Percent of cropped acres within subregion at four levels of soil wind potential (see figure 72)						
High soil vulnerability potential	17	4	0	0	0	0
Moderately high soil vulnerability potential	9	17	0	10	6	0
Moderate soil vulnerability potential	52	72	0	74	51	0
Low soil vulnerability potential	22	7	100	16	44	100

Note: Percents may not add to 100 within categories due to rounding.

Table B5. Percent of cropped acres for conservation treatment needs, by subregion, in the Arkansas-White-Red Basin

Category	1101	1102	1103	1104	1105	1106	1107
Percent of cropped acres within subregion with conservation treatment needs for sediment loss							
High level of treatment need	0	0	0	0	0	0	0
Moderate level of treatment need	0	0	3	0	6	6	6
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff							
High level of treatment need	0	0	0	0	0	0	0
Moderate level of treatment need	0	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for phosphorus lost to surface water							
High level of treatment need	0	0	1	0	4	5	7
Moderate level of treatment need	0	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows							
High level of treatment need	0	0	0	1	0	0	0
Moderate level of treatment need	37	0	10	0	12	17	18
Percent of cropped acres within subregion with conservation treatment needs for wind erosion							
High level of treatment need	0	14	1	2	0	0	0
Moderate level of treatment need	0	49	16	34	16	2	0
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern							
High level of treatment need	0	14	2	3	4	5	7
Moderate level of treatment need	37	49	27	33	31	20	19
Undertreated (high or moderate level of treatment need)	37	63	29	36	36	25	26

Table B5. Percent of cropped acres for conservation treatment needs, by subregion, in the Arkansas-White-Red Basin**--continued**

Category	1108 and 1109	1110	1111	1112	1113	1114
Percent of cropped acres within subregion with conservation treatment needs for sediment loss						
High level of treatment need	0	0	0	0	0	0
Moderate level of treatment need	1	0	0	0	0	14
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff						
High level of treatment need	0	0	0	0	0	0
Moderate level of treatment need	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for phosphorus lost to surface water						
High level of treatment need	0	0	0	0	0	11
Moderate level of treatment need	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows						
High level of treatment need	0	0	0	0	0	0
Moderate level of treatment need	6	0	44	0	1	36
Percent of cropped acres within subregion with conservation treatment needs for wind erosion						
High level of treatment need	7	4	0	4	4	0
Moderate level of treatment need	28	31	0	34	28	0
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern						
High level of treatment need	7	4	0	4	4	11
Moderate level of treatment need	36	31	44	34	29	41
Undertreated (high or moderate level of treatment need)	43	35	44	38	33	52