OPTIMAL ALLOCATION OF WASTE MANAGEMENT PRACTICES WITH ECONOMIC IMPLICATIONS FOR POLICIES TO REGULATE PHOSPHORUS POLLUTION IN THE EUCHA-SPAVINAW WATERSHED

By

TIHOMIR ANCEV

Bachelor of Science in Agriculture
University Saints Cyril and Methodius
Skopje, Macedonia
1992

Master of Science in Economics
University of Iceland
Reykjavik, Iceland
1997

Submitted to the Faculty of the
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Oklahoma State University
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Thesis Approved:

Arthur Stoecker
Thesis Adviser

D Sanders

Don

Francis Epplin

Timothy J.
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

1.1.General Overview

Serious environmental concerns regarding water pollution, odors, and soil pollution are associated with concentrated animal production in high capacity facilities. In particular, phosphorus pollution of surface water bodies contributes to the eutrophication of lakes and rivers, which impairs drinking water supply, reduces values of recreation and natural amenities, and impacts the ecological values of the water bodies. The Eucha-Spavinaw watershed, shared by the states of Oklahoma and Arkansas, has been troubled for a number of years and has been a source of considerable controversy between the two states. Eutrophication of Lakes Eucha and Spavinaw is blamed on high phosphorus loading in the watershed, attributed to excessive land application of litter produced by intensive poultry industry in the area, and discharges of municipal wastewater from the City of Decatur, AR, (Storm et *al.*, 2002). Water from these eutrophic lakes is not desirable for drinking due to bad taste caused by chemicals resulting from algae presence (OWRB, 2002). Drinking water treatment facilities are able to treat the water to achieve established drinking water standards, but find it difficult and extremely expensive to treat the water to remove the bad taste (TMUA, 2002). There are concerns regarding the recreational values of the area lakes, as well as concerns about the overall ecological impacts of phosphorus pollution in the watershed.

1.1.1. Historical Overview

Phosphorus pollution in the Eucha-Spavinaw watershed is a fairly recent phenomenon. The water quality in the watershed was quite high, which was the reason for the City of Tulsa to build the Spavinaw dam and reservoir in 1922-24 as a main source of its municipal water supply (TMUA, 2002). As Tulsa experienced population growth, the demand for water was steadily increasing, as was the requirement for reliable and consistent water supply. In order to assure the water supply from the Spavinaw reservoir, a second lake was created with the construction of the Eucha Dam in 1952. Lake Eucha acts as an environmental and hydrologic buffer for Lake Spavinaw, assuring a constant supply of clean water through the connecting Spavinaw Stream. At the time when Lake Eucha was created, the agricultural activity in the watershed was limited to raising cattle and a few row crops. Poultry was a minor industry in Arkansas portion of the watershed, while in Oklahoma an anti-corporate farming law was preventing the development of large poultry facilities.

The situation changed dramatically by the late 1980's and early 1990's with explosive growth of poultry farming on both sides of the state line. Reasons for this growth are discussed in greater detail further in the text. Because of increased poultry producing capacity there was a correspondent increase of production of poultry litter in the watershed. Since the poultry litter is a good quality and inexpensive fertilizer that provides nutrients for the pastures, local farmers have increasingly used it. However, the balance of nutrients in the litter is such that phosphorus is present in the excess of what is used by the plants, so it builds up in the soil and runs off during the storm events. Most of the phosphorus ultimately reaches Lake Eucha. Because of the specific characteristics of that lake, such as low turbidity and high clarity, the algae growth is promoted as a result of phosphorus loading. Phosphorus is a limiting nutrient for algae growth in Lake Eucha and its external loading promotes lake eutrophication. Eutrophication (“eu” – meaning “well”, “abundant”,“self” in Greek, and “trophos” meaning “food”, “feeding”) is a long-term natural process of water body aging, whereby the availability of nutrients in a water body slowly increases, promoting photosynthetic activity. The photosynthesis in the water bodies is mainly conducted by algae and other bio-plankton, and to a lesser extent by macrophyte organisms. In many lakes that are still in oligotrophic and mesotrophic states (as opposed to eutrophic), phosphorus is a limiting nutrient for algae growth (Shindler,1997). As phosphorus runoff or other forms of phosphorus loading in the water body occurs, the algae biomass increases, rising the photosynthetic activity and causing eutrophication. When the algae die-off, decomposing bacteria uses up the dissolved oxygen, and odor and taste causing chemicals are released. This causes fish kills, as well as water quality problems relevant for both drinking water supply and recreational uses.

Although the eutrophication of the Lake Eucha was probably present by early 1980’s (OCC, 1997) the problem did not come into public focus until mid 1990’s when the City of Tulsa started to experience water quality problems connected predominantly to water taste and odor. The causes for these taste and odor problems are not completely scientifically determined and documented (OWRB, 2002), but for the most part two chemicals, Geosmin and Methyl Iso Borneol (MIB) are identified as main sources of bad water taste. These chemicals are produced during the algae die-off and decomposition in the lakes. Faced with increasing costumer complaints, the City of Tulsa had to provide additional treatment for drinking water coming from Spavinaw Lake by using Powdered

Activated Carbon (PAC). The City also commissioned several research projects, to determine the causes of its water problems. Further, the City intensified water quality monitoring efforts at both Lake Eucha and Lake Spavinaw. All of these activities amounted to quite significant costs to the City, which prompted an initiation of a lawsuit against the parties that allegedly contributed to the water quality decline in the watershed ((The City of Tulsa et *al.* v. Tyson Foods Inc. et *al.*, 2001). At the present time, the lawsuit has been settled out of the court and the details of the settlement are not available to the public. In addition, political struggle between the States of Oklahoma and Arkansas over the Oklahoma numeric standard for phosphorus concentration in the scenic rivers continues. In the coming months and years we will witness further developments of these issues.

1.1.2. Economic Overview

The Eucha-Spavinaw watershed is predominantly located in portions of two counties, Benton County, Arkansas and Delaware County, Oklahoma. Table 1 presents the acreage breakdown of the watershed by county. A summary of the economic activities in Delaware County and Benton County is provided to serve as an introduction to the economic analysis of the watershed.

Table 1. Acreage Breakdown of the Eucha-Spavinaw Watershed by County.

County	Total hectares in the county	Hectares in the watershed by county	% of the total county hectares that are in the watershed
Delaware, OK	207,077	61,986	29.9%
Mayes, OK	172,302	1,808	1%
Benton, AR	216,490	35,593	16.4%

The twenty-year period from 1980 to 2000 witnessed considerable economic growth in the two counties. Total population grew at 3.3 percent annually and nearly doubled from 102,000 in 1980 to 192,000 by the year 2000. Total real personal income had a sustained annual growth rate of 5.6 percent and tripled from $1.5 billion to $4.6 billion by 2000. Real per capita income expressed in 1999-2001 dollars grew at an annual rate of 3.2 percent and increased from $14,000 to nearly $24,000 dollars by the year 2000. Data from the Bureau of Economic Analysis on the population growth and personal income is presented in Figure 1.

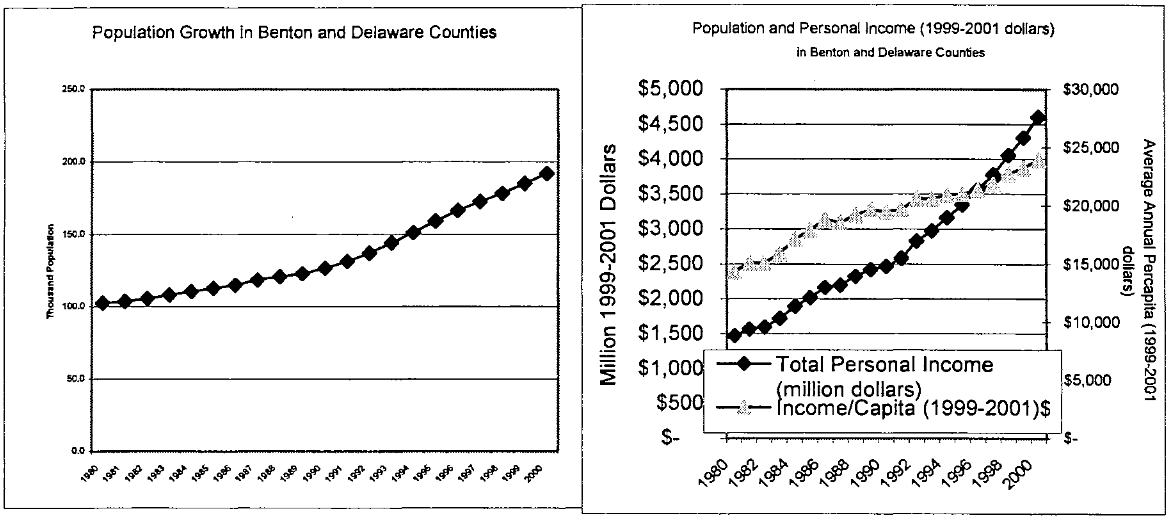


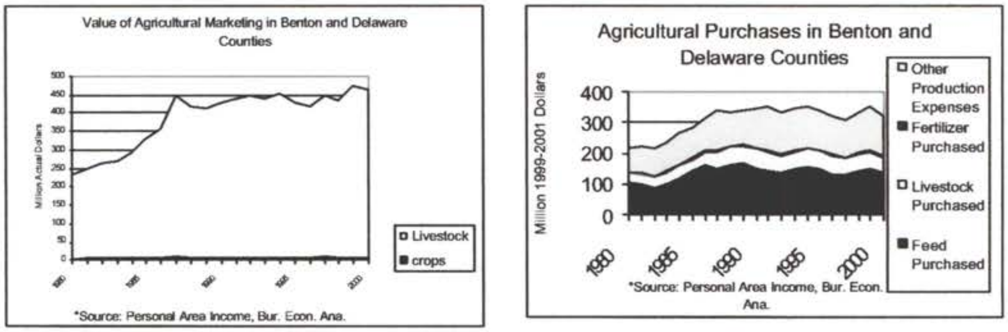
Figure1. Population and Real Income Growth in Benton County, Arkansas and Delaware County, Oklahoma.

Table 2 describes the growth of various economic sectors in the region. All sectors, except the mining sector, experienced positive economic growth over the past two decades. The fastest growing sectors were retail trade, finance-real estate-insurance, and transportation, which averaged more than seven percent growth per year from 1980 to 2000. The services, agricultural services, and food and kindred products sectors averaged between 5 and 7 percent annual growth in real terms during the twenty-year period. The data presented show that although agriculture is very important in the two-county area, the non-agricultural sector represents a much larger source of earnings.

Table 2. Comparison of Changes in Earnings by Sector Between 1980 and 2000 in Benton and Delaware Counties.

Sector	1980	2000	Average Annual Growth
	million 1999-2001 dollars		%
Ag. services, forestry, fishing	5	18	6.7
Mining	7	4	-4.7
Construction	73	190	5.7
Manufacturing	282	586	3.9
Durable goods	160	244	2.8
Nondurable goods	121	343	4.9
Food and kindred products (incl. ag. products)	62	199	5.5
Transportation and public utilities	46	203	7.1
Wholesale trade	23	115	9
Retail trade	136	989	9.5
Finance, insurance, and real estate	34	132	8.1
Services	138	485	6.6

Agricultural marketing in the two-county area is dominated by livestock production and by poultry production in particular. The importance of livestock marketing is shown in Figure 2. The two panels of Figure 2 show agricultural receipts and expenses expressed in constant prices (1999-2001 dollars). The right hand panel of Figure 2 shows that half of all agricultural expenses are just for purchases of feed and livestock. The increase in feed purchases represents the main avenue by which an increased quantity of nutrients enter the region. It could be noted that there has been little increase in the purchases of fertilizer over the last two decades. This indicates that the sources of nutrients (nitrogen and phosphorous) entering the watershed are more likely from purchased feed for livestock than from commercial fertilizers.


Value of Agricultural Marketing in Benton and Delaware Counties

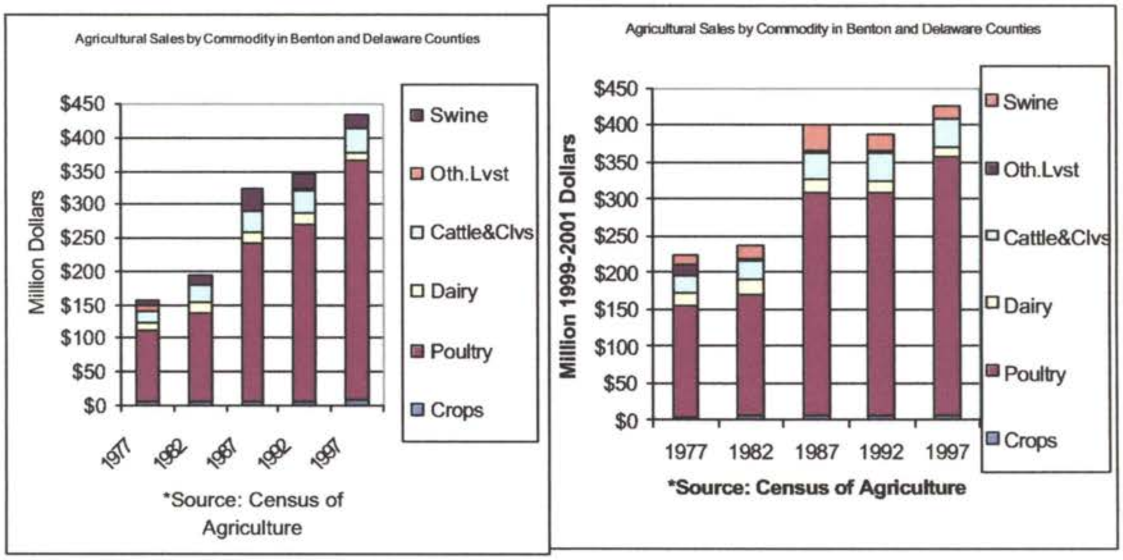
*Source: Personal Area Income, Bur. Econ. Ana.

Agricultural Purchases in Benton and Delaware Counties

*Source: Personal Area Income, Bur. Econ. Ana.

Figure 2. Agricultural Sales and Expenditures for Benton and Delaware Counties in Current and in 1999-2001 Prices.

Annual marketing data for the number of animals by type are not available for the two counties for the study period. Sales data from the Census of Agriculture are used to show the amounts of agricultural output for the census years in Figure 3. In the right panel of Figure 3, the sales data from the Census of Agriculture are converted to 1999-2001 dollars by using the GDP deflator. Total output in constant prices has been near $400 million since 1987.


Agricultural Sales by Commodity in Benton and Delaware Counties

*Source: Census of Agriculture

Agricultural Sales by Commodity in Benton and Delaware Counties

*Source: Census of Agriculture

Figure 3. Agricultural Sales of Crop and Livestock Commodities from Benton and Delaware Counties in 1999-2001 Dollars

Total agricultural output in the two counties is dominated by poultry production. Major expansion in poultry sales occurred between 1982 and 1987. Figure 4 shows that broiler production in Benton Co. (Arkansas Agricultural Statistics) and Delaware Co. (Census of Agriculture) is still increasing but at a slower rate than during the early 1980 period.

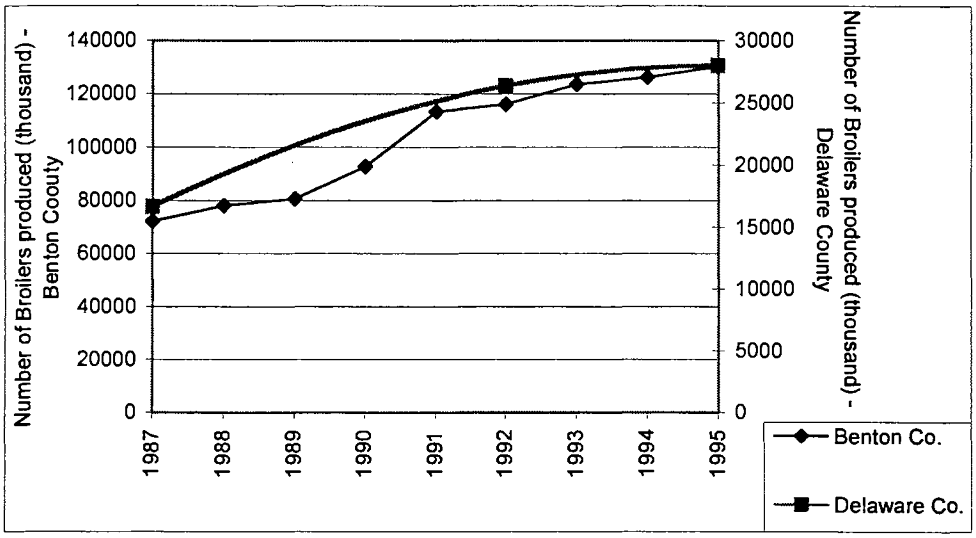


Figure 4. Broiler Production in Benton Co., AR, and Delaware Co., OK., 1987-1995.

The data presented in this summary show that agriculture is significant economic activity in the area, although not a predominant one. Agricultural activities in the region are dominated by the poultry sector, which is an important economic factor for the two counties that share the Eucha-Spavinaw watershed.

1.2. Problem Statement

The problem of phosphorus pollution in the Eucha-Spavinaw watershed and the consequent eutrophication of the area lakes are widely attributed to the external loading of phosphorus in the lakes. Several hydrological studies (Storm et *al.*, 2002, ORWB, 2002, OCC, 1997) found that some 25% of the total phosphorus loading in the watershed is generated by the City of Decatur, which is the major point source of pollution in the watershed. Another 65 % of the phosphorus loading comes from the crop growing, poultry and cattle raising agricultural enterprises in the watershed, the non-point sources of pollution. The cited hydrological studies recommended significant reduction of the external phosphorus loading in the watershed as a feasible and effective solution for the problem.[1] Any reductions in the phosphorus loading in the watershed will have to occur at both non-point sources and at the point source.

Economic theory and applied studies (Johansson, 2000, Jenq, 1982), show that when there are both point and non-point sources of pollution in a watershed, opportunities for economic tradeoffs in abatement between the two types of sources exist. In addition, there are considerable economic tradeoffs regarding the abatement among heterogeneous non-point sources of pollution. Economic efficiency requires that at the optimal level of abatement, the marginal costs are equated across all point and non-point sources of pollution.

Since the goal is to reduce total phosphorus loading in the watershed, the main economic problem treated in this dissertation is to determine how to achieve this goal at

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[1] Oklahoma Water Resources Board (OWRB, 2002) report recommended 54% reduction of external phosphorus loading to the lake Eucha and 44.6% reduction of the external phosphorus loading to lake Spavinaw.

least social cost. An economic model was constructed to obtain an optimal solution for the level of phosphorus abatement in the watershed and to allocate the abatement among the sources of pollution. The economic model was setup from the perspective of a watershed manager interested in the overall social well-being.

Abatement costs for point and the non-point sources were estimated and equated at the margin. For the point source, a wastewater treatment technology, which could be used to reduce the phosphorus concentration of the effluent was considered. The cost to use this technology to attain a given phosphorus abatement level was calculated, representing the abatement costs at the point source of phosphorus loading. Non-point sources of phosphorus loading were represented by the agricultural activities in the watershed, whereby poultry litter is applied to various crops (pasture, hay, row crops). The dissertation considered several technologies and policies related to poultry litter and land management that could be used by agricultural producers in the watershed to reduce phosphorus loading. The costs of these technologies to the agricultural producers were calculated, and they represent the abatement costs for the non-point sources.

In addition, the economic model estimated some of the environmental damage costs caused by the phosphorus pollution. These were represented by the additional cost for drinking water treatment and by the loss of recreational values of the area lakes. Other environmental damages were not considered because of the lack of data and technical limitations. The economic model then determined the optimal level of phosphorus abatement, accounting for both costs to the polluters (point and non-point sources) and costs to the parties that suffer from pollution (City of Tulsa, recreation users, etc). The determined level of phosphorus abatement was optimal from a social perspective, incorporating the interests of the stakeholders in the watershed. The distribution of costs and benefits to particular stakeholders is partially discussed in the presentation of the results, but it is not addressed in great detail since the distributional aspects were not of primary interest of this study.

1.3. Objectives of the Study

Given the stated problem, the overall objective of the dissertation was to develop a methodology that could be used to systematically address the economics of phosphorus pollution in the Eucha-Spavinaw watershed. This methodology was used to address and accomplish the following specific objectives:

1) Determine the socially optimal level of phosphorus abatement in the Eucha-Spavinaw watershed.
2) Determine the level of optimal phosphorus abatement at the point source, corresponding to a particular level of use of the abatement technology.
3) Determine the level of optimal phosphorus abatement from non-point sources.
4) Determine the most cost effective technologies and policies to reduce phosphorus loading.
5) Spatially allocate the optimal waste management practices to all distinct agricultural enterprises in the watershed.

CHAPTER II

LITERATURE REVIEW

2.1. Overview of the Political and Legal Aspects of Phosphorus Pollution in the Eucha - Spavinaw Watershed

It is useful for an economic study of the problem of phosphorus pollution in the Eucha-Spavinaw watershed to look at the main legislative, regulatory and litigation developments that are relevant to this issue, and in general, to the issues of agricultural pollution in the region of Eastern Oklahoma and Western Arkansas. This provides a legal background for any policies that would attempt to address the problem of excessive phosphorus loading in the watershed.

2.1.1. Legislative Overview

One of the main reasons for a rapid increase in the number of poultry produced in the region of the Eucha-Spavinaw watershed was the relaxation of laws prohibiting corporate farming, first in Arkansas and in Oklahoma (Hipp, 2002). Following this regulatory relaxation, the presence of corporate swine and poultry farms increased dramatically. The regulatory relaxation increased the protection against nuisance suits for concentrated animal feeding operations in Oklahoma, which aided further growth of swine and poultry corporate farming operations. These concentrated animal feeding operations (CAFOs) tended to concentrate in relatively small geographic areas, Eastern Oklahoma and Western Arkansas for poultry and Western Oklahoma for swine, which contributed to relatively quick occurrence of environmental problems.

Public response to environmental problems and public concerns related to odor and water quality started emerging by 1997 when legislative actions against CAFOs began to dominate. Oklahoma House Bill 1552 set up licensing requirements and notification of surrounding landowners for new CAFO facilities, stipulated setback rules, required a pollution prevention plan and increased penalties and fines (Oklahoma State Senate, 1997). Executive Order 97-07, established the Governor's Animal Waste and Water Quality Protection Task Force, a body intended to develop a plan with a mechanism for progressive monitoring of the state's water quality and put forth recommendations for legislation, regulatory change, structural and operational change, private-public partnerships, incentives, and other measures to protect the quality of Oklahoma's water supply (Office of the Governor of Oklahoma, 1997). In the same year, The Oklahoma House Joint Resolution 1093 imposed a moratorium on certain new hog farms until the next year or until new legislation was passed (Oklahoma State Senate, 1997). Also in 1997, the Arkansas – Oklahoma Arkansas River Compact Commission adopted a goal to reduce phosphorus pollution in the Illinois River by 40 percent (Hipp, 2002). The following year, 1998 was also marked by intensive legislative and regulatory activity. The EPA issued the Unified National Strategy for Animal Feeding Operations, where the principles, goals and expectations for control of pollution from Animal Feeding Operations were set forth (EPA, 1998). The EPA amended and finalized this strategy with the Final Rules on Concentrated Animal Feeding Operations in December 2002 (EPA, 2002). Also in 1998, the Oklahoma legislature passed the Senate Bills 1170 and 1175 that imposed several additional requirements and restrictions on poultry farms and swine farms respectively (Oklahoma State Senate, 1998). In particular, SB 1170 defined "nutrient threatened " and "nutrient vulnerable" watersheds in Oklahoma. In response to the concentration of poultry litter in limited geographic areas, the Oklahoma Legislature enacted the Oklahoma Poultry Waste Transfer Act in 2001, which provides tax relief to the parties that transport poultry waste from the regions where it is abundant and creates environmental problems (Eastern Oklahoma) to regions where phosphorus is in deficit (Central Oklahoma) (Oklahoma Statutes, 2001).

2.1.2. Regulatory Overview

On the regulatory stage, Oklahoma Water Quality Standards (OWRB, 1996) designate the following beneficial uses for the lakes Eucha and Spavinaw in the watershed: public and private water supply, cool water aquatic community, agricultural irrigation, primary body contact recreation, and aesthetics. Both lakes are also designated as sensitive drinking water supply. The Oklahoma Water Resources Board (OWRB), through its Beneficial Uses Monitoring Program (BUMP) continuously monitors the compliance to the designated beneficial uses and has a regulatory power over the activities that endanger these uses. In a response to numerous complaints on odor and taste characteristics of the drinking water coming from the Lake Spavinaw, the OWRB conducted a comprehensive study on the water quality in the Eucha-Spavinaw watershed (OWRB, 2002). The published report found that several of the designated beneficial uses of the lakes were impaired, most importantly the water supply and recreational uses. The report identified external phosphorus load as a main cause of impairment of lakes Eucha and Spavinaw. It further attributed most of the external phosphorus loading in the Lake Eucha to non-point agricultural sources and to a municipal point source in Arkansas. The report recommended a 54 percent reduction of total phosphorus load to the Lake Eucha and 44.6 percent reduction of total phosphorus load to the Lake Spavinaw to achieve the desired trophic state in the lakes. The recommended reduction relates to the current estimated phosphorus loading of 48,000 kg/year.

Other federal and state regulation pertaining to the water quality in the watershed (Clean Water Act, Nutrient Threatened Watershed Designation etc.) does not present a comprehensive legislative basis for a meaningful regulatory action on the part of Oklahoma regulators. The fact that the watershed is shared by the two states also contributes to limited possibilities for regulating phosphorus pollution.

2.1.3. Overview of Litigation Actions

Amid numerous reports and recommendations, the excessive phosphorus loading in the watershed continued, prompting the City of Tulsa to file a federal lawsuit against the poultry integrators and the municipality of Decatur, AR. On December 10, 2001, the City of Tulsa and the Tulsa Metropolitan Utility Authority (City of Tulsa et *al.*,) filed a complaint in the US District Court of the Northern District of Oklahoma against Tyson Foods, Inc., Cobb-Vantress, Inc., Peterson Farms, Inc., Simmons Foods, Inc., Cargill, Inc., George's, Inc., and the City of Decatur, Arkansas (Tyson Foods Inc. et *al.*). The complaint claimed that the defendants committed acts and omissions which caused damages to the water supply of the City of Tulsa. The legal action sought damages and injunctive relief to remedy the wrongful pollution by the defendants.

The complaint cited that the deleterious conditions of the water supply, in terms of nutrient loading in the Eucha-Spavinaw watershed and consequent eutrophication of the lakes, were directly caused by the acts and omissions of the Defendants in the course of a "meteoric" growth in their business and pollution activities in the watershed. The massive concentration of poultry operations in the watershed that is directly linked to the Defendants, results in enormous production of nutrient rich waste whose land application is directly responsible for the rapidly increasing levels of phosphorus in the lakes and is therefore a *proximate* cause of the eutrophication occurring in the lakes. In addition, the City of Decatur is alleged to contribute jointly with other Defendants to the pollution of the watershed by allowing enormous quantities of phosphorus discharge from its sewage treatment plant that also treats the wastewater from a poultry processing plant in the ownership of one of the other defendants. The complaint states that the Defendants have been aware of the rapidly increasing problems caused by their actions in the watershed. The City of Tulsa has pleaded and demanded that the defendants eliminate their polluting activities, but to no effect. Based on these allegations the complaint requested punitive damages for the plaintiffs.

The complaint also states that irreparable damage will be done if the polluting actions of the Defendants are not stopped. Therefore, the complaint requested an injunctive relief to prevent this irreparable harm. A lengthy pretrial process occurred after the complaint was filed. A number of expert witnesses were called for preliminary hearings. Just before the start of the trial, during the jury selection process, the parties announced an out of court settlement. The settlement was announced on March 24th, 2003 (Tulsa World, March 25, 2003). Details of the settlement are not yet available to the public, but it is expected that the settlement includes a mandate to the City of Decatur to upgrade its wastewater treatment. Subsequently the Tulsa World reported (Tulsa World, April 27th, 2003), that the poultry integrators prevent their growers from litter application to their land and from selling and giving out litter to other farmers. It is believed that this new development is directly linked to the settlement.

Another important litigation action with potential implications for the problem of phosphorus pollution in the Eucha-Spavinaw Watershed is the landmark Supreme Court decision on *Arkansas v. Oklahoma* in 1993. The dispute was over the NPDES permit for the City of Fayetteville, AR. Oklahoma won the case at the Federal Court of Appeals, revoking the issued NPDES. The State of Arkansas brought the case before the Supreme Court. The significance of the Supreme Court decision was in the fact that the court upheld the federal character of Oklahoma's EPA approved water quality standards. This decision implies that the water quality standards of the downstream state must be implemented by the upstream state. The same reasoning will be used in any future legal action involving the newly set 0.037 mg/l in-stream phosphorus concentration standard if the EPA approves that numeric standard. This is the motivation for continued EPA moderated negotiations between Oklahoma and Arkansas. The Supreme Court decision on *Arkansas v. Oklahoma*, although not directly in relation to the Eucha – Spavinaw watershed, will have a significant impact on any future legal actions regarding the phosphorus pollution in the watershed.

2.2. Overview of the Economic Literature on Agricultural Pollution

The general economics of pollution and environmental quality has been a subject of intensive literature in the past 30 years. A comprehensive review is not offered in the dissertation, but references are made to the literature sources that are summarizing the state of the art. In one of the most famous and widely used books on environmental economics, Baumol and Oates (1988) present a thorough review of the literature up to that point in time. Stavins (1999) edited a collection of papers in environmental economics containing work that is an irreplaceable prerequisite for a researcher in this field.

2.2.1. General Studies on Agricultural Pollution

The economic literature on agricultural pollution has been developed somewhat latter than the literature on the general environmental economics, because of the fact that agriculture was traditionally not seen as a source of pollution but rather as a creator of environmental amenities. An exception to this are the Concentrated Animal Feeding Operations that are considered as point sources of pollution, and as such are subject to the Clean Water Act provisions (EPA, 2003). Nonetheless, the general principles of environmental economics were adopted for the analysis of agricultural externalities (Zilberman and Mara, 1993). This overview will predominantly address the literature on the economics of water pollution from agricultural sources.

A detailed overview on the economics of both ground and surface water pollution from agricultural activities is presented in Bogges, Lacewell and Zilberman (1993). The study describes the relationship between pollution abatement and benefits from clean water. The optimal level of abatement is represented by the point of equivalence between the demand for water quality and marginal cost of additional improvements in water quality.

Several studies have focused on nitrate pollution, which is a predominate problem in ground water contamination. An economic model of ground water extraction where the water quality is affected by the ongoing agricultural practices is presented in Roseta-Palma (2002). The main finding is that optimal water table level is higher when the water quality is included in the model as compared to the quantity only models, and that private common property solution will never achieve the optimum, hence a regulatory action was found appropriate. Johnson, Adams and Perry (1991) investigated the farm level costs of reducing ground water nitrate pollution using a plant growth simulation model and found that there is a room for more efficient management of water and nitrogen inputs so that nitrate leaching is reduced, while maintaining profitability. An economic analysis of groundwater nitrate pollution on the regional level is given in Mapp et *al.*(1994). A somewhat surprising result in the study is that broad policies of quantity restrictions on nitrogen use may be more effective than targeting of particular soil types. It is recommended to target nitrogen restrictions on particular production systems rather than soil types, in which case the targeting policy becomes more effective than uniform quantity restrictions.

2.2.2. Studies Exploring Point vs. Non-Point Source Tradeoffs in the Watershed

Agricultural sources of pollution are generally classified as non-point sources. There are several classifications that make a distinction between point and non-point sources of water pollution. One commonly used is that point sources discharge into surface waters at a specific location through a pipe, outflow or ditch while non-point sources pollute the waters in more diffuse and indirect way (Tietneberg, 2000). Also, non-point source pollution is intermittent and affected by random meteorological events (runoff after big storms), while pollution from point sources is more or less constant and dependent on the level of production activities (Loehr, 1984). There are instances where agricultural sources of pollution are classified as point sources. If the agricultural operation qualifies as Concentrated Animal Feeding Operation it is classified as a point source of pollution. This is regulated by the rules set by the EPA (EPA, 2002). In this dissertation, the analysis will focus on the crop and cattle growers in the Eucha-Spavinaw watershed that use poultry litter as a fertilizer. The actual level of poultry production will be treated as given. Since the crop and cattle growers are fairly dispersed and occupy small land areas, and the pollution they generate is in the form of phosphorus runoff, they are treated as non-point sources of pollution. A single point source of phosphorus pollution in the watershed, the City of Decatur, AR, was considered, which emits significant amount of phosphorus from its sewage treatment plant that is combined with a poultry processing facility (ADEQ, 2001). There are other smaller and insignificant point sources of phosphorus loading in the watershed that were not considered in the study.

Economic theory and applied studies (Johansson, 2000, EPA, 1992, EPA, 1985, Jenq, 1982), show that when there are both point and non-point sources of pollution in a watershed, opportunities for tradeoffs in abatement between the two types of sources exist. In particular, there is an economically optimal, least-cost allocation of abatement between point and non-point sources for any given level of pollutant emissions. This optimal abatement corresponds to the point where the marginal abatement costs at the point source are just equal to the marginal abatement costs from the non-point sources. Stated differently, the optimal abatement for the point source is where the cost of removing another unit of pollution from the point source is equal to the cost of removing another unit of pollution from the non-point sources.

In addition to point versus non-point source tradeoffs, there are considerable economic tradeoffs regarding the abatement among the non-point sources. If the non-point agricultural sources are heterogeneous (non identical), the optimal, least cost solution would require non-uniform levels of abatement at each non-point source (Pearce and Turner, 1990). In particular, it would be optimal to abate more at the non-point sources that have lower marginal cost of abatement than at the non-point sources that have higher marginal cost. At the optimal level of abatement, the marginal costs are equated across all non-point sources of pollution as well as equated to the marginal abatement costs at the point source (Johansson, 2000).

2.2.3. Watershed Level Studies

The economic analysis of surface water pollution has traditionally been conducted on the watershed level by using a combination of economic and biophysical modeling. The economic methods typically fall in the class of optimal control problems while biophysical methods range widely across studies. The integration of economic models with a biophysical simulation models is suitable for conducting watershed level studies of agricultural pollution since the processes that need to be modeled are both bio-physical (runoff, sediment loading, leaching) and economic (returns, abatement costs). The present dissertation also uses a biophysical (SWAT (Soil and Water Assessment Tool)) model and an economic (linear programming) model.

A dynamic programming approach for modeling sediment losses and associated pollution agents using SOILSED (Budget and Soil Erosion Generator) as biophysical model is presented in Bouzaher, Braden and Johnson (1990). This study is very important for the purposes of the dissertation since it was among the first to notice the possibilities to pinpoint locations within a watershed where changes in agricultural practices will be the most cost effective for reducing sediment and nutrient loads. A non-linear mathematical programming economic model combined with AGNPS (Agricultural Non-

Point Source Pollution Simulation) biophysical model is presented in Lintner and Weersink (1999). The study modeled a small watershed and found that an ambient tax scheme was most likely to achieve cost-effective patterns of farming and abatement activities in the presented empirical case study. The financial impacts on dairy farms from reduction of phosphorus runoff in a watershed was modeled combining FLIPSim (Farm Level Income and Policy Simulation Modeling System) as a financial simulation model with GISPLM (GIS Phosphorus Loading Model) biophysical model in Parsons (2002). The study found that a combination of row crop field buffers, nutrient management plans and conservation cropping would be the least financially distressful waste management practice for the farms in an attempt to reduce phosphorus runoff. An integrated enviro-economic modeling framework comprising of an APEX (Agricultural Policy/Environmental Expander) model, which essentially represents a multi-field version of EPIC (Erosion-Productivity Impact Calculator), a watershed level biophysical model SWAT and a farm level economic simulation model was presented in Osei et *al.*(2000). One of the main findings is that waste management based on agronomic rates for phosphorus application may not be as costly for the farms as usually believed, especially in watersheds with plenty of land available for application. The SWAT model combined with farm level economic simulation was also employed by Harman (2002). Various policy instruments targeting phosphorus pollution from agricultural sources in a watershed were analyzed in Westra, 2001. The ADAPT (Agricultural Drainage and Pesticide Transport) biophysical simulation was used in a combination with positive mathematical programming (Howitt, 1995) to find that site-specific regulation and mitigation is economically superior policy relative to the uniform restrictions approach.

The economics of phosphorus pollution in the Eucha-Spavinaw watershed was treated by Phan (2003). Using a combination of SWAT and EPIC as bio-physical models and constrained dynamic profit maximization as an economic model, the study examined the effects of various litter application rates on profitability and phosphorus loading in the watershed. The study also derived marginal phosphorus abatement costs for the analyzed alternative litter application rates.

2.3. Overview of the Literature on Environmental Damage Costs

It is very difficult to account for the full set of environmental damages caused by phosphorus pollution in the Eucha-Spavinaw watershed. Eutrophication of the area lakes has a major impact on their use as a source of drinking water and as recreational sites, but it also has an impact on the overall ecological state of the water bodies in the region, biodiversity, and long term sustainability of the whole ecological system. This dissertation considers only the environmental damages inflicted upon the drinking water supply and recreational uses, which are reasonably assumed to account for a significant part of the overall damages and the associated damage costs. Feenberg and Mills (1980) define two types of surface water uses, in stream and withdrawal uses. The in stream use of the waters in the Eucha-Spavinaw watershed treated in this dissertation are the recreational use of the area lakes. The withdrawal use of water is the use as a water supply for the City of Tulsa.

2.3.1. Literature on the Cost of Drinking Water Treatment

The benefits of using cleaner raw water for the municipal water treatment are contrasted to the costs of treating polluted water in Feenberg and Mills (1980). Several options that are available to the municipal water treatment facility when faced with polluted raw water (treatment, alternative water sources, delivering lower water quality, etc.) are analyzed in the study and optimal choices under different set of assumptions are derived. A model in which a water treatment and delivery company faced with random contamination of its source chooses a treatment system, treatment levels and an attitude towards its customers (notify or not when the water quality is low) is presented in Innes and Cory (2001). The study presents the optimal levels of water treatment under various policy settings in the light of the Safe Drinking Water Act (SDWA). An analysis of the cost structure of various water treatment systems is given in Schmit and Boysvert (1997). The study shows that urban water systems are less flexible and are at a cost disadvantage compared to smaller (rural) treatment systems. The City of Tulsa used Powdered Activated Carbon (PAC) as a main treatment technology against taste and odor chemicals in the raw water coming from lake Spavinaw. A technological overview and some economic considerations on the use of PAC are provided in AWWA (2001).

2.3.2. Literature on the Cost of Recreational Losses

The recreation values of lakes, rivers and other water bodies in relation to environmental quality are substantial, but difficult to measure and quantify, (Bockstael et *al.*, 1991). Three main methods presented in the literature have been used to measure the recreational benefits of improved water quality. The hypothetical market, or the contingent valuation method is based on using survey techniques to value the willingessto-pay for environmental improvement (Randal et *al,* 1974). The random utility model of choice is based on utility maximization (expenditure minimization) that is framed in a logistic econometric model to determine the choice of quantity and location of individual recreational activities, (Bockstael et *al.,* 1991). This dissertation will use the travel cost method for valuing recreational losses in the Eucha-Spavinaw watershed caused by excessive phosphorus loading in the lakes. The travel cost method was first proposed by Hotteling (1947) and a vast literature followed (Fletcher et *al.* ,1990). A thorough review on the theoretical and empirical aspects is also provided in Ward and Loomis (1986).

The travel cost method estimates the demand for recreation by accounting for differences in costs of transportation, preparation and time, among individuals from various geographic locations that attend a particular recreation site. Dependent on the data availability and the goals of the conducted study, ordinary (Marshallian) or compensated (Hicksian) demand functions for recreation could be derived. Using the Hicksian demand function, two welfare measures, the equivalent and the compensating variation, could be used to assess the changes in benefits regarding the water quality. They can mathematically be represented by,

$$(3.1) \qquad EV = \int_{p_0}^{p_1} h(p_0, p_1, U_1) = e(p_1, U_1) - e(p_0, U_1) \qquad \text{and,}$$

$$(3.2) \qquad CV = \int_{p_0}^{p_1} h(p_0, p_1, U_0) = e(p_1, U_0) - e(p_0, U_0),$$

where *EV* and *CV* denote equivalent and compensating variation respectively, *h* denotes the Hicksian demand function, *e* denotes the expenditure function (income), p_0 and p_1, denote the old and new price level respectively and U_0 and U_1, denote the old and the new utility respectively (Kolstad and Braden, 1991). Compensating variation can be defined as the amount of income that compensates a consumer for a price change (give money to consumer, so that he/she experience the same level of utility even when a price of a product increases (has to go further to experience the same quality of recreation because of pollution)). Equivalent variation is the amount of income, which is equivalent to a utility change experienced if the price were to change (the amount of income that could be taken from the consumer, so that he/she is on the same utility level that would be attained if the price would have changed).

Using the Marshallian demand function, another welfare measure could be derived, the consumer surplus. The consumer surplus is represented by,

$$CS = \int_{p_0}^{p_1} x(p_0, p_1, m), \tag{3.3}$$

where CS denotes the consumer surplus, x is the Marshallian demand function and m denotes the level of income. The consumer surplus measures the benefit for the consumer from being able to buy a product (recreation) of a given quality (phosphorus concentration, water clarity) below its reservation price (maximum willingness-to-pay). All of the stated welfare measures can be represented by the areas below the appropriate demand curves and the price line. This is presented in Figure 5. In the figure, the consumer surplus of price drop from p_1 to p_0 is represented by the area p_1, D, B, p_0. The equivalent variation for the same price change is represented by the area p_1, D, A, p_0. The compensating variation for the price change from p_1 to p_0 is represented by the area p_1, C, B, p_0. As can be seen, the consumer surplus is in between compensating variation and equivalent variation measures. Thus, although the consumer surplus does not measure exactly the benefits associated with price (or quality) change, since it ignores

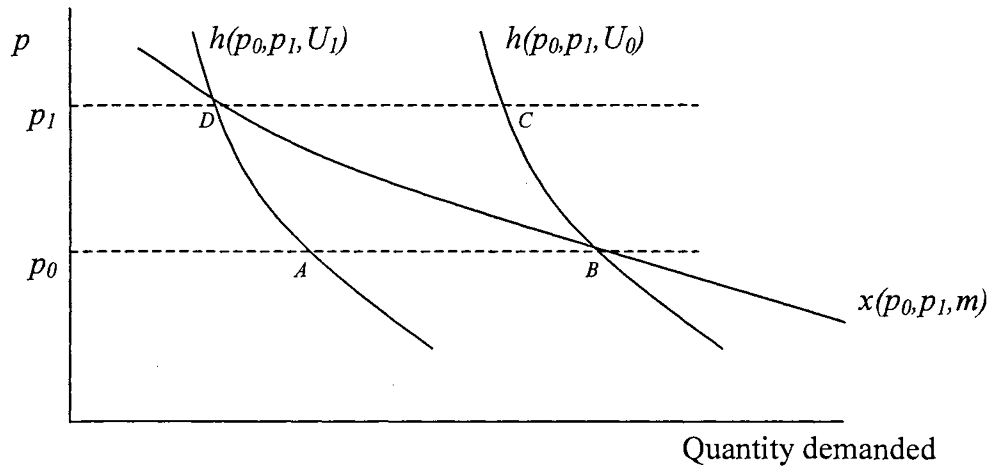


Figure 5. Equivalent and Compensating Variation and Consumer Surplus.

the income effects, it can be used as a fairly appropriate approximation for most studies (Willig, 1976). This is done in the present dissertation where consumer surplus is used as a measure of costs of lost recreational values of lakes Eucha and Spavinaw as a consequence of excessive phosphorus loading in the watershed.

2.4. Overview of the Literature on Biophysical and Hydrologic Modeling

As discussed above, biophysical modeling is a crucial part of the methodology used in the dissertation. The estimated phosphorus runoff, produced biomass and yields that were outputs from the Soil and Water Assessment Tool (SWAT) simulation runs were used in the economic optimization model. This section provides an overview of the general literature on the SWAT model, on studies that used this model for biophysical modeling of the Eucha-Spavinaw watershed, and on studies that used other methods for hydrological and biological analysis of that watershed.

2.4.1. The SWAT Model

SWAT is a hydrological water quality model that uses geographic information systems (GIS) data, to perform parameter estimation and graphical analysis. Hydrologic and water quality models incorporate hydrology and water quality parameters and describe the occurrence and movement of water, nutrients, pesticides and other materials through the hydrological system (Haan and Storm, 1996). SWAT is a basin scale, physically based, continuous time hydrologic model that is used to simulate hydrology, sediment and nutrient dynamics in a large watershed or a basin (Neitch et *al.*, 2002, Arnold et *al.*,1998 , Shrinivasan et *al.*, 1998). It uses input data that are often readily available from government agencies. The data requirements for a biophysical simulation in SWAT relevant for the present study consists of: Digital Elevation Model (DEM) data, soil data layer, land cover data layer, agricultural management data, soil nutrient availability data, precipitation files and stream flow files. SWAT is interfaced with the ArcView software, which is one of the most popular GIS software products (Di Luzio et *al.*, 2001). However, SWAT can be used outside of the ArcView platform as well, and that mode was employed for all runs in this study.

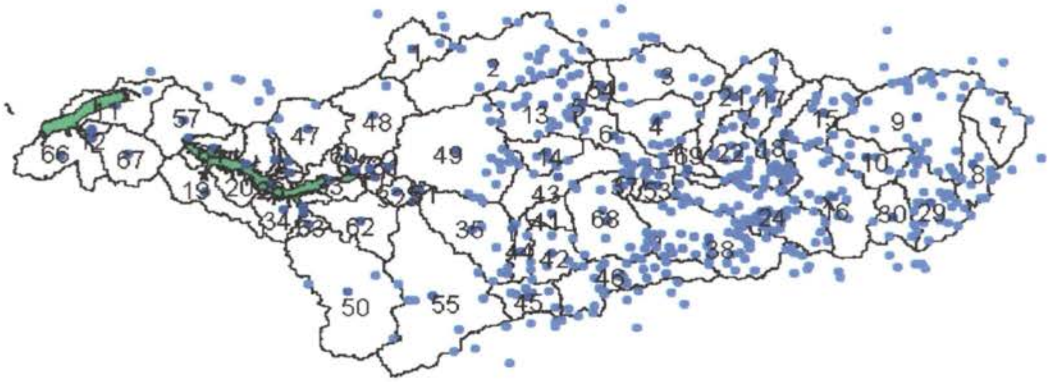
Using the specified data, SWAT partitions the watershed in sub-basins (69 for the Eucha-Spavinaw watershed) and creates unique areas of a land use and soil type combination (hydrologic response units, HRUs) within each sub-basin (1052 HRUs for the whole Eucha-Spavinaw watershed) (Storm et *al.* 2002). The HRUs are homogenous areas of given land use and soil type. Given the watershed delineation, SWAT calculates the catchments parameters and simulates the hydrologic cycle in the watershed. The hydrological cycle has three main components: precipitation, movement of water over and below the land surface and evaporation into the atmosphere. The sediment, nutrient and pesticide movement in the watershed is governed by the simulated hydrological cycle.

The parameters estimated in SWAT need to undergo the process of calibration, to at least partially remove the uncertainty in model predictions. Calibration is based on observed data on water flows and water chemical data. Before using the results, the model is also being validated to ensure that it behaves sufficiently close to the real system that is being modeled. An additional analysis of the uncertainty in the model predictions may also be performed (Hession, Storm and Haan, 1996, Hession and Storm, 1996).

2.4.2. Hydrological and Biological Studies of the Eucha-Spavinaw Watershed

The SWAT model has been recently used for hydrological and water quality modeling of the Eucha-Spavianw watershed (Storm et *al.*, 2002). This dissertation used the calibrated and validated model presented in the cited study and therefore an overview of that study is provided here.

The study modeled the Eucha-Spavinaw watershed using SWAT to evaluate the non-point source nutrient loading to the area lakes and its origins. Available geographic information systems (GIS) and weather data were used in the model. Land cover data were developed from satellite imagery and ground truth data. High detail daily rainfall estimates were derived from Next Generation Weather Radar (NEXRAD) data and incorporated in the model. The SWAT model delineated the watershed into 69 sub-basins and in 1052 hydrologic response units (HRUs). The GIS image of the watershed including the poultry houses is given in Figure 6. Land uses, the number of poultry houses and the quantity of litter produced in the watershed are summarized in Table 3.



Legend: • Broiler Houses ; Numerals - Sub Basins ; Shaded areas - Lakes Eucha and Spavinaw.

Figure 6. GIS Image of the Eucha –Spavinaw Watershed

Table 3. Summary of the SWAT modeled Eucha-Spavinaw Watershed.

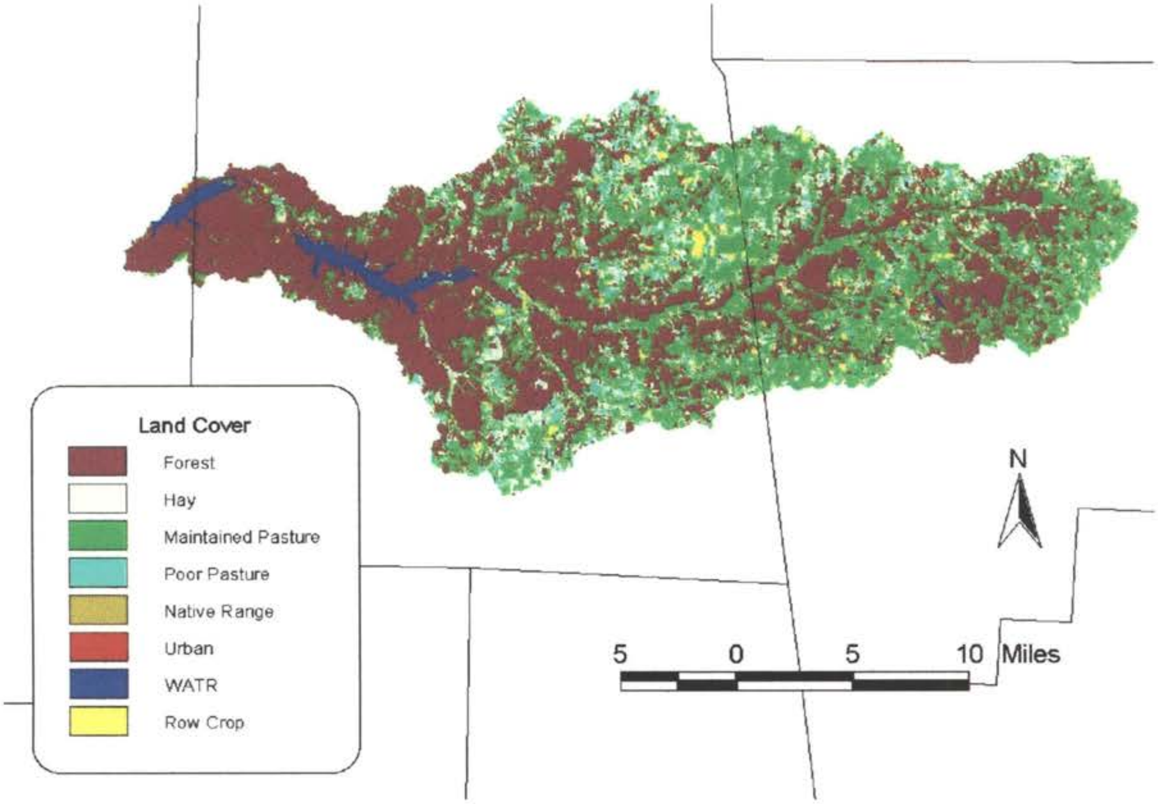
Total Area	1,006 km^2	Sub basins	69
Forested Area	509 km^2	HRU's	1052 (695 agricultural)
Agricultural Land	458km2	Est. no. of broiler houses	957
Urban Area	13 km^2	Est. quantity of litter produced	84000 tons
Water Area	17 km^2	Est. quantity of P runoff	48 tons

The estimated parameters in SWAT pertaining to the hydrologic portion of the model were calibrated using the three USGS stream flow stations. The estimated parameters pertaining to the phosphorus loading portion of the model were calibrated using data from eight water quality stations. The calibrated SWAT model estimated the average annual total phosphorus loading to Lake Eucha to be 48,000 kg/yr, which includes 11,400 kg/yr from the City of Decatur point source for the period 8/1/1998 to 3/15/2002. Out of this 48,000 kg, about 34,000 kg were attributed to agricultural land covers in the watershed (hay, well maintained pasture, overgrazed pasture, and row crop), while the estimated background load was about 2,600 kg/year.

Table 4 presents the estimated area of the agricultural land uses and their percentage contribution to the total land area and the total phosphorus loading in the watershed. The spatial distribution of the land cover in the watershed is presented in Figure 7. The Storm et *al.*, 2002 study found that some agricultural land covers (row crop, overgrazed pasture) contribute disproportionably to the phosphorus loading in the watershed relative to their land area. In this light, the study proposed a land cover pattern change as a potential solution to the problem of the agricultural pollution in the watershed. The study also suggested that phosphorus abatement at the point source would significantly reduce the total phosphorus loading to the lakes in the Eucha-Spavinaw watershed.

Table 4. Agricultural Land Uses in the Eucha Spavinaw Watershed

Land Use	Acronym	Area (ha.)	Land Area (% of total)	Phosphorus loading (% of total)
Grassland used for hay	HAY	13402	13.3%	9.8%
Grassland used for pasture (not maintained)	OPAS	6542	6.5%	11.5%
Grassland used for pasture (well maintained)	WPAS	23250	23.1%	23.2%
Row crop	WWHT	2625	2.6%	13.2%



Source: Applied Analysis Inc

Figure 7. Landsat Thematic Mapper Derived Land Cover for the Lake Eucha/Spavinaw Basin.

Another study of the Eucha-Spavinaw watershed that this dissertation draws upon is the water quality evaluation study conducted by the Oklahoma Water Resources Board (OWRB, 2002). The study assessed the current chemical and biological status of Lake Eucha, Lake Spavinaw and Lake Yahola, which is the terminal reservoir for the Mohawk water treatment plant in Tulsa. The study used both SWAT and BATHTUB models to estimate the effects of changing nutrient loads on the trophic state of the lakes. In particular, a detailed phosphorus budget for the lakes was established. Three trophic state indices were used to express the water quality in the lakes, Secchi depth, Chlorophyll-A content and total phosphorus concentration. The Chlorophyll-A trophic state index serves as the most direct and accurate measure of the trophic status (eutrophication) of a water body, Secchi depth is used to assess the impact of water clarity on the trophic status, while total phosphorus is used to measure the trophic state potential for a water body. The trophic status of a water body is determined by the following values of the trophic state indices (TSI): oligotrophic (high clarity, low algae growth, TSI<40), mesotrpohic (moderately clear water, transition to eutrophic, 40<TSI<50), eutrophic (cloudy water, high algae growth, 50<TSI<60) and hypereutrophic (low water clarity, excessive algae growth, TSI>60).

The OWRB (2002) study found that the trophic status of lakes Eucha and Spavinaw is eutrophic and in some instances hypereutrophic, and linked this trophic status to the excessive external phosphorus loading in the lakes. The study also found that there is a significant potential for a change of the trophic status, from eutrophic to mesotrophic. The study evaluated several possible technologies and policies that would lead to the desired change in the trophic status, and recommended that reduction of the external phosphorus load is the best available option.

Another important aspect covered in this study was a survey of the biological characteristics of the lakes. In particular, the phytoplankton and zooplankton communities in the lakes were analyzed and their presence was linked to the taste and odor causing chemicals in the water. It was identified that species of blue green algae (Cylindrospermosis spp., Anabaena spp., Oscillatoria spp.) and diatoms (Melorisa spp., and Stephanodiscus spp.) were dominating in various time periods and that were causing high concentration of Geosmin and MIB in the water. The presence of the algae was linked to the presence of these two chemicals in the water and to customer complaints for the quality of the delivered drinking water from the Mohawk treatment plant in Tulsa.

The last of the studies extensively used in the preparation of this dissertation was the report published by the Oklahoma Conservation Commission (OCC) as a diagnostic and feasibility study for Lake Eucha. This study approached the problem by considering morphological, hydrological, biological and chemical aspects, but also evaluating the recreational aspects and sociological impacts of changes in the lake water quality. The study found that eutrophication of Lake Eucha has been caused by elevated nutrient loading from Beaty Creek and Spavinaw Creek. It was estimated that Beaty Creek and Spavinaw Creek supply approximately 85% of the phosphorous entering the lake. The study found that the phosphorous in Beaty Creek likely originates from non-point source pollution resulting from agricultural practices associated with the poultry litter application. The phosphorous in Spavinaw Creek likely originates from a combination of both point source pollution (Decatur, AR) and non-point source pollution.

Various lake uses, the economic activities associated with recreation and other social aspects of the lake uses were identified in the study (OCC, 1997). It was stated that Lake Eucha ranks as one of the finest largemouth bass fisheries in the state and offers good channel catfish and crappie fishing. In the course of the study, surveys of recreation visitors to the state parks were conducted. The results from these surveys were used in the present dissertation to determine the zones for the travel cost model, and to allocate percentage participation of the visitors from particular zones to the total number of visits.

2.5. Contributions of the Dissertation

The present dissertation could be classified as a watershed level economic study of agricultural pollution. It builds up on the cited work, and goes beyond the current level of knowledge in this area in several aspects. Mathematically simple methodology is developed and applied whereby GIS based simulation methods are used to generate data for watershed optimization models. The developed methodology would allow policy researchers to determine optimal non-point source abatement patterns that are relevant when setting TMDLs (Total Maximum Daily Loads) for watersheds.

Another contribution of the dissertation is that uses both pollution abatement costs and the environmental damage costs, to obtain a socially optimal level of phosphorus abatement in the Eucha-Spavianw watershed. This has not been done previously, at least not at the level of disaggregation presented here. Many of the studies cited used exogenous goals of pollution reduction. Further, within the abatement costs estimation, the dissertation explicitly considers both point and non-point sources of pollution. This point/non-point tradeoff is brought to a level beyond cited studies, by explicitly modeling abatement technologies at both types of sources and estimating the associated abatement costs. As an extension to models of smaller watersheds presented in cited studies, this dissertation models a larger scale watershed, at a high level of spatial detail. The model determines optimal poultry litter management practices and land use patterns, which can be used to improve the efficacy of site-specific regulation policies. Finally, the developed methodology provides a framework upon which some future studies regarding general aspects of agricultural pollution in the watershed could be built.

CHAPTER III

CONCEPTUAL FRAMEWORK

As noted before, the dissertation approaches the problem of phosphorus loading in the watershed from a social perspective, or a perspective of a hypothetical watershed manager. The objective of the manager would be to choose a particular level of phosphorus abatement that would maximize total benefits to the society, accounting for the interests of both the polluters and the parties affected by pollution. Given this objective, the conceptual framework of the dissertation is based on the notion of minimizing the sum of pollution abatement costs and environmental damages costs (Freeman, Haveman and Kneese, 1973). To explain this concept, let W represent the total social well-being function. Then, the following relationship can be stated

$$W = M + E, \tag{3.1}$$

where M represents the value of the market goods and services consumed in a society (poultry and agricultural crops for the study of interest), which are usually accounted for in the national accounts of a country, and E represents the value of environmental services directly or indirectly consumed in a society (clean water). Define E^* as the maximum potential value of environmental services obtained from a pristine environment. Define D as the costs of environmental damages caused during the processes of production and consumption of market goods and services (ex. difference in drinking water treatment costs between treating polluted water and pristine water). The value of environmental services actually provided is then

$$E = E^* - D. \tag{3.2}$$

Let M^* denote the maximum value of market goods and services that could be produced in a society when no resources are devoted to pollution abatement. Then

$$M = M^* - A, \tag{3.3}$$

where A represents the costs associated with pollution abatement technologies (ex. more expensive poultry litter management practice that reduces phosphorus runoff, and/or more expensive treatment of the municipal wastewater). The total social well-being function can then be written by substituting Eqs. (3.2) and (3.3) into Eq. (3.1) as

$$W = (M^* - A) + (E^* - D) = M^* + E^* - (A + D). \tag{3.4}$$

Since M^* and E^* are fixed, the total social well-being can be maximized by minimizing the sum of pollution abatement costs and environmental damage costs.

Suppose that both the abatement costs and the damages costs are functions of a single pollutant (p - phosphorus). It follows from Eq.(3.4) that the social well-being will also be a function of that pollutant. The following optimization problem arises

$$\max_p W(p) = M^* + E^* - \left(A(p) + D(p)\right). \tag{3.5}$$

To obtain a solution to the above problem one needs to differentiate the well being function with respect to p and set the derivative equal to zero

$$\frac{dW}{dp} = -\frac{dA}{dp} - \frac{dD}{dp} = 0 \quad \Rightarrow \quad -\frac{dA}{dp} = \frac{dD}{dp}, \tag{3.6}$$

where dA/dp represents marginal abatement (treatment) cost and dD/dp represents marginal environmental damage costs. The minus sign before the marginal abatement cost simply indicates that they are "read" from right to left, (Pearce and Turner, 1990). Marginal abatement cost is the change in treatment cost as an additional unit of pollutant is abated while marginal damage cost is the change in the cost of environmental damages as an additional unit of pollutant is discharged (not being abated). It follows directly from Eq. (3.6) that if the social well-being is to be maximized, the marginal abatement costs must be equal to the marginal environmental damage costs. Consequently, the optimal level of abatement (the one that will maximize *W*) occurs where the marginal cost of abating an additional unit of pollutant is just equal to the marginal cost of environmental damages caused by that unit of pollutant. To ensure that the derivative taken in Eq. 3.6, corresponds to the point of maximum of the welfare function (the welfare function is concave in pollution), the second order derivative has to be non-positive

$$\text{(3.7)} \qquad \frac{d^2W}{dp^2} = -\frac{d^2A}{dp^2} - \frac{d^2D}{dp^2} \leq 0 \quad ,$$

implying that both $\frac{d^2A}{dp^2}$ and $\frac{d^2D}{dp^2}$ should be non-negative at the optimal point. This is quite intuitive, since this requirement states that the abatement cost function should be increasing at a non-decreasing rate as the amount of abatement increases. For the damage cost function this requirement goes in opposite direction, stating that the damage cost function should be increasing at a non-decreasing rate as the amount of abatement decreases. In essence, this requirement is equivalent to the convexity requirement for the abatement and damage cost functions.

For the above theoretical approach to be operational in the case of phosphorus pollution in the Eucha – Spavinaw watershed, empirical estimation of both the abatement and the environmental damage cost is needed. The theoretical concepts used in the estimation are discussed further.

3.1. Abatement costs

The abatement costs in this dissertation consisted of phosphorus abatement costs to the point source and the non-point sources of phosphorus loading in the Eucha-Spavinaw watershed. The abatement costs for a point source were modeled as costs of wastewater treatment used to attain various levels of phosphorus emissions. Abatement costs for non-point sources were approximated by changes in expected net income from agricultural enterprises under alternative poultry litter and land management techniques.

To theoretically derive the marginal abatement cost, an optimization problem was set up with an overall objective to maximize producers' income from agricultural activities at the watershed level minus the abatement cost at the point source, subject to a limit for total phosphorus pollution in the watershed. The total pollution limit could then be parametrically varied to derive the marginal abatement cost curve. To model the agricultural enterprises in the watershed, assume that the watershed is composed of n unique land areas each denoted by index i. Let the quantity of agricultural production from the i^{th} land area be denoted by $\mathbf{Y}_i = f_i(\mathbf{X}_i)$, where $\mathbf{X}_i$ is the vector of input quantities (litter) used in area i, and $\mathbf{Y}_i$ is a vector of agricultural outputs produced on that land area (hay, beef). Let Z_i be the amount of an agricultural pollutant that leaves area i when $\mathbf{X}_i$ units of input are used, $Z_i = g_i(\mathbf{X}_i)$. In this study, Z_i denotes the quantity of total phosphorus loading from the $i'th$ land area. The total allowed quantity of pollution in the watershed is denoted by $Zmax$. It is assumed that the region of the watershed is sufficiently small so that all commodity (**Py**) and input (**Px**) prices are fixed in the short-run.

The profit to the agricultural producer operating in the *i'th* land area is [2]

$$\Pi_i(\mathbf{X}_i) = \mathbf{Py}' f_i(\mathbf{X}_i) - \mathbf{Px}_i'\mathbf{X}_i . \tag{3.8}$$

Total net benefits from agricultural production for the whole watershed are represented by the sum of the profits over all *n* land areas, $\sum_{i=1}^{n} \Pi_i(\mathbf{X}_i)$. The constrained profit maximization problem is to maximize total profits from agricultural activities in the watershed net of the abatement cost at the point source, subject to a limit on total phosphorus pollution. The abatement cost at the point source under the j^{th} level of treatment is denoted by PSC_j. The resulting phosphorus load from the municipal wastewater treatment system is denoted by ZPS_j. Clearly, *PSC* is a function of ZPS_j, denoted by *PSC(ZPS).* The optimization problem can be expressed in the form of the Lagrangian function as

$$\max_{\mathbf{X}_i, Z, ZPS_j, \lambda_i, \Psi} L = \left(\sum_{i=1}^{n} \Pi_i(\mathbf{X}_i) - PSC(ZPS_j) \right) + \sum_{i=1}^{n} \lambda_i [Z_i - g_i(\mathbf{X}_i)] + \Psi \left(Z_{\max} - \sum_{i=1}^{n} Z_i - ZPS_j \right), \tag{3.9}$$

where the Lagrangian variables λ_i and Ψ represent the changes in the value of the objective function that would result from a change in the allowable phosphorus loading. Ψ represents the amount of net income gained (lost) if the quantity of allowable phosphorus pollution from the entire watershed is increased (decreased). The term λ_i represents the change in profits from the land area *i* as a result of a change in the quantity of phosphorus pollution from the *i*'th land area due to a change in the quantity of poultry litter applied, X_i.

The first order conditions of the Lagrangian function (Eq.3.9) with respect to the control variables $\mathbf{X}_i$, Z_i, ZPS_j, , λ_i and Ψ are respectively given by

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[2] Only the agricultural outputs from crop production and grazing are considered in the study. The poultry production in the watershed is held constant at current levels.

(3.9.1) $L_{X_i} = \Pi'(\mathbf{X}_i) - \lambda_i (g_i'(\mathbf{X}_i)) = 0, \quad \forall i,$

(3.9.2) $Lz_i = \lambda_i - \Psi = 0, \quad \forall i,$

(3.9.3) $L_{ZPS_j} = PSC'(ZPS_j) - \Psi = 0, \quad \forall j$

(3.9.4) $L_{\lambda i} = Z_i - g_i(\mathbf{X}_i) = 0, \quad \forall i,$

(3.9.5) $L_\Psi = Z_{max} - \sum_{i=1}^{n} Z_i - ZPS_j,$

where the subscripts on the left-hand side denote the partial derivative of the Lagrangian function taken with respect to a variable and the terms Π', g' and PSC' on the right hand side denote first order derivatives.

Equation 3.9.2 indicates that $\lambda_i = \Psi$ for each of the n land areas. This is reasonable in the case where pollution flows are channeled and there are no pollutant transport losses within the reach system of the watershed. The biophysical simulation in this study did not consider transport losses of phosphorus.

Equations (3.9.1) and (3.9.2) can be combined to obtain

(3.10) $\Pi'(\mathbf{X}_i) = \Psi g_i'(\mathbf{X}_i), \quad \forall i.$

At the optimum, the marginal profit from using an additional unit of an input is equal to the marginal abatement costs to remove the pollution caused by the use of that input. Also, substituting in Eq. (3.10) from Eq. (3.8)

(3.10.1) $\boldsymbol{Py}`\, f_i(X_i) = \boldsymbol{Px}_i + \Psi g_i'(\mathbf{X}_i),$

which states that the optimal quantity of input **X** to use in the *i'th* land area is the quantity $\mathbf{X}_i$ for which the value of the marginal product is equal to the marginal factor cost plus a penalty cost (or tax) on phosphorus loading that insures the maximum allowed phosphorus pollution is not violated. From Eqs.(3.9.2) and (3.9.3), $PSC'(ZPS_j) = \lambda_i$, the optimal level of phosphorus abatement at the point source is where the marginal abatement cost at the point source is equal to the marginal abatement cost at each non-point source. Since the calculations are expected to be unique for each area *i*, the model should allow for the quantity of input $\mathbf{X}_i$ to be unique to each land area. This implies that the optimal litter application rate, as well as all other litter management practices are non-uniform across individual land areas. The marginal abatement costs would consequently be equal to the shadow prices on the phosphorus constraints that in this case are equivalent to each other and correspond to the estimated Lagrangian multiplier.

3.2. Environmental damage costs

Two main environmental damages caused by phosphorus pollution in the watershed were identified as the impairment of the quality of drinking water for city of Tulsa (OWRB, 2002) and the losses of recreational values of the area lakes, reflected in a drastic reduction of annual visitation to the Eucha and Spavinaw state parks (OTRD, 2003). This section briefly discusses the theoretical concepts used in the estimation of these costs.

The costs for the additional water treatment to the City of Tulsa could be estimated directly as a function of the observed phosphorus load in the lakes (or the phosphorus concentration in the water) as

$$CT_t = \Gamma(Z_t; \varepsilon_t), \tag{3.11}$$

where CT_t represent the observed cost of additional drinking water treatment to the City of Tulsa in time period *t*, Z_t represents the observed phosphorus load in the watershed from both non-point sources (Z_{it}) and the point source (ZPS_{jt}) in time period *t*, and

$\varepsilon_t \sim N(0, \sigma^2)$ represents random disturbance. The time periods t considered in estimation could be months or years and a choice between them should be made based upon the estimation results and their practical interpretability.

The theoretical concept of travel cost was used in the estimation of the recreational losses attributed to phosphorus pollution in the watershed. As discussed above, the consumer surplus was used as a welfare measure for quantification of recreational benefits associated with water quality improvement, or equivalently for quantification of the recreational losses associated with higher levels of phosphorus loading in the lakes. The zonal approach, where the visitors to the site are allocated to several iso-travel cost zones allows for computation of the consumer surplus separately for each zone. Total consumer surplus for the site is the sum of consumer surpluses over the individual iso-travel cost zones

$$CS = \int_{i} \int_{p_i}^{MWP_i} x_i(p_i, MWP_i, m_i) \,, \tag{3.12}$$

where CS denotes the total consumer surplus for the site, i is an index for the iso-travel cost zones, p_i is the average travel cost from zone i, MWP_i is the average maximum willingness-to-pay for recreation at a particular site for the visitors from zone i, and m_i is the average per capita income for the zone i. The demand functions for each iso-travel cost zone x_i can be represented by

$$x_i = \Lambda(p_i, MWP_i, m_i; Q; \mu_i), \tag{3.13}$$

where Q_l denotes the number of visits per 1000 population from the zone i, μ_i represents the random disturbance, while MWP_i is the maximum willingness-to-pay as before, which is distinct for each zone i, and effectively represents the intercept parameter.

However, the maximum willingness-to-pay is likely to change for the visitors from all zones in response to changes in water quality. Therefore, allow for the intercept parameter in Eq. 3.13. to be a function of phosphorus concentration in the lake

$$MWP_i = \gamma\,(\mathbf{r};PC;\varphi), \qquad (3.14)$$

where, PC denotes the phosphorus concentration in the lake which is a function of the phosphorus load, $PC = \Gamma(Z)$ and Z is the total phosphorus loading in the watershed (from both point and non-point sources), **r** represents a vector of parameters to be estimated and φ represents a vector of random normal disturbances. Substituting for MWP from Eq.(3.14.) into Eq.(3.13.) and (3.12.) makes the consumer surplus an implicit function of the phosphorus concentration in the lakes (and consequently of the phosphorus loading in the lakes). The change in consumer surplus, as the phosphorus loading increases from one level to another could be used as an approximation for the costs of recreational losses. The expression $\Delta CS / \Delta Z$ in the context of Eq. (3.12.) would not represent a closed form and would hence not have an analytical solution. However, direct numerical computations could be used to approximate the changes in the consumer surplus that correspond to the costs of recreational losses caused by phosphorus loading in the watershed.

The sum of costs of additional drinking water treatment to the City of Tulsa and cost of lost recreational values represent the total cost of environmental damages, $D = CT(Z) + \Delta CS(Z)$, where both terms are functions of phosphorus load in the watershed. The marginal damage costs are obtained by differentiating the total damage cost function with respect to the phosphorus load. Optimal phosphorus abatement level is derived using the condition described in Eq.(3.6).

CHAPTER IV

METHODS AND PROCEDURES – CALCULATING ABATEMENT AND DAMAGE COSTS

4.1. Calculating Costs of Alternative Technologies to Reduce Phosphorus Loading in the Eucha-Spavinaw Watershed

4.1.1. Point Source Phosphorus Abatement Technology and Associated Abatement Costs

The City of Decatur, Arkansas is a major source of phosphorus loading in the Eucha-Spavinaw watershed (Storm et *al.*, 2002, OWRB, 2002, OCC, 1997). The reason for such high phosphorus loading from community as small as Decatur is the Peterson Farms poultry processing plant, which is located in the town. As is the case in many small communities in the United States (Rossi, Young and Epp, 1979), the wastewater treatment process for the municipality and the processing plant is combined to achieve greater economic efficiency. The current wastewater treatment system of the City of Decatur consists of treatment in bioreactors (lagoons). This system discharges on average 1.16 million gallons per day (MGD) of flow into a surface water stream (Colombia Hollow). Some of the characteristics of the effluent are presented in the following table (ARDEQ, 2001).

Table 5. Average Characteristics of the Effluent from the City of Decatur Sewage Treatment Plant for the period 1/31/1990 to 3/31/2001

Average Daily Flow	Average pH value	Average concentration of phosphorus*	Average concentration of nitrates	Average concentration of ammonia	Average concentration of BOD
MGD	Value	mg./l	mg./l	mg./l	mg./l
1.16	6.64	6.54	25.09	8.05	3.74

*Measures of P concentration start from 11/30/1997.

Source: Arkansas Department of Environmental Quality (ARDEQ, 2001)

Table 5 shows that the effluent has a very high phosphorus concentration. The literature reports a value of around 1 mg/l phosphorus concentration of the effluent when using best available technology (Metcalf&Eddy, 2003). The concentration of the effluent from Decatur exceeds this benchmark by more than six times and consequently contributes an average of 11,686 kilograms of phosphorus loading per year to the lake Eucha. This represents 24 percent of the estimated total phosphorus load of 48,000 kg (Storm et *al*., 2002). Therefore, a reduction in the phosphorus concentration of the effluent from the City of Decatur may provide a significant and cost effective reduction of total phosphorus load.

To model the cost of phosphorus abatement in the wastewater effluent from the City of Decatur, a specific design for the additional wastewater treatment had to be modeled. Chemical treatment using aluminum sulfate was chosen due to its relative simplicity and cost effectiveness for comparably small treatment plants. The effectiveness of alum precipitation for reduction of phosphorus concentration in wastewater has been reported for a number of North American and European wastewater treatment plants (Klute and Herman, 1994, WPCF, 1983). The process is based on the chemical reaction involving the aluminum ion (Metcalf & Eddy),

$$Al^{+++} + H_n PO_4^{3-n} \leftrightarrow AlPO_4 + nH^+. \tag{4.1}$$

The aluminum ion precipitates phosphorus as flocs of aluminum phosphate that can be removed from wastewater in the form of sludge.

The particular design used to estimate the costs of phosphorus abatement is presented in the Appendix Figure A1. The design consists of several components: Structures and equipment for alum addition; Settling basin for flocs; Gravity thickener for primary sludge; Liquid/Solid Separation for secondary sludge; Transportation and landfilling of wastewater treatment residuals (WWTR). Individual components of the design are briefly discussed in the following text.

1) Structures and Equipment for Alum addition

The structures and equipment for alum addition consist of storage for the alum product, conveyors, feeder, dissolver, holding tank, a pump and a flocculation chamber. The design and cost estimation is based on EPA, (1980), Fact Sheet 5.1.1. Since the cost calculations by EPA (1980) are based on an alum dose of 200 mg/l, the effective flow was calculated for alternative alum dosages by using the suggested formula:

$$Q_E = Q_D * (\text{Actual Alum Dose} / 200\ \text{mg/l}),$$

where Q_E is the effective flow and Q_D is the design flow (equal to the average daily flow of 1.16 MGD). Construction costs for each effective flow were then taken from the cost curve provided in the fact sheet. Operation and maintenance cost net of chemical cost (since the alum usage and price ($0.06/lbs) were obtained outside the fact sheet) for each effective flow were also read from the corresponding cost curve. Since the cost data in the fact sheet were given in 1976 prices, the costs were inflated by the factor 2.4514 to obtain current cost levels. This factor was determined by using an inflation calculator for adjusting costs from one year to another using the Gross Domestic Product (GDP) Deflator inflation index available at NASA web site (NASA, 2003). The inflation calculator is based on the inflation rate during the US Government Fiscal Year, which begins on October 1 and ends on September 30. The calculator is able to convert nominal to current cost for the period 1940 to 2005.

The construction costs (capital costs) were annualized using the suggested 20-year amortization period and 6 percent interest rate. The total annual costs of alum addition were obtained as a sum of annualized capital costs and operation and maintenance cost.

2) Settling basin for flocculation.

After alum is added and flocculation is completed, the wastewater is directed toward a settling tank where the flocs settle and form sludge, which collects in the bottom of the tank and may be released from there. The designed size of the settling tank was based on hydraulic retention time of 120 minutes, degree of flocculation of 30, on mean velocity gradient of 20, and safety factor of 10 percent (Henze et *al.*, 1983).

The capacity of the settling tank was calculated at 106,400 gallons as a function of the average daily flow of wastewater and the required retention time, increased by the safety factor of 10 percent. The cost of constructing the settling tank was obtained by using the data from MEANS Construction Costs (2000) (page 444). The costs for the desired capacity were extrapolated using the estimated function: $Y = 8.19*X^{-.3815}$, where Y is the cost in \$/gallon and X is the capacity of the tank in thousand gallons. It is assumed that the settled sludge removed from the settling tank contained 2 % solids (Sitig, 1969). The relationship between sludge creation and alum addition was adopted from Klute and Hahn (1994) as seven grams of sludge for each gram of alum added.

3) Gravity thickener for primary sludge

After exiting the settling tank, the sludge is directed through a gravity thickener to achieve higher concentration of solids and reduce the disposal costs. The design of the gravity thickening process and estimation of associated costs were also based on EPA

(1980), Fact Sheet 6.3.7. The calculations assumed three days retention time. The effective flow for various alum dosages and hence for various sludge quantities were calculated according to the proposed formula:

$$Q_E = Q_D * [\text{new sludge mass} / 820 \text{ lb/MGD of flow}],$$

where Q_E is the effective flow and Q_D is the design flow (average daily flow of 1.16 MGD). The construction costs were read from the cost curve in Fact Sheet 6.3.7. for each effective flow. Operation and maintenance costs were calculated in a similar manner, using the provided cost curve. Costs were translated to current prices using the above-mentioned inflation calculator. The construction costs were annualized using a 20-year amortization period and 6 percent interest rate. Total annual costs were calculated as a sum of the annualized construction and operation costs. The solids concentration of the sludge exiting the gravity thickener was assumed to be 10 percent.

4) Liquid/Solid Separation for secondary sludge

The sludge from the thickener was modeled as passing over an inclined screen separator to achieve greater solids concentration. The cost of separation is a function of the volume of sludge coming from the thickener, which is directly related to the applied alum dosage. The Department of Agricultural Economics, Oklahoma State University has developed a swine waste management decision support system, which contains a routine for calculating Liquid/Solid separation costs (Ancev, Stoecker and Carreira, 2001). The decision support system was used to generate estimates of separation costs for various volumes of sludge coming from the thickener. Final waste materials after the separation were assumed to be wastewater residuals containing 40-50 percent solids.

5) Transportation and landfilling of wastewater treatment residuals (WWTR)

It was assumed the WWTR were transported 10 miles to a landfill site at cost of \$20 per cubic yard, (MEANS 2000, page 64). A landfilling fee of \$40 per ton was also assumed (MEANS 2000, page 50).

The detailed cost calculations for all alum dosages are given in the Appendix Table A1. These costs in effect represent abatement costs at the point source. For each alum dosage there is a corresponding level of phosphorus abatement and associated abatement cost. Abatement costs at the point source of phosphorus loading were subsequently used in the mathematical programming model to determine the marginal abatement costs at the watershed level.

4.1.2. Non-Point Source Phosphorus Abatement Technologies and Associated Abatement Costs

4.1.2.1 Reducing Litter Application Rate

One way to reduce phosphorus loading in the watershed would be to reduce the amount of litter applied on the agricultural land within the watershed. This could be achieved by reducing the litter application rate applied on the crops. Since the agricultural enterprises in the watershed are heterogenous with respect to grown crops, soil types, and topography, it is to be expected that the optimal litter application rate would be different for each spatially distinct agricultural HRU. The optimality of the litter application rate is regarded here both in relation to the crop yield response to nutrients applied with the litter (nitrogen and phosphorus) and in relation to the phosphorus runoff from any given HRU. The goal of economic modeling is to allocate the litter produced in the watershed to the agricultural HRUs according to the economic criterion of highest value of the marginal product and at the same time to account for the total phosphorus loading at the watershed level [3].

In previous modeling (Storm et *al.*, 2002), the litter was allocated on a sub-basin basis, by allocating the litter produced in every sub-basin uniformly to the agricultural uses in that sub-basin. In this dissertation, a transportation component to the economic model was developed that allows shipment of litter among the sub-basins in the watershed as well as shipping of litter out of the watershed. Transportation costs within the watershed were estimated using the distances between sub-basins calculated with the Network Analyst Extension software for ArcView. The costs for transporting litter out of the watershed were approximated by using the potential for manure phosphorus application of the surrounding counties in the states of Oklahoma, Arkansas, Kansas and Missouri (Gollehon *et al.*, 2001) and estimated distances.

If the farmers were required to reduce or halt the application of poultry litter on their land, they may choose to replace nitrogen by purchasing and applying commercial fertilizer. Under the profit maximization hypothesis, the farmers should apply nutrients up to the point where the value of the marginal product of nutrients is equal to the marginal cost of purchasing commercial fertilizer. In most cases, commercial nitrogen is more expensive than nitrogen from poultry litter and hence the farmers would not apply commercial nitrogen at the same rates as they apply nitrogen from poultry litter. On the other hand, nitrogen is am important nutrient for plant growth, which affects the quality of land cover, and ultimately the potential for erosion and nutrient runoff. All else equal, the more nitrogen applied on the land, the better the land cover would be and the lower

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[3] The value of the marginal product is defined as the value of the product (crop yield) produced by using an additional unit of input (litter).

the phosphorus runoff (however nitrate runoff may increase). Since this dissertation looks at the phosphorus loading from a social perspective (watershed manager) the nitrogen has a role in preventing phosphorus runoff. Consequently the economic model allows for a choice between substituting nitrogen with commercial fertilizer or not when the litter application rates are reduced.

Table 6 presents the alternative litter application rates by agricultural land uses in the watershed and the quantities of nitrogen applied under the two alternative strategies regarding nitrogen replacement with commercial fertilizer. The agricultural land uses are hay (HAY), overgrazed pasture (OPAS), well maintained pasture (WPAS) and row crop (WWHT), which was simulated as a grazeout wheat / green bean rotation.

Table 6. Alternative Litter Application Rates for Agricultural Land Uses and Quantity of Nitrogen Applied under Nitrogen Replacement (N w. replac.) and no Nitrogen Replacement (N w/o replac.) strategies in the Eucha-Spavinaw Watershed

Land Uses											
HAY			OPAS			WPAS			WWHT*		
Litter rate	N w. replac	Nw/o replac	Litter rate	N w. replac	Nw/o replac	Litter rate	N w. replac	Nw/o replac	Litter rate	N w. replac	Nw/o replac
kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
6000	300	300	3230	161.5	161.5	6000	300	300	1950	132.7	132.7
4800	240	240	2585	130	130	4800	240	240	1560	113	113
4000	200	200	2154	107.7	107.7	4000	200	200	1300	100	100
3400	200	170	1830	107.7	91.5	3400	200	170	1105	100	90.5
3000	200	150	1615	107.7	81	3000	200	150	975	100	84
2000	200	100	1077	107.7	54	2000	200	100	650	100	68
1000	200	50	538	107.7	27	1000	200	50	325	100	51
0	200	0	0	107.7	0	0	200	0	0	100	35.2

* The row crop receives 35.2 kg/ha nitrogen irrespective of the litter application rate.

Phosphorus could only be applied using poultry litter (no substitution possibility with commercial fertilizer) and for each litter application rate the applied phosphorus was calculated as 1.5 percent of the applied quantity of litter. The litter and nitrogen application rates were based on fertilization recommendations. For grassland land uses (hay (HAY) and well-maintained pasture (WPAST)) the rates were based on OSU Extension Fact sheet F-2559. Based on the recommendations, a litter application rate of 4000 kg/ha was assumed as a base case application rate. The two higher litter application rates (4800 kg/ha and 6000 kg/ha) assumed nitrogen always came from the poultry litter. The five lower application rates in Table 6 assumed that nitrogen could be replaced or not replaced from commercial fertilizer. Overgrazed pasture (OPAS) was assumed to receive less fertilizer than well-maintained pasture (WPAS) (a fixed proportion of 0.538) as one of the characteristics that distinguishes these two land uses. This assumption was based on the land cover satellite imagery data and ground truth data.

For row crops, fertilizer recommendations were based on OSU enterprise budgets for grazeout wheat, and on recommendations for green beans from various sources. These recommendations are reflected in the base litter application rate of 1300 kg/ha with two higher and five lower litter application rates. In addition to the application of litter the row crop was simulated as always receiving 35.2 kg/ha of nitrogen from commercial fertilizer (anhydrous ammonia), irrespective and independent of litter application.

The SWAT model simulations were run for the eight levels of litter application rates (the baseline level, two higher levels, and five lower levels) in combination with the two nitrogen replacement strategies for a total of thirteen SWAT simulation runs. [4] Yield, produced biomass, grazed biomass and phosphorus runoff was taken from the SWAT output files for each of the 695 agricultural HRUs in the watershed. These results were used as inputs to the mathematical programming model discussed below.

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[4] Eight litter application levels, for five of which there is a choice between replacing nitrogen or not (8 + 5 =13).

Net income from agricultural activities was estimated using data from the SWAT model (yield and biomass data), the Oklahoma State University Enterprise Budgets (OCES, 2003), and data from various published (USDA, 2002) and unpublished (personal communications) sources. An overview of prices and costs used in the computations is provided in Table 7.

Table 7. Prices, Costs and Conversion Factors Used in Estimating Income from Agricultural Activities in the Eucha –Spavinaw Watershed.

Prices:		Cost :	
Hay	$60/ton	Litter appl.	$4/ton
Beef	$1300/ton	Urea appl.	$12/ha.
Green beans	$230/ton	Urea	$200/ton
		Alum	$220/ton
Conversion:		Costs of transporting poultry litter	$0.12/ton/mile
Mixed pasture/Beef	10 kg / 1 kg		
Wheat pasture/Beef	7 kg / 1 kg		

The net income for the four types of agricultural enterprises: HAY, overgrazed pasture (OPAS), well-maintained pasture (WPAS), and row crop (WWHT), in each HRU were estimated by using the OSU enterprise budgets (OCES, 2003) to calculate the costs of production. Revenues for hay were calculated using the prices in Table 7 and the yields obtained from the SWAT output. Net income was obtained as the difference between revenues and costs. Revenues for well-maintained and overgrazed pasture were estimated using the exogenous price for beef and the calculated annual beef weight gain from the SWAT output. There was a difference in the cost structure for well-maintained and overgrazed pasture reflecting the differences in management. Net income for the row crop was estimated by using the enterprise budget for calculating production costs for grazeout wheat, the exogenous price for beef and the SWAT based calculations for beef weight gain to calculate the revenues, and an enterprise budget to calculate the net income for green beans (Greaser and Harper, 1994).

4.1.2.2. Using Alum to Reduce Phosphorus Loading

Aluminum sulfate (Alum) is characterized with potential to tie up soil labile phosphorus and transform it into more stable aluminum phosphate compounds that are insoluble and hence are not readily available for plant and algae uptake (Moore and Miller, 1994). The possibility to add aluminum sulfate to the litter was modeled using data published in Moore (1999). The alum product is added to litter in the poultry house in a ratio of 1 part alum to 10 parts litter. Alum ties up phosphorus, thereby significantly reducing the potential for soluble phosphorus runoff once the litter is applied to agricultural land. The reduction of phosphorus runoff when alum treated litter is used was estimated from the experimental data published by Moore (1999) from a controlled small-scale watershed experiment. The experiment showed that the addition of alum reduced the phosphorus runoff attributed to litter application by 75 percent. This result was incorporated in the modeling as

$$Prunoff\ alum = ((1 - 0.75)(P\ current - P\ zero)) + P\ zero, \tag{4.2}$$

where $P\ current$ is the phosphorus runoff under given litter application rate and $P\ zero$ was the phosphorus runoff under zero application rate. Phosphorus runoff was assumed to occur even if no litter were applied because of phosphorus already accumulated in the soil. Net income estimates from the agricultural activities in HRUs where alum treated litter was applied were lowered by 2 percent. Some studies found that the use of alum increases the income to the poultry growers, which is attributable to the reduction of ammonia emissions and consequent reductions of health related costs and ventilation costs as well as improvement in growth performance (Moore, 1999). However, a confirmation to this finding is not widely observed in the practice. Even if these economic effects of treating the litter with alum are present, they pertain to the poultry growers and integrators and are not necessarily passed on to crop and cattle growers. The reason for this may be asymmetric information and/or income distribution problems. It is conceivable to think that using alum treated litter would inflict some costs at least to crop producing farmers. Therefore a small, arbitrary reduction of income was assumed.

The possibility to add alum to the litter is treated as a management practice for reduction of phosphorus loading in the watershed. Alum treated litter is regarded as a resource separate from the non-treated litter. In effect, the economic linear programming model takes the litter as produced in the poultry house and either allocates it to an alum treated litter accounting row or to non-treated litter accounting row. Both types of litter could be shipped between the sub-basins in the watershed. The model can apply one of the two types of litter (alum treated or not treated) at previously defined litter application rates to each agricultural HRU in the watershed. The litter application rates used for both alum-treated and non-treated litter were the same as described in Table 6. Thus, including alum, the various litter application rates and the two strategies for nitrogen replacement there were 24 distinct litter management activities defined for each of the 694 HRU's (13 litter application rates which can be either with alum treated or non-treated litter except for the zero litter application rate, where obviously no alum is applied, hence 13 + 11 = 24).

4.1.2.3. Litter Application According to Soil Test Phosphorus (STP)

Another possible management strategy at the disposal of a watershed manager aiming at reducing phosphorus loading for the watershed as a whole would be to allow litter application only to those soils where the Soil Test Phosphorus is not higher than a certain critical value. Soil Test Phosphorus (STP) index is used to represent the amount of phosphorus needed in a fertilizer or manure program for obtaining optimum yield. Above a certain value of STP the yield reaches the plateau and it is not responsive to further application of phosphorus. For Oklahoma, this value is often stated as a STP value of 120 (120 lbs of available P per acre), as described in OSU Extension Fact sheet F-2249. At this value, the soil has sufficient phosphorus that could be used for plant uptake. A great proportion of any additional phosphorus applied to the soils with high STP may runoff during storm events. Therefore, the usual recommendation is not to apply poultry litter on the soils with STP higher than 120. This recommendation was not followed in the Eucha-Spavinaw watershed in the past, especially not on the Arkansas side of the watershed where the litter is continuously used for its nitrogen fertilizer value, resulting in high STP values of the soils. Figure 8 presents the average spatial distribution of STP by sub-basins across the Eucha-Spavinaw watershed. In addition to the critical value of 120, STP thresholds of 200, 250 and 350 were also considered.[5]

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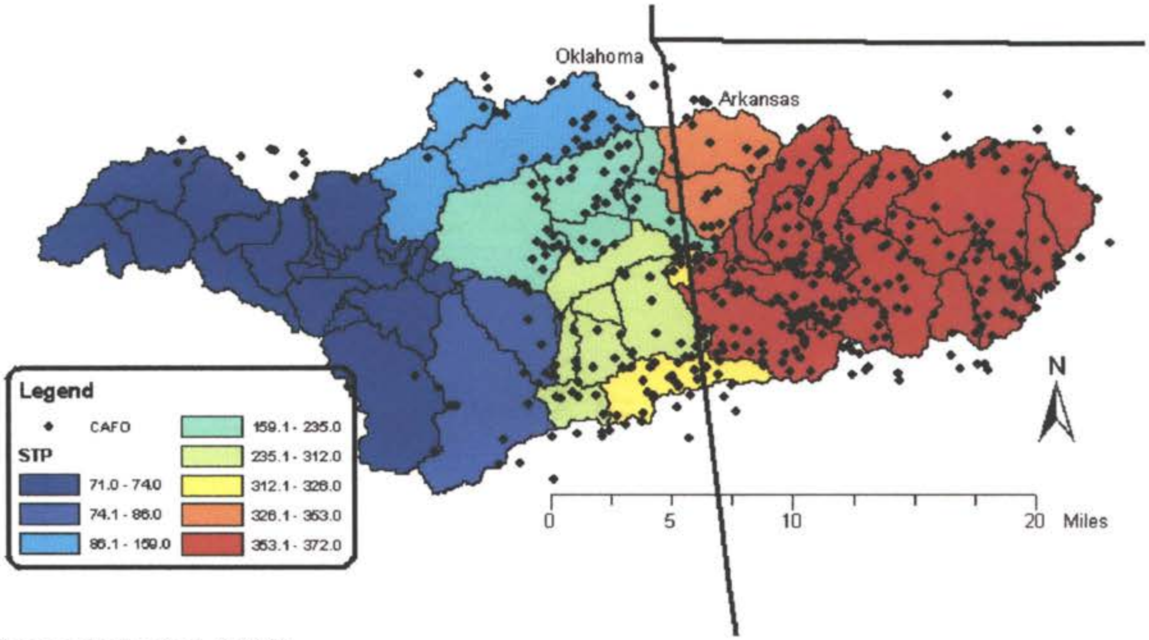
[5] Litter application is not recommended to any soil with STP higher than 120. In the economic analysis however the threshold values of 200, 250 and 350 were also included, to analyze the changes in the net income and in the transportation patterns when the STP criterion is relaxed.



Source: Storm et al. (2002).

Figure 8. Average Spatial Distribution of STP by Sub-Basins and Poultry Houses in the Eucha-Spavinaw Watershed.

The strategy of applying poultry litter only to soils with STP values lower than a given threshold is directed toward reducing phosphorus loading in the watershed by preventing the runoff of the excess phosphorus during the storm events. This strategy is a representative of the "command and control" regulatory approach, where threshold standards are set and enforced. The policy was simulated by not allowing for litter application on the agricultural land where STP was higher than a given threshold value. Not even application of alum treated litter was allowed on this land. On the land that did not receive litter, the producer could choose whether or not to meet the nitrogen requirement with commercial fertilizer. On the land where litter application was allowed (STP lower than a given threshold value), the litter application rates discussed above, including the use of alum treated or non-treated litter were allowed as modeling options. Net income from agricultural activities for both HRU's that received litter and those that did not was calculated using the procedures and data described above.

Mandatory phosphorus abatement at the point source was coupled with the STP based litter application policy. Instituting mandatory point source abatement has the characteristics of "command and control" regulatory approach and is consistent with the STP based watershed management strategy. The rationale for this was that if the hypothetical watershed manager were going to use the STP based criterion for the non-point sources, it would have used the mandatory abatement at the point source as well. The mandatory abatement at the point source was set to achieve the benchmark phosphorus concentration of the effluent of 1 mg/l.

The main aspect regarding the STP based litter application policy analyzed from an economic perspective, was that the litter produced in the watershed has to be either land applied in the watershed (or used in some other activity, like methane and electricity generation) or be transported out of the watershed. If litter application were restricted only to soils with STP values lower than the threshold value, a great proportion of litter produced in the watershed could not be land applied. This was modeled by requiring any litter that was not land applied to be shipped out of the watershed. The distances necessary to haul litter out of the watershed were determined by locating counties in Arkansas, Kansas, Missouri, and Oklahoma to the East, North, West and South of the watershed where there is a potential for manure phosphorus application (Gollehon *et al.*, 2001).[6] The distances were estimated from boundary sub-basins in the watershed to the centroid of a county with sufficient capacity to receive manure phosphorus so that shipments of poultry litter could be made to that county. Average transportation costs were calculated using average distance to the counties centroids in each direction and per

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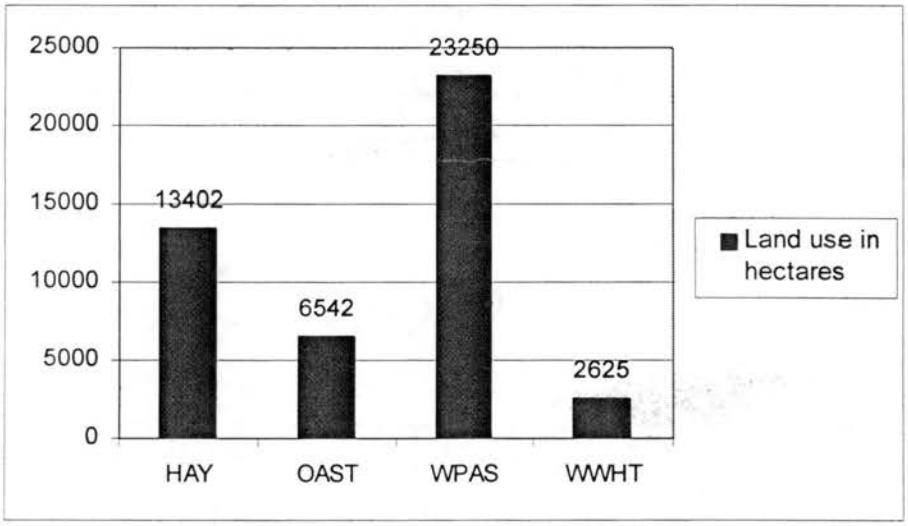
[6] Counties that were identified as having a potential to import poultry litter: Kansas – Allen, Bourbon, Chautauka and Elk; Oklahoma – Osage, Pawnee, Rogers and Wagoner; Arkansas – Faulkner; Missouri – Taney and Texas.

ton per mile transportation cost. Because of lack of data and the fact that animal manure is quite abundant in the whole region of Southern Missouri and Kansas and Northern Oklahoma and Arkansas, it was assumed that the exported litter does not have commercial value.

4.1.2.4. Changes in Land Use Patterns Directed Towards Reduction of Phosphorus Loading

As noted above, the agricultural land in the Eucha-Spavinaw watershed is classified into four land uses. Figure 9 represents the distribution of land area by agricultural land uses.



HAY = hay, OAST = overgrazed pasture, WPAS = maintained pasture, WWHT = row crop.

Figure 9. Agricultural Land Area by Land Uses in the Eucha-Spavinaw Watershed

As shown in Figure 9, the greatest land area is occupied by well-maintained pasture, followed by hay, overgrazed pasture and row crop. However, previous studies (Storm et *al*., 2002) (Ancev et *al*., 2003) found that despite the small land area they occupy, overgrazed pasture and row crop contribute relatively more to the phosphorus loading than do hay and well-maintained pasture. It was therefore decided to model the effect of potential land use change, whereby a conversion of overgrazed pasture to well-maintained pasture and conversion of row crop to hay was simulated. The decision was based on the fact that overgrazed pasture is situated on the land with similar characteristics as the well-maintained pasture, and main differences between the two land uses are with respect to quantity of applied nutrients (nitrogen, lower for the overgrazed pasture) and the minimum biomass when the grazing is allowed to begin (minimum biomass is lower for the overgrazed pasture). The parameters that control these characteristics were reconfigured in the SWAT model to simulate the land use conversion. The conversion from row crop to hay was simulated in a similar fashion. The same rates of litter application as described in Table 6, using alum treated or not treated litter were used for the newly simulated agricultural enterprises in the watershed. Net income from the agricultural activities was calculated according to previously described procedures and data.

The dissertation simulated two types of land use change policies. One type corresponded to mandatory uniform conversion where all land under overgrazed pasture and row crop was converted to well-maintained pasture and hay respectively. The other policy type corresponded to site-specific (optimal) land use conversion, where land areas were chosen for conversion based on their economic characteristics and phosphorus runoff potential.

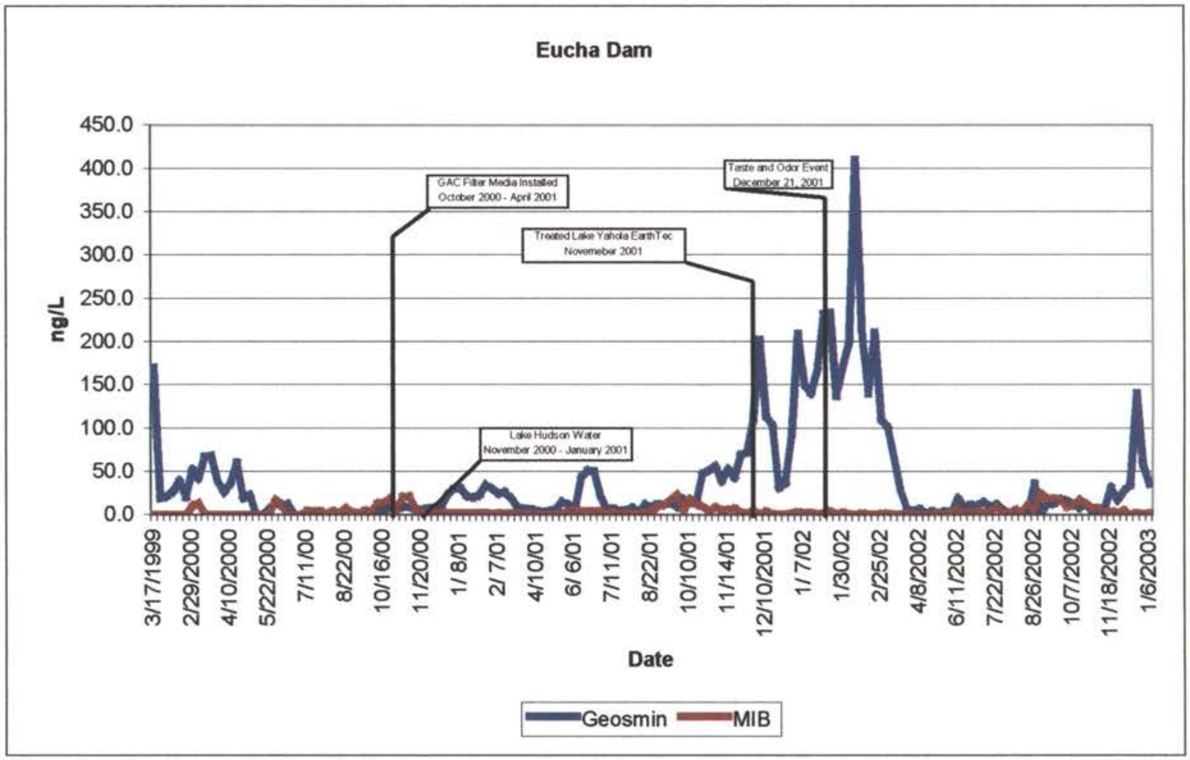
4.2. Calculating Environmental Damage Costs

The present study focused only on two types of environmental damages caused by phosphorus pollution in the Eucha-Spavinaw watershed. One was the impairment of the quality of drinking water for the City of Tulsa (OWRB, 2002) and the other was the loss of recreational values of the area lakes, as reflected by the drastic reduction in the reported number of annual visits (OCC, 1997, OTRD, 2003). Other possible environmental damages, such as long-term ecological values, were not considered because of lack of data and technical limitations.

4.2.1. Costs of Additional Drinking Water Treatment

The costs of additional drinking water treatment to the City of Tulsa are dependent on the taste and odor characteristics of the water, which are in turn determined by the concentration levels of the two chemicals, Geosmin and MIB (methyl iso-borneol) in the drinking water. These chemicals are produced in the process of algae die-off and are believed to cause the bad odor and taste of the water (OWRB, 2002). As reported above, OWRB conducted a thorough analysis on the algae community and chemicals related to water odor and taste in the Eucha and Spavinaw lakes. The study found increasing algae population in the lakes and increasing production of Geosmin and MIB. In recent years, the City of Tulsa has closely monitored the odor and taste characteristics of its water supply. Figure 10 displays information about the Geosmin and MIB concentration in the water at the Lake Eucha Dam, as well as the taste and odor complaints (denoted as events in the figure) for the supplied water.

To control the odor and taste causing chemicals, the Tulsa Municipal Utility Authority (TMUA) is using additional filtration with powdered activated carbon at the Mohawk water treatment plant. Alternatively, the raw water supply to the Mohawk plant was occasionally diverted from Lake Spavinaw to Lake Hudson. Thus, the costs imposed on the City of Tulsa due to high concentrations of Geosmin and MIB, consist of costs for additional use of powdered activated carbon in water treatment and costs of pumping from an alternative water reservoir. The powdered activated carbon (PAC) is effective in removing odor and improving the taste of drinking water (AWWA, 2001), but is quite costly (the price of PAC is \$0.2/kg.). Diverting the water supply from Lake Spavinaw to water supply from Lake Hudson greatly reduces chemical treatment costs (very little or no PAC used) but inflicts high pumping costs (\$61.44 per million gallons). The data on water treatment costs were obtained from the City of Tulsa and the TMUA.



Source: The City of Tulsa

Figure 10. Geosmin and MIB Concentration and Taste and Odor Complaints.

Regression analysis was used to estimate the costs for the additional drinking water treatment to the City of Tulsa based on Eq.3.6. The estimation was conducted using the observed monthly costs for the city of Tulsa and observed average monthly phosphorus concentration in the lakes. The equation was specified as

(4.3) $$CT_t = \sum_{T=1}^{5} y_1^{\,T} D^T + PC_{t-2} + PC_{t-3} + PC_{t-4} + \varepsilon_t \ ,$$

where CT_t is the observed cost to the City of Tulsa in month t (expressed in thousands of dollars), y_1^T is the estimated parameter for the year dummy variable, D^T denotes the year dummy variable, PC_{t-i} $(i = 2,3,4)$ denotes the corresponding average monthly lagged phosphorus concentration in the lakes and ε_t is a normally distributed random disturbance term. The results of maximum likelihood estimation are provided in the Appendix Table A.2. The results suggest a good fit, but the interpretation and the practical applicability of estimated equation is not straightforward. Therefore the equation was re-specified using annual grouped data. Observed annual costs of additional water treatment to the City of Tulsa and five different levels of SWAT simulated annual phosphorus loadings were used. For each level of SWAT simulated phosphorus loading, the observed costs were linearly regressed on the simulated phosphorus loading.

(4.4) $$CTK_T = b_0 + b_1\, ZK_T + \mu_T \ ,$$

where CTK_T denote the observed annual cost to the City of Tulsa (in actual dollars) in year T, ZK_T denotes the phosphorus loading in the watershed in year T under the K^{th} level of SWAT simulated loadings, and μ_T is a random disturbance term. The expected average annual cost to the City of Tulsa calculated from Eq.(4.4) were then regressed on the mean phosphorus loading for each level of SWAT simulated loadings, to obtain the following estimated equation (t-values in parenthesis)

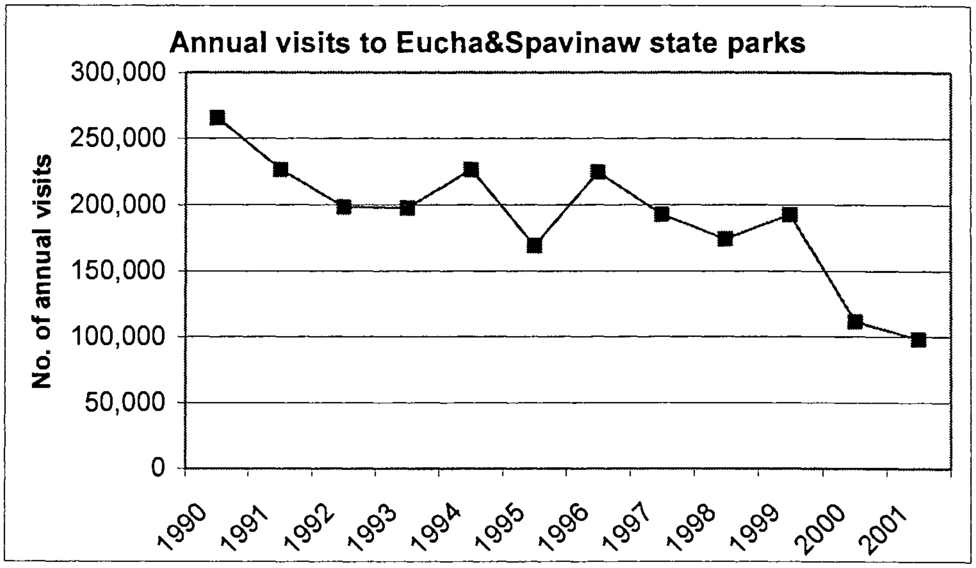
(4.5) $$E(CTK) = \underset{(-5.36)}{-226394} + \underset{(10.08)}{11.14}\, E(ZK),$$

where E(CTK) denotes the expected average annual costs to the City of Tulsa at phosphorus loading level K, and $E(ZK)$ is the expected average phosphorus load of level

K. The equation was estimated using ordinary least squares estimation and had an R^2 of 0.971. The estimated equation indicates a strong positive linear relationship between the average annual phosphorus loading in the watershed and the average annual costs of additional drinking water treatment for the City of Tulsa. This is expected since the high phosphorus load results in intensive algae growth, which in turn results in production of Geosmin and MIB. For this alternative specification it should be noted that average annual data were analyzed and that the distribution of costs and phosphorus loading within a year reflects the lagged effects of phosphorus loading (Eq.4.3) on the Geosmin and MIB production. The results from the regression analysis were used in the subsequent computations of the total and marginal environmental damage costs.

4.2.2. Costs of Reduced Recreational Values

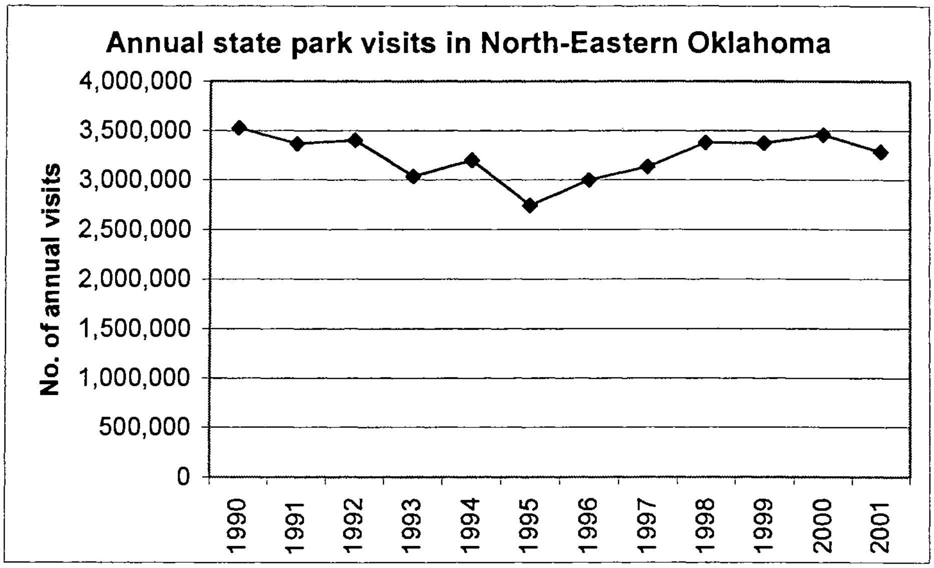
The Eucha-Spavinaw watershed is located in the Ozark region of Eastern Oklahoma and Western Arkansas, and is characterized with hilly landscape, forested areas and water bodies. This makes the region attractive for recreation activities that range from picnicking and fishing to camping and motor boating. The watershed is home to two state parks, Lake Eucha State Park and Spavinaw State Park, both of which were once very popular recreational sites. However, during the last decade the number of recreational visits to the two state parks decreased sharply (OTRD, 2003). This is in spite of the fact that the number of visits to the state parks for the whole region of North-East Oklahoma remained fairly stable during the same time period. Figure 11 presents combined data on the number of visits to the Eucha-Spavinaw state parks over the 1990-2001 period. Figure 12 presents data on the number of visits to all state parks in North-East Oklahoma for the same period.



Source: Oklahoma Tourism and Recreation Department

Figure 11. Number of Annual Recreational Visits to Eucha-Spavinaw State Parks

As Figure 11 suggests, the two state parks have experienced a sharp drop in the annual number of visits, from 265,000 visits in 1990 to a little less than 100,000 visits in 2001. In the same time, the number of recreational visits to all state parks in the North-Eastern Oklahoma remained relatively stable at about 3,3 million per year.



Source: Oklahoma Tourism and Recreation Department

Figure 12. Number of Annual Recreational Visits to All State Parks in North Eastern Oklahoma.

This reduction in the number of visits to Eucha and Spavinaw State Parks was interpreted as a shift of recreational visits away from lakes Eucha and Spavinaw and toward other recreational sites in the area for the period 1990-2001. During this period, a significant increase in phosphorus loading in the watershed occurred and was followed by increased phosphorus concentration in the lakes. This in turn ultimately resulted in eutrophication and reduction of the subjective value of recreational experience (Feenberg and Mills, 1980). In the same period, there were significant public debates and numerous media reports regarding the phosphorus pollution and the poultry industry in the Eucha-Spavinaw watershed (Tulsa World, various issues). The effect of the actual increase in the phosphorus loading to the lakes combined with the media reports and public debates, most probably played an important role leading toward drastic reduction of annual visits to the Eucha and Spavinaw Lakes. The analysis of the available visitation data for the Oklahoma State Parks did not reveal any other significant aspect that could be used to explain the reduction of annual visitation to the Eucha/Spavinaw state parks.

The reduction in annual visitation however, implies monetary costs to the current participants in recreation that travel to other sites when they would prefer a recreational experience at Eucha/Spavinaw state parks, were the water quality acceptable (revealed preference). Losses also accrue to current non-participants in recreation who would participate in recreation at Eucha/Spavinaw state parks if the phosphorus loading to the lakes were lower. These monetary losses can be expressed in economic terms as losses of Consumer Surplus. Consumer Surplus was defined in Eq.(3.3) and in Figure 5. In economic terms, the consumer surplus is known as the area under the demand curve and above the price.

The travel cost method, which uses costs of travel to the recreational sites to represent the price for recreation, was used to estimate lost recreational values due to increased phosphorus loading and phosphorus concentration of the area lakes (Bockstael et *al.*, 1991). The concept of travel cost uses estimates of the costs to travel to and from a recreational site, as well as the costs for preparation, gear, and entrance fees, to estimate a demand function for recreation at a particular site. Changes in the consumer surplus under various levels of phosphorus concentration in the lakes were used to approximate the costs of lost recreational values. In particular, it was assumed that the maximum willingness-to-pay (MWTP) for recreation changes as the phosphorus concentration in the lake changes. At higher levels of phosphorus concentration the MWTP for recreation is lower, while at lower levels of phosphorus concentration the MWTP is higher. This is graphically represented in Figure 13, where the number of visits decline from Q_1 to Q_2 as the MWTP declines from $MWTP_1$ to $MWTP_2$. In the figure, $MWTP_1$ corresponds to maximum willingness-to-pay for recreation at better water quality, say WC_1 (lower phosphorus concentration), while $MWTP_2$ corresponds to

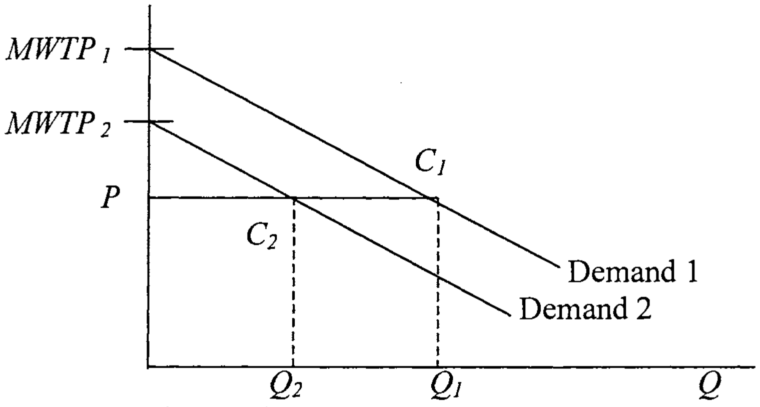


Figure 13. Changes in Consumer Surplus from Recreation under Various Levels of Phosphorus Concentration in the Lakes due to Changes in the Maximum Willingness-to-Pay

maximum willingness-to-pay for recreation at lower water quality, WC_2 (higher phosphorus concentration). Consumer surplus under the better water quality is represented by the triangle area bounded by $MWTP_1$, P and C_1. Consumer surplus under the lower water quality is represented by the triangle area bounded by $MWTP_2$, P and C_2. The difference between them, marked by the area $MWTP_1$, $MWTP_2$, C_1 and C_2 represents the change in consumer surplus. This change can be interpreted as a benefit obtained by increasing water quality from WC_2 to WC_1, or equivalently as a loss in recreational values when the water quality declines from WC_1 to WC_2. This concept was used to empirically estimate the losses in recreational values under alternative phosphorus concentrations of water in the Eucha and Spavinaw lakes.

Data on annual visitations to the Eucha and Spavinaw state parks were obtained from the Oklahoma Tourism and Recreation Department (OTRD, 2003). Visitors to the lakes were divided in iso-travel cost zones according to survey results published in a report by the Oklahoma Conservation Commission (OCC, 1997). The iso-travel cost zones are geographic zones from which it would cost approximately the same to travel to a given recreational site. Four iso-travel cost zones were identified for the lakes Eucha and Spavinaw: Zone 1 – Tulsa Metropolitan Area, Zone 2 - Siloam Springs and Fayetteville, AR, Zone 3- visitors from Oklahoma other than Tulsa, (mainly including cities and towns on the East of Tulsa), and Zone 4 – Local area (communities of Jay, Spavinaw and other smaller communities). Travel cost from each zone was calculated using road distances and average gasoline consumption and prices. The value of time spend on recreation (McConnel, 1992) was incorporated in the travel cost estimates using income data (USDC, 2000) to estimate the hourly earnings.

The demand equation for recreation in price flexibility form was estimated according to the following model (see Eq.3.8)

$$TC_l = \sum_{k=1}^{12} MWTP^k D^k + dQ_l, \tag{4.6}$$

where TC_l denotes the travel cost to the recreational site from the l^{th} zone, $MWTP^k$ denotes maximum willingness-to-pay at a given level of phosphorus concentration, D^k is a dummy variable for each level of phosphorus concentration (twelve levels, k), and Q_l is the observed number of visits from the zone l. [7] The results from the estimation are presented in Table A3 in the Appendix. The estimated maximum willingness–to–pay parameters were regressed on the observed phosphorus concentration (see Eq.3.9) to obtain the following estimated equation (t-values in parenthesis)

$$MWTP^k = \underset{(4.93)}{72.7} - \underset{(-2.1)}{788.5}\, PC^k, \tag{4.7}$$

where PC is the observed phosphorus concentration in the lakes. Data published in OWRB, 2002, (pp-120-121) were used to convert the phosphorus concentration to phosphorus loading using the following estimated linear equation (t-values in parenthesis)

$$PC = \underset{(27.34)}{0.0105} + \underset{(48.44)}{0.0000007}\, Z, \tag{4.8}$$

where Z denotes the annual phosphorus load to the lakes.

Consequently, distinct intercepts (maximum willingness-to-pay) for each level of phosphorus loading in the watershed were estiamated. The calculation of the consumer surplus and the change in the consumer surplus at the various levels of phosphorus load were conducted using numerical integration.

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[7] Dummy variable (or indicator variable) in this case is defined as unity at some particular level of k and zero otherwise . For example, $D^1 = 1$ for $d_l^{\,1}$ and zero otherwise.

Given the Eqs. (4.6) and (4.7) the expected number of visits from a given iso-travel zone at a given phosphorus loading can be calculated as

$$E(Q_l^k) = (TC_l - MWTP^k)/(d/N_l), \tag{4.9}$$

where N_l is the population of the l^{th} zone. Consumer surplus for the visitors from this zone and under given phosphorus loading can be calculated as

$$CS_l^k = [(MWTP^k - TC_l)\, E(Q_l^k)]/2. \tag{4.10}$$

The total consumer surplus for the lakes for a particular level of phosphorus loading *k*, was obtained by summing over all iso-travel cost zones, $CS^k = \sum_{l=1}^{L} CS_l^k$. As the level of phosphorus loading was varied, the cost of recreational losses were calculated as a change in consumer surplus from one phosphorus loading level to another. The results of the computations are provided in Table A4. in the Appendix.

4.2.3. Estimates of Total and Marginal Environmental Damage Costs

The sum of costs for drinking water treatment that the City of Tulsa incurs and the cost of recreational losses, resulted in an estimate of the total environmental damage cost for the Eucha-Spavinaw watershed.[8] As noted in the conceptual framework, derivation of the marginal environmental damages may be quite useful for the further discussion on the optimal level of phosphorus abatement in the watershed.

The marginal damage costs could be obtained by first expressing the total damage costs as a function of the phosphorus load and by differentiating the function

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[8] The word "total" here is meant to make a distinction from the word "marginal". It is not claimed that these environmental cost estimates comprise all possible environmental damages in the watershed, so that the word "total" does not have a meaning of "all" environmental damages.

with respect to the phosphorus load. The estimated total damage cost as a function of phosphorus load in the watershed was (t-values in parenthesis)

$$DC = \underset{(10.25)}{585446.9} - \underset{(-15.45)}{59.93}\, Zmax + \underset{(25.18)}{0.0015}\, Zmax^2, \tag{4.11}$$

where *DC* is the total damage cost and *Zmax* is the amount of phosphorus load in the watershed. The marginal damage cost is then

$$MDC = -59.93 + 0.003\, Zmax\,. \tag{4.12}$$

Marginal damage costs expressed in this way were used in the subsequent discussion to equate with the marginal abatement costs as one way of calculating the socially optimal phosphorus loading for the watershed.

An alternative way of calculating the socially optimal phosphorus loading considered in the dissertation was to use the total damage cost function in the linear programming model to derive a single solution. The function was segmented and linearized and was incorporated in the linear programming model as environmental damage cost activities. This enabled direct calculation of the optimal phosphorus loading with the linear programming optimization procedure.

CHAPTER V

MATHEMATICAL PROGRAMMING FRAMEWORK FOR FINDING OPTIMAL SOLUTIONS

5.1. Specification of the model

To find the least-cost way to achieve any given level of phosphorus loading in the watershed, litter management practices are to be optimally allocated to agricultural enterprises (non-point sources of phosphorus loading), and the level of wastewater treatment is to be optimally assigned to the wastewater treatment plant at the City of Decatur (point source of phosphorus loading). In particular, the objective of the economic model was set to maximize the sum of agricultural income from all agricultural HRUs in the watershed minus the costs to the point source and the costs of transportation of litter, by choosing litter management practices (LMP) and wastewater treatment level to meet a certain limit on total phosphorus loading in the entire watershed. This is best represented in the linear programming framework, which can be mathematically stated as,

$$\max_{X_{ij},Y_q} \sum_{i=1}^{N}\sum_{j=1}^{695}\Pi_{ij} * X_{ij} - \sum_{q=1}^{35} PSC_q(Z_q) * Y_q - \sum_{s=1}^{695}\sum_{r=1}^{695}\sum_{t=1}^{2} T_{tsr}c_{sr} - \sum_{b=1}^{B}\sum_{t=1}^{2} T_{tb}c_{tb} \tag{5.1}$$

subject to

$$\sum_{i} X_{ij} = 1 \text{ and } X_{ij} \geq 0, \forall j \text{ (Select the most profitable LMP in each HRU)} \tag{5.2}$$

$$\sum_{q} Y_q = 1 \text{ and } Y_q \geq 0, \forall\, q \text{ (Select a level of phosph. abat. at point source)} \tag{5.3}$$

$$T_s = \sum_{t=1}^{2} T_{ts}, \quad \forall s = 1 \text{ to } 69,\ t = 1,2 \text{ (Litter treatment with alum, } t = 1 \text{ for litter without alum, 2 for alum)} \tag{5.4}$$

(5.5) $T_{st} = T_{sst} + T_{rst} - T_{rst}$, $\forall s \neq r$ (All litter applied or shipped out of the watershed)

(5.6) $Z_q + \sum_{i=1}^{N} \sum_{j=1}^{694} Z_{ij} X_{ij} \leq Z_{\max}$, $\forall i,j,q$ (total phosphorus loading less than $Z_{\max}$)

(5.7) $T_{tsr} \geq 0$, $T_{tb} \geq 0$, $\forall$ t,s,r,b (non-negative transportation quantities within and outside of the watershed)

where:

Π_{ij} is the net income from the i^{th} LMP in j^{th} HRU,
X_{ij} denotes the adoption of the i^{th} LMP in the j^{th} HRU.
PSC_q is the point source abatement cost for the q^{th} level of phosphorus abatement (Y_q).
T_s is the total quantity of litter produced in s^{th} sub-basin.
T_{tsr} is the quantity of litter with treatment t shipped from the s^{th} to the r^{th} sub-basin[9].
c_{tsr} is the cost of transporting litter with treatment t from the s^{th} to the r^{th} sub-basin.
T_b is the quantity of litter shipped out of the watershed from point b.
Z_{ij} is the amount of phosphorus runoff in tons from the j^{th} HRU under the i^{th} BMP.
Z_q is the q^{th} level of phosphorus emission from the point source.
Z_{max} is total allowed phosphorus loading.

The quantity of allowable phosphorus loading in the watershed, Z_{max} was varied from 18,000 to 46,000 kilograms per year. The upper level of 46,000 kg/year corresponds to the estimate of total current phosphorus loading in the watershed from the non-point agricultural sources and the point source (Storm et *al*., 2002). The lowest level of 18,000 kg/year corresponds to the estimated phosphorus load if no litter were applied in the watershed and if there were maximum abatement at the point source (no phosphorus loading from the point source). The intermediate phosphorus loading targets (40000, 35000, 30000, 25000, 20000 (all in kg/year)) were chosen to determine how the marginal abatement cost curve changed as the amount of abatement changed. The program was solved using standard MPS linear programming format in the C-WHIZ Version 4 Linear Programming Optimizer (Ketron Management Science).

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[9] Treatment *t* refers to alum treated or not treated litter. Also, the SWAT model divides the watershed in total of sixty nine sub-basins.

As noted above, the notation X_{ij} denotes the i^{th} litter management practice, which can be chosen in the j^{th} HRU of the watershed. The basic litter management practices were described above as eight litter application rates for five of which (lower litter application rates) there was a choice between replacing the reduced nitrogen with commercial fertilizer or not. These constituted the thirteen baseline litter application rates. These base activities were used for the linear programming runs under four distinct simulated policies. The policies differ by the set of choices (options) available for reducing phosphorus loading in the watershed from the non-point sources. The abatement technology at the point source was the same across each of the alternative policies, but the amount of abatement was optimally chosen by the program.

5.2. Description of the variants of the model – the Alternative Policies

5.2.1. Baseline case – Changing the Amount of Litter Applied

A set of linear program runs was first conducted using just the various litter application rates and the possibility to replace nitrogen with commercial fertilizer, essentially using only the thirteen baseline litter application rates. The linear program was solved to maximize the sum of the net income from agricultural activities in the watershed, minus the cost of the point source abatement, and minus the cost for litter transportation. The model selected one of the thirteen basic litter management practices for each particular HRU in the watershed and selected a level of phosphorus abatement at the point source. These runs were used to analyze the optimal allocation of litter across the watershed and the optimal litter application rates in each HRU under various requirements for allowed phosphorus loading. The transportation of litter across individual sub-basins in the watershed as well as transportation of litter out of the watershed was observed and analyzed. The model chose whether to substitute nitrogen with commercial fertilizer in the HRUs where lower litter application rates were found optimal. The model also chose the optimal level of phosphorus abatement at the point source. The linear programming model was run for each level of allowed total phosphorus loading in the watershed, (Z_{max}, the phosphorus constraint was parametrically varied). Results from the linear programming runs are presented in the following section. Of particular interest in the analysis of this baseline case was to observe how reduction of phosphorus loading could be achieved without using any particular litter management technology, and just varying the litter application rates. It was also important to observe the intensity of transportation within and out of the watershed and the level of abatement at the point source, as the allowed phosphorus loading for the watershed was parametrically reduced.

5.2.2. Policy 1 – Using Alum Treated Litter as a Management Practice

As an additional possibility to reduce phosphorus loading in the watershed, the use of alum treated litter was simulated. This was done by allowing the litter used with the various litter application rates be either alum treated or not treated. Thus, in addition to the thirteen basic litter application rates, eleven new options were added when the alum treatment possibility was introduced. For each non-zero litter application rate (eleven rates) litter could be alum treated or not. This amounted to twenty-four (13+11) management practices that could be chosen in each HRU (eight various litter application rate, for five of which there is a possibility of nitrogen replacement, plus the eleven options using the alum treated litter). These twenty-four litter management practices were further considered in each of the analyzed policies.

The first simulated policy was the one that used the described twenty-four litter management practices and the point source abatement to meet a phosphorous target. The linear program was solved to maximize the sum of the net income from agricultural activities in the watershed, minus the cost of the point source abatement, and minus the cost for litter transportation. The model selected one of the twenty-four litter management practices for each particular HRU in the watershed and a level of phosphorus abatement at the point source. This policy was used to simulate the possibilities for short-run reduction of phosphorus loading in the watershed by transporting litter across individual sub-basins, varying litter application rates, using alum as a litter amendment, choosing whether to substitute nitrogen with commercial fertilizer, and choosing the optimal level of phosphorus abatement at the point source. The linear programming model was run for each level of allowed phosphorus loading in the watershed, (Z_{max}, the phosphorus constraint was parametrically varied). Results from the linear programming runs are presented in the following section. Of particular interest in the analysis of this policy was to observe the use of alum, the intensity of transportation within the watershed, the average litter application rates by soil type/land slope, and the level of abatement at the point source, as the allowed phosphorus loading for the watershed was parametrically reduced.

5.2.3. Policy 2 – Applying Litter According to the STP Criterion

The next policy considered was the application of poultry litter according to the soil test phosphorus (STP) criterion. As discussed before, there are numerous recommendations stating that litter application be allowed only on the land that meets a certain phosphorus based criteria. One such criterion is the STP, which uniformly classifies the soils according to their available phosphorus content. Another criterion that addresses better the specific characteristics of individual soils and land uses is the Phosphorus Risk Index (PRI) (Storm and Smolen, 2001). Although PRI is generally preferred, especially from an economic standpoint, its practical application is fairly limited. At present time a research effort is underway at Oklahoma State University that attempts to classify the soils in the Eucha-Spavinaw watershed according to the PRI criterion. Since the results from the research are still not available, a policy that uses the STP criterion was simulated in the present study.

Under the STP based policy, litter application was only allowed on soils that have STP lower than a certain threshold value.[10] All other land could not receive poultry litter. For the agricultural HRUs that do not receive litter, required nitrogen could either be replaced by commercial fertilizer or not. In the linear programming framework, in effect, there were just two options available for the HRUs that do not receive litter, to substitute or not for nitrogen using commercial fertilizer. If the nitrogen is substituted, the phosphorus load from a particular HRU is reduced due to improved plant growth and better land cover (nitrate runoff however may increase). At the same time, net agricultural income is reduced due to the cost of commercial fertilizer and its application. For the HRUs that were allowed to receive litter (STP lower than a particular threshold

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[10] Threshold values of 120, 200, 250 and 350 STP were analyzed.

value) the twenty-four litter management practices described above were available as options in the linear programming runs. Abatement at the point source was modeled as mandated by a regulation, so a full abatement to a fixed level of 1 mg/l phosphorus concentration of the effluent was simulated. The linear program was run to maximize the sum of the net income from agricultural activities in the watershed minus the litter transportation cost by choosing one of the twenty-four litter management practices for HRUs that were allowed to receive litter in the watershed, and by choosing whether to replace the required nitrogen by commercial fertilizer or not for HRUs that were not allowed to receive litter. Note that under this policy there was no constraint on the phosphorus loading. The policy in itself implied phosphorus abating actions (not applying litter to high STP soils) and a further constraint on phosphorus would be infeasible from political and regulatory aspects. Therefore, the total phosphorus constraint was "freed" in the linear program to reflect this situation.

The linear programming model was run for four levels of STP thresholds (120, 200, 250, 350). Results from the linear programming runs are presented in the following section. Of particular interest for this policy was to observe the transportation activities within and out of the watershed, the use of commercial nitrogen by agricultural land uses and the litter application rates on the HRUs where litter application was allowed.

5.2.4. Policy 3 – Mandatory Land Use Conversion

The third policy analyzed in the study assumed mandatory changes in agricultural land use patterns in the watershed. This policy was used to represent a simulation of a mandatory (uniform) conversion of overgrazed pasture to well maintained pasture and conversion of row crop to hay. Since the overgrazed pasture and row crop land uses were identified as contributing the most to the phosphorus loading, the simulated policy comprised of a mandatory order to the land owners to convert those two land uses to well-maintained pasture and hay respectively. These changes in land use patterns in the watershed present a significant opportunity for phosphorus load reduction, but are only attainable in the longer run and require changes in the economic structure of agriculture and related industries in the watershed. Also, mandatory land use change may not be very popular and for that matter politically feasible policy.

The SWAT model was used to simulate the conversion of the overgrazed pasture to maintained pasture and of row crops to hay. The SWAT simulation provided estimates of the phosphorus load, crop yield, and biomass for the newly converted HRUs. For the HRUs where the conversion was conducted, the calculations of the net agricultural income were repeated for the newly assigned land uses. The twenty-four litter management practices discussed above were then used as options in the linear programming model.

The linear program was run to maximize the sum of the net income from hay and well maintained pasture activities in the watershed [11] minus the abatement cost at the point source and minus the litter transportation cost, by choosing one of the twenty-four litter management practices for each HRUs, and by choosing a level of phosphorus abatement at the point source. The linear programming model was run for each level of allowed phosphorus loading in the watershed, (the phosphorus constraint was parametrically varied). Results from the linear programming runs are presented in the following section. Of particular interest for this policy was to observe how the possibility of land use change affects the use of alum, the intensity of transportation within the

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[11] Under this policy there were only two agricultural land uses, hay and well-maintained pasture.

watershed, average litter application rates for particular land uses, the level of abatement at the point source, and to compare the net income for the watershed as a whole to the policies that do not allow for land use change. These characteristics were observed as the allowed phosphorus loading for the whole watershed was varied from higher to lower levels.

5.2.5. Policy 4 – Site Specific (Optimal) Land Use Conversion

As opposed to the policy of uniform (mandatory) land use conversion, the last policy considered in this study was to simulate a site-specific (optimal) land use conversion. This was achieved by combining Policy 1 and Policy 3 in a single linear programming model. Separate production activities for each of the two policies were constructed in each HRU and were combined together. For the part of the linear program pertaining to Policy 1, the twenty-four litter management practices discussed above were assigned as possible production activities for each HRU. For the part of the linear program pertaining to Policy 3, the overgrazed pasture and row crop HRUs were first converted to maintained pasture and hay HRUs respectively, and then one of the twenty-four litter management practices was assigned to each HRU in the watershed. Each production activity for each HRU was specifically labeled to distinguish between the two policies (Policy 1 and Policy 3) they originated from.

The linear program was run to maximize the sum of the net income from agricultural activities in the watershed minus the abatement cost at the point source and minus the litter transportation costs, by choosing whether to change the land use in a particular HRU, and then by choosing one of the twenty-four litter management practices for each HRU, and by choosing a level of phosphorus abatement at the point source. The linear programming model was run for each level of allowed phosphorus loading in the watershed. The phosphorus constraint was again varied parametrically. The results from the linear programming runs are presented in the following section. Of particular interest for this policy was to observe the optimality of land use change for particular land uses, the use of alum by land uses, average litter application rates by land uses, the level of abatement at the point source and to compare the net income for the watershed as a whole to the individual policies discussed above. It was expected that since this policy was a combination of two previously described policies (Policy 1 and Policy 3), it would be least restrictive and hence should yield the highest value of net income for the watershed as a whole.

The considered policies for which linear programs were run and their main characteristics are summarized in Table 8.

Table 8. Summary of the Considered Policies and their Characteristics

	Policy – Set of Linear Program Runs				
Characteristics	Baseline case	Policy 1	Policy 2	Policy 3	Policy4
Alum use	No	Yes	Yes	Yes	Yes
STP criterion	No	No	Yes	Yes	Yes
Land use change	No	No	No	Mandatory	Site-Specific

5.3. Tracing the Total and Marginal Abatement Cost Curve

For the baseline case and for each of the four policies for which linear programs were run, the total and marginal abatement costs were determined. Total abatement costs were determined as a difference in the value of the objective function of the linear program under the estimated current level of phosphorus loading (46,000 kg/year) and the value of the objective function at each other level of phosphorus loading for which a linear program was run (for example, value of the objective function at the allowed phosphorus loading of 46,000 kg/year minus the value of the objective function at the allowed phosphorus loading of 30,000 kg/year represents total cost of abating the 16,000 kg/year of phosphorus loading in the watershed using a given Policy).

The marginal abatement costs were determined using the shadow price on the phosphorus constraint from the linear program (Eq.5.6). In the linear programming framework (Beneke and Winterboer, 1973) (Hazel and Norton, 1986) each binding constraint has an associated shadow price (Lagrangian multiplier). This can be formulated as an interpretation of the Kuhn-Tucker complementary slackness conditions, which state that at the optimal solution for each resource in the program, either the marginal condition holds as equality or the shadow price vanishes, or both. Formulated in other words, it is either that a constraint is binding or that the shadow price on that resource is equal to zero. The shadow price states the amount by which the value of the objective function changes as the constraint in question is relaxed (or constrained further) by an additional unit. The interpretation in the sense of a Lagrange multiplier is that the shadow price states the value of a partial derivative of the objective function with respect to the constraining variable. Thus the shadow price on phosphorus loading in the linear program represents the reduction in the value of the objective function as the phosphorus constraint in the program is restricted by one more unit. This corresponds exactly to the definition of the marginal abatement costs discussed before. Therefore, the shadow prices on the phosphorus constraint, which were obtained as output from the linear programming runs, were used to represent the marginal abatement costs.

One way to determine the socially optimal level of phosphorus abatement for the watershed as a whole is to equate the marginal abatement and damages cost (see Eq.

(3.6)). Marginal damage costs were formulated in Eq. (4.12). The marginal abatement cost curve could be approximated by a mathematical function mapping from the set of observed levels of phosphorus loading to the set of the observed marginal costs. A quadratic function was specified and the quadratic term was tested for significance (using Wald or Likelihood Ratio type statistical tests) to determine whether the appropriate function is quadratic or linear.

An alternative way to determine the socially optimal level of phosphorus abatement in the watershed is to directly minimize the sum of the total abatement and damage costs. This was done in the linear programming framework by segmenting the damage cost function (Eq. 4.11). Damage costs activities were then added to the program, essentially subtracting segmented damage costs from the objective function (Eq. 5.1). Each damage cost activity had an associated value for the phosphorus loading opposite in sign to the phosphorus loading values associated with the point and each non-point source. The phosphorus constraint was thereby "freed", which amounted to a requirement that the phosphorus associated with point and non-point source activities balances with the phosphorus associated with damage cost activities. A convex constraint (the sum of all damage cost activities equal to unity) was additionally imposed. Solving the linear program model that was set up in this manner yielded a direct solution for the socially optimal phosphorus loading.

Both the use of functional approximation (quadratic or linear) to the marginal abatement cost function and the segmentation of the damage cost function and its use in the linear program have some positive and some negative aspects. The functional approximation is quite precise when the appropriate functional form is linear and it could be used to trace out the marginal abatement cost curve, but may be far from the optimum when the appropriate approximation is quadratic. The segmentation of the damage cost function is precise at the segments with greater curvature, but the linearization dominates at the flatter parts of the function. In addition, this method cannot be used to trace the abatement cost curves since it provides a single solution, without a possibility to parametrically vary the phosphorus constraint. In the discussion of the results, the socially optimal values for the phosphorus loading refer to the values obtained by functional approximation of the marginal abatement cost function. The values obtained with segmentation of the damage cost function and the direct linear programming solutions are provided in the Appendix Table A.5.

5.4. Spatial Detail of Optimal Solutions

In addition to the aspects that were of interest when examining individual policies described above, there was interest to observe the spatial characteristics of the HRUs, classifying them by optimal litter management practices assigned by the mathematical program. The spatial characteristics of the HRUs are mainly composed of soil type, slope steepness and geographic location (sub-basin). For example, it was of interest to observe the spatial characteristics of HRUs that were assigned alum treated litter by the model, and it was of interest to observe the spatial characteristics of the HRUs where conversion of row crop to hay was found optimal. Also, in the linear programming framework, since each HRU had to be assigned a specific litter management practice (constraint represented in Eq.5.2), there was a shadow price on each HRU. This shadow price essentially represents the value that would be added to the objective function if a specific

HRU was duplicated and added to the watershed. In other words, the shadow price is the marginal value that the agricultural area represented by an HRU adds to the overall objective function. The shadow price reflects both the economic and environmental value of an HRU. If the agricultural production in an HRU is profitable, its per hectare shadow price would be high and vice versa. On the other hand if the phosphorus runoff from an HRU is high its shadow price would be low (even negative), reflecting the high marginal contribution of that HRU towards the fulfillment of the binding constraint on phosphorus loading. The shadow prices could be used to identify the HRUs that are the most "environmentally inefficient" and that should be targeted first by a conservation or other phosphorus loading reduction program. The "environmental efficiency" can be defined here as the contribution to the net income for the watershed as a whole per unit of emitted phosphorus runoff. For example, an HRU may contribute significantly to the net agricultural income but also may contribute significantly to the total phosphorus loading. This HRU will be "less environmentally efficient" than another HRU that also contributes significantly to the net agricultural income, but only contributes marginally to the phosphorus loading. Thus the information contained in the HRU shadow prices represents a combination of information on the net agricultural income and on the phosphorus runoff and therefore is more efficient than each of these two peaces of information individually.

The results on spatial detail for each alternative policy were sorted descending by HRUs shadow prices per hectare of agricultural land (the shadow price of an HRU divided by the HRU area). Those HRUs with the lowest per hectare shadow prices (sometimes negative) could be identified as the ones that contribute the least to the net income on the watershed level. The HRUs with high shadow prices per hectare are the most profitable ones and at the same time they are not characterized with extreme phosphorus runoff values. The spatial distributions of optimal litter management practices have important policy implications. They provide guidelines for more effective site-specific regulation and management. Therefore, summaries of the spatial characteristics of HRUs by land use and by the chosen management practice, sorted by the HRU per hectare shadow prices is provided in the Appendix Tables 6 through 10 for the optimal solutions of each of the analyzed policies.

CHAPTER VI

RESULTS

6.1. Baseline Case – Various Litter Application Rates

Results obtained from the linear program runs for the baseline case, where the thirteen litter application rates (eight rates for five of which there was a choice whether to replace nitrogen or not) were used, are presented in Table 9.

Table 9. Results from the Linear Program Runs for the Baseline Case.

Phosphorus loading (Zmax)	Value of the objective function	Marginal Phosphorus Abatement Costs	Total abatement cost for Agricultural Enterprises	Total abatement cost to the point source
kg / year	dollars/watershed	dollars/ kg P	dollars/watershed	dollars/watershed
46000	5,582,072	14.53	0	32,540
40000	5,492,860	18.12	0	112,484
35025[1]	**5,368,440**	**33.01**	**65,067**	**148,564**
35000	5,367,615	33.01	65,067	149,390
30000	4,989,344	141.16	408,368	184,360
25000	3,985,006	227.3	1,412,706	184,360
20000	2,570,318	361.21	2,827,394	184,360
18000*	1,441,260	inf	3,956,452	184,360

[1] socially optimal value of phosphorus loading obtained with functional approximation of the marginal abatement cost function

* Solution not feasible, because P loading cannot be less than 19.7 t/year for this setting.

The results show that reduction of phosphorus loading in the watershed could be achieved by reducing litter application rates and by phosphorus abatement at the point source. However, if the desired reductions of phosphorus loading are significant, they could be achieved only at considerable cost both to the agricultural enterprises (non-point sources) and to the City of Decatur (the point source). For example, to reduce the phosphorus loading from the current 46 t/year to say, 30 t/year, it would cost about $600,000 distributed to agricultural enterprises ($410,000) and the point source

($190,000). Further reductions of the phosphorus loading would be even more expensive, indicated by the dramatic increase in both total and marginal abatement cost. Another important result from the Table 9 is that the abatement at the point source is less costly than the abatement at the agricultural sources. This is represented by the high level of abatement at the point source within the optimal solution for even low reduction of the phosphorus loading target.

To determine the socially optimal level of phosphorus abatement in the watershed for this baseline case using the functional approximation of the marginal abatement costs, a summary of costs to the City of Tulsa and losses of recreational values, as well as the abatement costs for the various levels of phosphorus loading is provided in Table 10. The optimal level of abatement is indicated in the rightmost column of Table 10 at the point where the sum of abatement plus damage costs is at minimum (see Eq.3.5). The optimal point was found by equating the marginal abatement costs to the marginal damage costs

Table 10. A Summary of the Abatement and Damages Costs and their Sum for the Baseline Case Litter Application Rates and Point Source Abatement.

P loading	City of Tulsa Costs	Predicted Total Number of Visits to State Parks	Consumer Surplus	Total damage costs	Abatement costs	Sum of abatement and damage costs
kg/year	dollars/year	count	dollars/year	dollars/year	dollars/year	dollars/year
46000	276,863	17238	129,851	780,235	32,540	812,775
40000	232,107	60840	195,939	669,390	112,484	781,874
35025[i]	**169,072**	**96759**	**265,562**	**536,732**	**213,631**	**750,363**
35000	168,849	96826	265,994	536,077	214,457	750,534
30000	99,758	138890	353,001	379,980	592,728	972,708
25000	52,281	151756	457,509	227,995	1,597,066	1,825,061
20000	7,693	198325	579,518	61,397	3,011,754	3,073,151
18000*	0	263256	633,222	0	inf	inf

[i] socially optimal value of phosphorus loading obtained with functional approximation of the marginal abatement cost function

* Solution not feasible, because P loading cannot be less than 19.7 t/year for this setting.

(see Eq.3.6). As discussed before, the marginal abatement cost curve was traced out by formulating it as a quadratic function of the phosphorus loading, which in this case was of the form (t-values in parenthesis)

$$(6.1) \qquad \underset{}{MAC_{BC}} = \underset{(12.83)}{1242.6} - \underset{(-9.27)}{0.05712\, Zmax} + \underset{(7.11)}{0.00000066\, Zmax^2}.$$

with an R^2 of 0.987. Solving simultaneously for the *Zmax* using calculated marginal damage costs (Eq.4.12) and the estimated abatement marginal cost function gives a quadratic equation with a root of 35025, which represents the socially optimal level of phosphorus loading in kilograms per year using the baseline litter management practices. Figure14 graphically represents the point of optimal phosphorus abatement where the marginal abatement costs are equal to marginal damage costs.

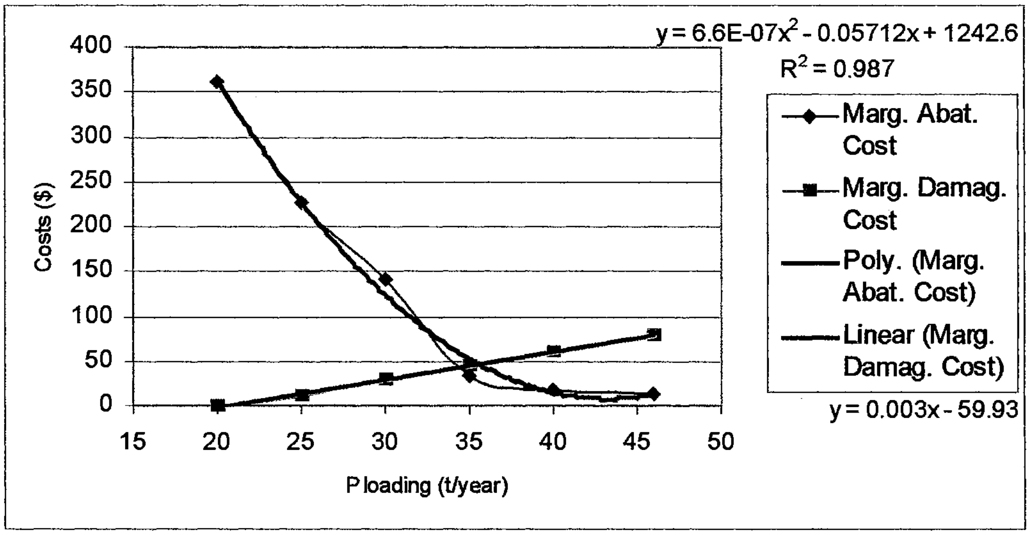

Figure14. Marginal Abatement and Marginal Damage Costs for Baseline Case.

Results for the optimal litter application rates for the HRUs, as well as the intensity of transportation within and out of the watershed were observed for the linear program runs under the current phosphorus loading (46t/year), under the optimal phosphorus loading (35 t/year) and under the minimum attainable phosphorus loading (20 t/year). These levels of phosphorus loading were chosen so that the changes in optimal uses could be observed as the allowed phosphorus loading was reduced from higher to lower levels.

Results on optimal litter application rates and the optimal decision on nitrogen replacement for hay (HAY) and well-maintained pasture (WPAS) are reported for the three levels of phosphorus loading in Table 11. Presented results suggest that profitability of hay production is more responsive to increased litter application rates compared to the profitability of the well-maintained pasture. As the required phosphorus loading target was reduced however, well maintained pasture received higher litter application rates reflecting the reduced use of litter on other land uses. At the most restrictive phosphorus loading, great majority of the land from both land uses did not receive poultry litter, as a

Table 11. Litter Application Rates and the Choice of Nitrogen Replacement by Commercial Fertilizer for the HAY and WPAS for the Baseline Case.

		Land use					
		HAY			WPAS		
Litter application rates		Land area, Current P load (46t.)	Land area, Optimal P load (35 t.)	Land area, minimum P load (20 t.)	Land area, Current P load (46t.)	Land area, Optimal P load (35 t.)	Land area, minimum P load (20 t.)
tons/ha		ha	ha	ha	Ha	Ha	ha
0	w. N replac	0	0	10810	0	0	0
	w/o N replac	11	11	43	11355	12681	20450
1	w. N replac	0	0	17	0	0	0
	w/o N replac	0	0	0	11191	8353	2655
2	w. N replac	0	0	24	0	0	0
	w/o N replac	0	0	0	704	2216	143
3	w. N replac	0	0	0	0	0	0
	w/o N replac	0	0	776	0	0	0
3.4	w. N replac	0	0	22	0	0	0
	w/o N replac	533	654	4	0	0	0
4		3553	3496	1261	0	0	0
4.8		5402	5227	444	0	0	0
6		3903	4013	0	0	0	0

result of the stringent phosphorus loading requirement. It should be noted that for the minimum phosphorus load (20 t/year), the nitrogen that would normally come from litter was not replaced on the well maintained pasture, suggesting a danger of transforming well maintained pastures into overgrazed ones.

Results on optimal litter application rates and the optimal decision on nitrogen replacement for overgrazed pasture (OAST) and row crop (WWHT) are reported for the three levels of phosphorus loading in Table 12. Presented results show that at the socially optimal level of phosphorus abatement, a significant proportion of the overgrazed pasture in the watershed should receive nitrogen from commercial fertilizer (1,245 ha.), while another significant portion should receive high litter application rates (1,534 ha.) This suggests that management improvements (better N fertilization) on the overgrazed pasture would be beneficial for reduction of the phosphorus loading in the watershed. If

Table 12. Litter Application Rates and the Choice of Nitrogen Replacement by Commercial Fertilizer for the OPAS and WWHT Under Baseline Case.

OPAS					WWHT				
Litter application rates		Current P load (46t.)	Optimal P load (35 t.)	Minimum P load (20 t.)	Litter application rates		Current P load (46t.)	Optimal P load (35 t.)	Minimum P load (20 t.)
tons		Land Area (ha.)			tons		Land Area (ha.)		
0	w. N rep	0	1245	5521	0	w. N rep	1513	2040	2619
	w/o N rep	4987	3763	70		w/o N rep	366	19	0
0.54	w. N rep	0	0	0	0.32	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	136	50	0
1.08	w. N rep	0	0	0	0.65	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	86	53	0
1.62	w. N rep	0	0	0	0.975	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	14	25	0
1.83	w. N rep	0	0	0	1.1	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	29	15	0
2.15		48	0	0	1.3		0	0	0
2.6		0	0	0	1.56		12	21	0
3.2		1507	1534	951	1.95		470	401	7

the phosphorus loading target was reduced even further, most of the land under overgrazed pasture (5,521 ha.) should receive its nitrogen requirement from commercial sources. A similar pattern was observed for the row crop, where nitrogen use from commercial fertilizer seems to be very important at the determined optimal level of phosphorus loading (2,040 ha.). The implication for land management comprising of a shift from nitrogen supplied with litter to nitrogen supplied with commercial fertilizer is suggested by the results.

The intensity of litter transportation within and outside of the watershed is reported in Table 13. The results show that significant decline of the net income on the watershed level can be partly attributed to the rising transportation costs.

Table 13. Litter Transportation Intensity Under the Baseline Case.

	Transport of litter			
Phosphorus Loading	Within the watershed		Out of the watershed	
	Thous. ton miles	Cost in dollars	Thous. ton miles	Cost in dollars
Current (46t)	604.6	72,552	0	0
Optimal (35t)	612.4	73,488	0	0
Minimum (20 t)	812.0	97,440	2,308.6	277,032

* a ton mile represents a quantity of one metric ton transported to a distance of one mile

At the minimum phosphorus loading target, litter is not applied on the majority of agricultural land and has to be hauled out of the watershed, which results in high transportation costs.

Disaggregated results by HRU, for the determined optimal phosphorus loading (35 t./year) for the baseline case are provided in the Appendix Table A6. The HRUs are sorted by their per hectare shadow price. On the top of the table are the HRUs with high shadow prices, implying high profitability. It can be seen that row crop and hay land uses dominate in this group of HRUs. At the bottom of the table are the HRUs with low (negative) shadow prices, which can be labeled as “environmentally inefficient” (high phosphorus runoff). Overgrazed pasture and row crop dominate in this group of HRUs.

6.2. Policy 1 – Alum Treated Litter as a Management Practice

In addition to the thirteen litter application rates, this policy was simulated by adding an option of using either alum treated or not treated litter. This addition created eleven new management options, so that for each HRU there were now twenty-four litter management practices available in the programming model. Aggregate results obtained from the linear program runs for these twenty-four litter management practices (change in litter application rates, with and without alum amendments, with and without nitrogen replacement by commercial fertilizer) are presented in Table 14. The results show that the changes in litter management practices and point source abatement can significantly reduce the total phosphorus load in the watershed. The costs of doing so are now much lower compared to the baseline case where alum treatment was not present as an option.

Table 14. Results from the Linear Program Runs for Policy 1.

Phosphorus loading (Zmax)	Value of the objective function	Marginal Phosphorus Abatement Costs	Total abatement cost for Agricultural Enterprises	Total abatement cost to the point source
kg / year	dollars/watershed	dollars/ kg P	dollars/watershed	dollars/watershed
46000	5,616,335	9.17	0	0
40000	5,546,346	14.53	57,139	12,850
35000	5,473,694	14.53	56,645	85,996
30000	5,387,629	22.46	98,573	130,133
26062[i]	**5,273,857**	**40.70**	**183,754**	**158,724**
25000	5,221,834	56.75	226,826	167,675
20000	3,605,787	886.56	1,826,188	184,360
18000*	1,610,470	Inf	3,821,505	184,360

[i] socially optimal value of phosphorus loading obtained with functional approximation of the marginal abatement cost function

* Solution not feasible, because P loading cannot be less than 19.7 t/year for this setting.

For example, the phosphorus load could be reduced from current 46 t/year to 30 t/year (16 tons reduction) at total cost of about $230,000 distributed to agricultural enterprises ($100,000) and to the point source ($130,000). However, any further reduction comes at excessively high costs, characterized by the dramatically increasing marginal abatement cost at lower levels of phosphorus loading. The burden of this drastic phosphorus load reduction was almost exclusively on the agricultural enterprises, since the maximum reduction at the point source has already been achieved.

To determine the socially optimal level of phosphorus abatement in the watershed for Policy 1 using the functional approximation of the marginal abatement costs, a summary of costs to the City of Tulsa and losses of recreational values, as well as the abatement costs for the various levels of phosphorus loading are provided in Table 15.

Table 15. A Summary of the Abatement and Damages Costs and their Sum from a Policy of changing Litter Management Practices and Point Source Abatement.

P loading	City of Tulsa Costs	Predicted Total Number of Visits to State Parks	Consumer Surplus	Total damage costs	Abatement costs	Sum of total abatement and damage costs
kg/year	dollars/year	count	dollars/year	dollars/year	dollars/year	dollars/year
46000	276,863	17238	129,851	780,235	0	780,235
40000	232,107	60840	195,939	669,390	69,989	739,379
35000	168,849	96826	265,994	536,077	142,641	678,718
30000	99,758	138890	353,001	379,980	228,706	608,686
26062[i]	**63,937**	**149298**	**434,927**	**262,232**	**342,478**	**604,710**
25000	52,281	151756	457,509	227,995	394,501	622,496
20000	7,693	198325	579,518	61,397	2,010,548	2,071,945
18000*	0	263256	633,222	0	inf	inf

[1] socially optimal value of phosphorus loading obtained with functional approximation of the marginal abatement cost function .

* Solution not feasible, because P loading cannot be less than 19.7 t/year for this setting.

The optimal level of abatement is indicated in the rightmost column of Table 15 at the point where the sum of abatement plus damage costs is at minimum (See Eq.3.5). At the optimal point, the marginal abatement costs will be equal to marginal damage costs (Eq.3.6). The marginal abatement cost curve could be traced out by formulating a quadratic function, which in this case was of the form (t-values in parenthesis)

$$MAC_1 = \underset{(3.43)}{300.72} - \underset{(-2.74)}{0.01422\,Zmax} + \underset{(2.42)}{0.000000173\,Zmax^2}. \tag{6.2}$$

with an R^2 of 0.925. Solving simultaneously for the *Zmax* using calculated marginal damage costs (Eq.4.12) and marginal abatement costs, yielded a quadratic equation with a root of 26062, which represents the socially optimal level of phosphorus loading in kg/year for Policy 1. Figure 15 graphically presents the point of optimal phosphorus abatement where the marginal abatement costs are equal to marginal damage costs. The linear program was rerun for this optimal phosphorus constraint. The optimal level of phosphorus abatement at the point source was 9,687 kg/year, which corresponds to the effluent phosphorus concentration of 1.13 mg./liter.

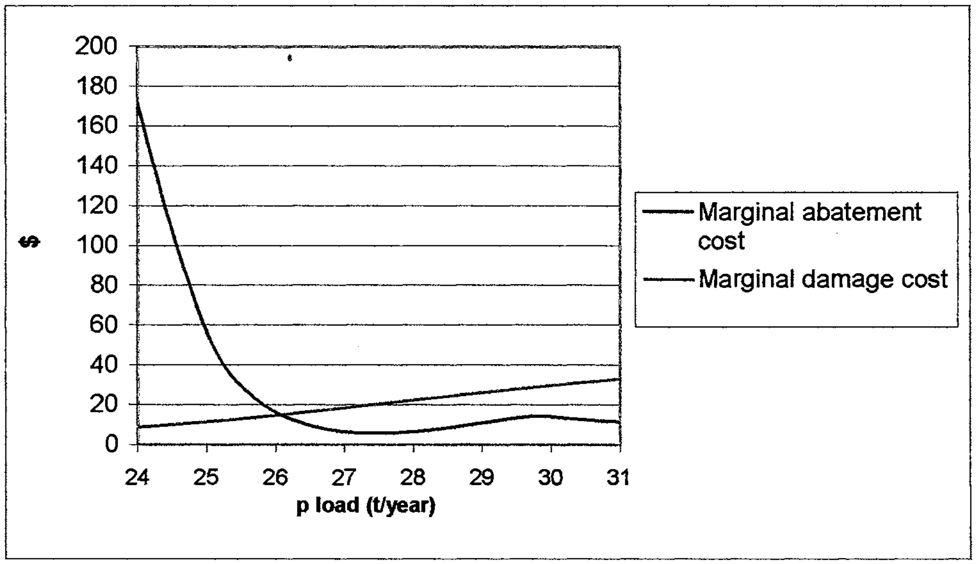

Figure15. Marginal Abatement and Marginal Damage Costs for Policy 1.

Results for the alum use and the average litter application rates for the HRUs, as well as the intensity of transportation and the level of abatement at the point source are observed for the linear program runs under the current phosphorus loading (46 t/year), under the optimal phosphorus loading (26 t/year) and under the minimum attainable phosphorus loading (20 t/year). These levels of phosphorus loading were chosen so that the changes in optimal alum use and litter application rates could be observed as the allowed phosphorus loading is reduced from higher to lower levels.

The results on optimal litter application rates and the optimal decision on nitrogen replacement for hay and well-maintained pasture (WPAS) are reported for the three levels of phosphorus loading in Table 16. The results show that at the current level of phosphorus loading, it would be optimal to apply litter at higher rate for hay than for well-maintained pasture. As the allowed phosphorus loading was reduced, the amount of litter applied was reduced and the use of commercial nitrogen was increased for hay, while for the well maintained pasture the litter application rates were increased, as a

Table 16. Litter Application Rates and the Choice of Nitrogen Replacement by Commercial Fertilizer for the HAY and WPAS Under Policy 1.

		Land use					
		HAY			WPAS		
Litter application rates		Land at current P load (46t.)	Land at optimal P load (26 t.)	Land at minimum P load (20 t.)	Land at current P load (46t.)	Land at optimal P load (26 t.)	Land at minimum P load (20 t.)
tons/ha		ha	ha	ha	ha	ha	ha
0	w. N replac	0	0	6913	0	0	468
	w/o N replac	11	11	10	12458	13961	15973
1	w. N replac	0	0	113	0	0	0
	w/o N replac	0	0	0	10230	8611	1493
2	w. N replac	0	0	0	0	0	0
	w/o N replac	0	0	0	562	677	4307
3	w. N replac	0	0	0	0	0	0
	w/o N replac	0	0	0	0	0	932
3.4	w. N replac	102.5	0	227	0	0	0
	w/o N replac	0	0	0	0	0	0
4		4101	2831	850	0	0	77
4.8		5610	5706	2612	0	0	0
6		3578	4854	2677	0	0	0

result of “freeing” litter from other land uses. It was found more efficient to replace nitrogen on hay than on pasture.

The results on optimal litter application rates and the optimal decision on nitrogen replacement for overgrazed pasture (OAST) and row crop (WWHT) are reported for the three levels of phosphorus loading in Table 17. The results for these two land uses show that they are responsive to litter application and in general to nitrogen application, in both economic and environmental terms. However, since these two land uses were identified as most susceptible to phosphorus runoff, the optimal litter application rates were reduced as the allowed phosphorus loading was reduced. As this was taking place, nitrogen was substituted from commercial sources to ensure good land cover, which

Table 17. Litter Application Rates and the Choice of Nitrogen Replacement by Commercial Fertilizer for the OPAS and WWHT Under Policy 1.

OPAS					WWHT				
Litter application rates		Current P load (46t.)	Optimal P load (26 t.)	Minimum P load (20 t.)	Litter application rates		Current P load (46t.)	Optimal P load (26 t.)	Minimum P load (20 t.)
tons		Land Area (ha.)			tons		Land Area (ha.)		
0	w. N rep	4674	1338	5656	0	w. N rep	938	2049	2619
	w/o N rep	0	3636	8		w/o N rep	456	14	0
0.54	w. N rep	0	0	0	0.32	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	199	47	0
1.08	w. N rep	0	0	0	0.65	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	137	53	0
1.62	w. N rep	0	0	0	0.975	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	11	10	0
1.83	w. N rep	0	0	0	1.1	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	45	28	0
2.15		0	0	0	1.3		7	1	0
2.6		407	21.3	0	1.56		28	0	0
3.2		1356	1546	878	1.95		804	424	7

reduces phosphorus runoff. This did take a toll on the net agricultural income, which was reflected in the low income at lower allowed levels of phosphorus loading.

The results on the use of alum for hay and well-maintained pasture (WPAS) are reported for the three levels of phosphorus loading in Table 18. The results show that the use of alum is quite important as an optimal solution for hay. At all levels of allowed phosphorus loading, higher litter application rates were combined with the use of alum treated litter. For the well-maintained pasture, the optimal use of alum increased significantly as the allowed level of phosphorus loading was reduced.

Table 18. Use of Alum for HAY and WPAS Under Policy 1.

	HAY			WPAS		
Litter application rates	Alum use at current P load (46t.)	Alum use at optimal P load (26t.)	Alum use at minimum P load (20t.)	Alum use at current P load (46t.)	Alum use at optimal P load (26t.)	Alum use at minimum P load (20t.)
tons	Land Area (ha)			Land Area (ha)		
1	0	0	113	844	7234	1493
2	0	0	0	274	677	4307
3	0	0	0	0	0	932
3.4	0	0	227	0	0	0
4	2606	2831	850	0	0	77
4.8	3030	5706	2612	0	0	0
6	1020	4854	2677	0	0	0

The results on the use of alum for overgrazed pasture (OPAS) and row crop (WWHT) are reported for the three levels of phosphorus loading in Table 19. The results show that the alum use was important in the optimal solution for these two land uses as well, especially at higher rates of litter application. However, as the allowed phosphorus loading was reduced, the application of litter was halted on most of these two land uses and hence the alum was not used as well. The 20 ton phosphorus loading constraint,

Table 19. Use of Alum for the OPAS and WWHT Under Policy 1.

OPAS				WWHT			
Litter application rates	Alum use at current P load (46t.)	Alum use at optimal P load (26t.)	Alum use at minimum P load (20t.)	Litter application rates	Alum use at current P load (46t.)	Alum use at optimal P load (26t.)	Alum use at minimum P load (20t.)
tons	ha	ha	ha	tons	ha	ha	ha
0.54	0	0	0	0.32	0	0	0
1.08	0	0	0	0.65	9.6	36	0
1.62	0	0	0	0.975	0	0	0
1.83	0	0	0	1.1	14	28	0
2.15	0	0	0	1.3	7	1	0
2.6	407	21.3	0	1.56	15	0	0
3.2	105	350	0	1.95	523	387	7

allowed little opportunity to apply litter on the agricultural land. Since litter had to be shipped out of the watershed, treating litter with alum was not optimal (because it is cheaper to ship non-treated litter out of the watershed).

The pattern of transportation and total alum use under the three phosphorus loading levels is reported in Table 20. The results show that transportation of litter within the watershed is a very important activity if the net income on the watershed level is to be maximized. The optimal level of litter transportation intensified as the allowed phosphorus loading was restricted. At the 46t./year and 26 t./year levels of phosphorus loading, it was not optimal to ship litter out of the watershed. However, if greater

Table 20. Transportation of Litter and Use of Alum Treated Litter for the Three Levels of Phosphorus Loading Under Policy 1.

	Transport of litter		Total litter used	
Phosphorus Loading	Within the watershed	Out of the watershed	Alum treated	Non-treated
	Thous. ton miles	Thous. ton miles	Thous.tons	Thous.tons
Current (46t.)	566.5	0	34	50
Optimal (26t.)	567.3	0	78.6	5.4
Minimum (20 t).	691.2	1220.1	46.1	37.9

reduction in phosphorus loading were desired, considerable amount of litter had to be shipped out of the watershed and at considerable distance. This was one of the most significant reasons for the dramatic increase of abatement costs (reduction of net income) at lower levels of phosphorus loading. The results also show that it was optimal to use alum treated litter to efficiently prevent phosphorus loading. At the optimal solution, almost all litter used in the watershed was treated with alum. At lower phosphorus loading levels, since the litter is shipped out of the watershed, the use of alum was lower than at the optimal rate.

The spatial distribution of the alum use by HRUs for Policy 1 is presented in Figures 16, 17 and 18.

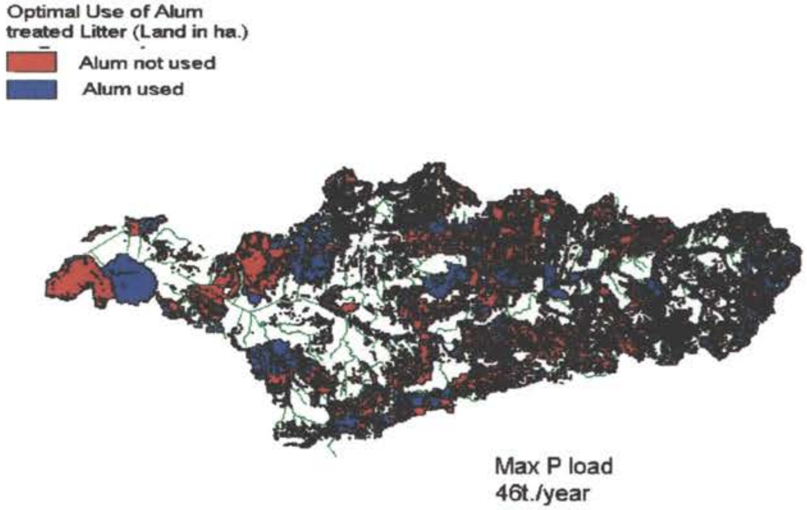

Figure 16. Spatial Distribution of Alum Use, Policy 1, at P Loading Target of 46 t/year

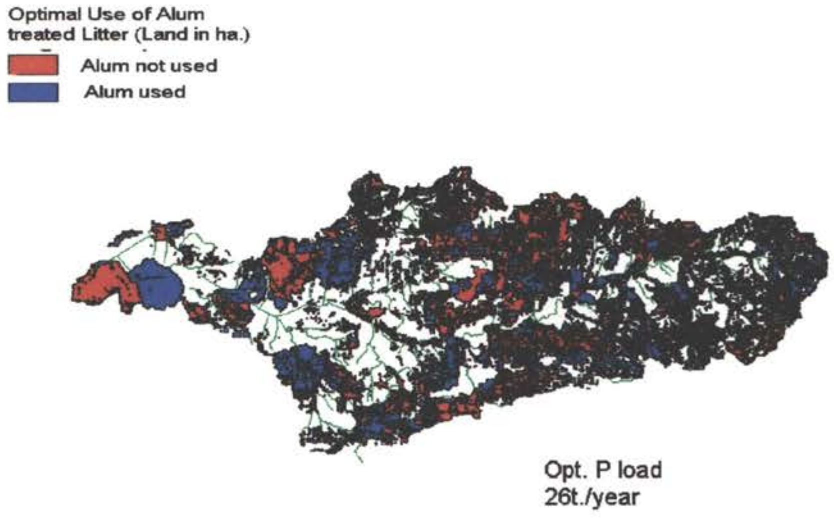

Figure 17. Spatial Distribution of Alum Use, Policy 1, at P Loading Target of 26 t/year

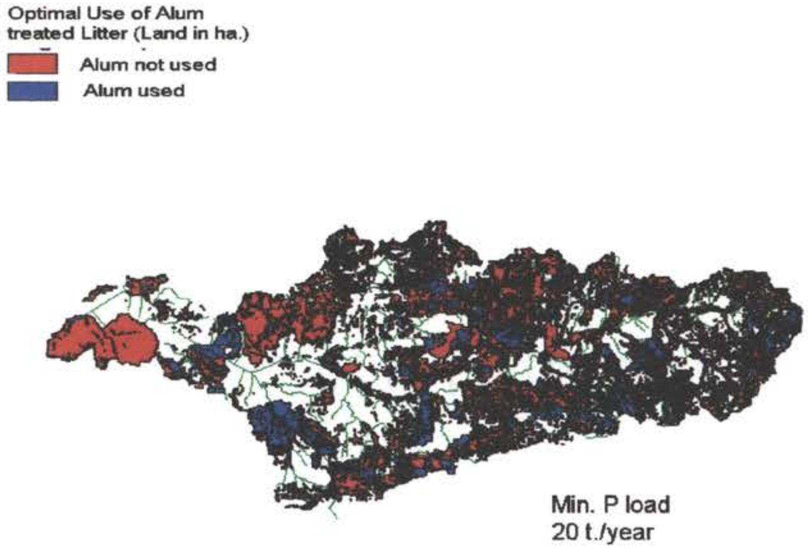

Figure 18. Spatial Distribution of Alum Use, Policy 1, at P Loading Target of 18 t/year

The land inclination is an important characteristic of the agricultural HRUs that has a significant effect on the potential for phosphorus runoff. A summary of optimal litter application rates by average slope of the agricultural land for hay and well maintained pasture is provided below in Table 21 while a summary for overgrazed pasture and row crop is provided in Table 22. The results show that in general, applying litter on land with steeper slopes is not optimal, especially if a reduction of phosphorus loading is desired. This general finding however, needs to be addressed carefully since there is significant interaction between the slope of a land area, the crop grown, and the initial phosphorus content in the soil. Therefore, these interactions have to be taken into account when devising policies to reduce phosphorus loading in the watershed.

The results for the optimal litter application rate for hay with respect to soil types are presented in Table 23. The results could be used to identify the areas within soil types for which litter could be applied on hay land at six tons per hectare even when drastic reductions of the phosphorus loading target are required. Those soils are Doniphan, Newtonia, Razort and Tonti. The results could be also used to identify the soil types for which litter application on hay land use was not optimal as the target P loading was reduced. These soils are Captina, Nixa, and Macedonia.

Table 21. Optimal Litter Application by Average Slope of the Agricultural Land for Hay and Well-maintained Pasture Under Policy 1.

	Land Use					
	Hay			Well-maintained Pasture		
Current P loading (46 t.)						
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%
tons	ha	ha	ha		ha	ha
0	0	1	10	4779	6119	1560
1	0	0	0	4893	4779	557
2	0	0	0	177	111	274
3.4	0	39	63	0	0	0
4	2133	1634	334	0	0	0
4.8	2088	2368	1154	0	0	0
6	1241	2281	56	0	0	0
Optimal P loading (26 t.)						
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%
tons	ha	ha	ha	ha	ha	ha
0	0	1	10	5706	6208	2047
1	0	0	0	3966	4411	235
2	0	0	0	177	390	110
4	1510	1067	253	0	0	0
4.8	2085	2329	1292	0	0	0
6	1867	2925	62	0	0	0
Minimum P loading (20 t.)						
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%
tons	ha	ha	ha	ha	ha	ha
0	3392	3148	382	6527	7940	1975
1	0	0	113	652	646	195
2	0	0	0	2447	1642	218
3	0	0	0	224	703	4
3.4	0	28	199	0	0	0
4	109	613	128	0	77	
4.8	808	1245	560	0	0	0
6	1153	1289	234	0	0	0
Total land (ha):	5462	6323	1617	9849	11009	2392

Table 22. Optimal Litter Application by Average Slope of the Agricultural Land for Overgrazed Pasture and Row Crop Under Policy 1.

				Land Uses			
	Overgrazed Pasture			Row crop			
Current P loading (46 t.)							
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%	Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%
Tons	ha	ha	ha	tons	Ha	ha	ha
0	1677	2266	731	0	1275	76	44
0.54	276	130	0	0.32	80	49	69
1.08	0	0	0	0.65	109	40	0
2.15	0	0	0	1.1	44	0	1
2.6	0	0	0	1.56	0	0	15
3.2	899	551	10	1.95	733	61	8
Optimal P loading (26 t.)							
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%	Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%
Tons	ha	ha	ha	tons	ha	ha	ha
0	1976	2266	731	0	1722	197	143
0.54	0	0	0	0.32	47	0	0
1.08	0	0	0	0.65	41	12	0
1.62	0	0	0	0.975	10	0	0
1.83	0	0	0	1.1	28	0	0
2.6	21	0	0	1.56	0	0	0
3.2	855	680	10	1.95	407	16	0
Minimum P loading (20 t.)							
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%	Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope >8%
Tons	ha	ha	ha	tons	ha	ha	ha
0	2405	2520	738	0	2248	226	144
3.2	446	427	4	1.95	7		
Total land:	1741	2947	742		2255	226	144

Table 23. Optimal Litter Application by Soil Type for Hay Under Policy 1.

	Current P load (46t.)					Optimal P load (26t.)				MinimumP load (20t.)					
	Litter application rate (t./ha)					Litter application rate (t./ha)				Litter application rate (t./ha)					
Soil Type	0	3.4	4	4.8	6	0	4	4.8	6	0	1	3.4	4	4.8	6
	Land Area (ha.)					Land Area (ha.)				Land Area (ha.)					
Tonti	0	0	34	0	1039	0	34	0	1039	315	0	21	0	0	737
Clarksville	0	47	454	2812	727	0	226	2678	1136	1123	0	176	641	1941	159
Captina	0	7	1025	684	201	0	695	816	407	1916	0	0	0	2	0
Nixa	0	7	1228	407	260	0	1183	460	260	1860	0	7	36	0	0
Peridge	0	4	162	31	0	0	103	95	0	193	0	0	0	5	0
Britwater	1	0	97	96	19	1	82	111	19	76	113	0	7	18	0
Healing	0	26	27	0	0	0	53	0	0	0	0	23	0	29	0
Noark	0	0	35	0	0	0	35	0	0	0	0	0	0	35	0
Jay	0	0	182	0	0	0	182	0	0	182	0	0	0	0	0
Razort	0	11	393	46	0	0	135	159	156	58	0	0	166	42	183
Doniphan	0	0	0	756	1113	0	0	544	1324	0	0	0	0	541	1328
Macedonia	0	0	0	410	156	0	0	354	212	566	0	0	0	0	0
Parsons	0	0	59	122	0	0	59	122	0	181	0	0	0	0	0
Taloka	0	0	45	0	0	0	45	0	0	45	0	0	0	0	0
Newtonia	0	0	360	234	60	0	0	360	294	397	0	0	0	0	256

Table 24. Optimal Litter Application by Soil Type for Well-maintained Pasture Under Policy 1.

	Current P load (46t.)			Optimal P load (26t.)			MinimumP load (20t.)				
	Litter application Rates (t/ha)			Litter application Rates (t/ha)			Litter application Rates (t/ha)				
Soil Type	0	1	2	0	1	2	0	1	2	3	4
	Land Area (ha.)			Land Area (ha.)			Land Area (ha.)				
Tonti	52	1666	0	52	1500	166	52	0	1666	0	0
Clarksville	2330	4334	111	2828	3663	284	5256	1111	408	0	0
Captina	2035	566	0	2119	483	0	2602	0	0	0	0
Nixa	3797	35	274	4072	35	0	4106	0	0	0	0
Peridge	795	0	0	795	0	0	795	0	0	0	0
Britwater	325	151	0	333	143	0	476	0	0	0	0
Noark	517	0	0	517	0	0	517	0	0	0	0
Jay	417	0	0	417	0	0	417	0	0	0	0
Razort	740	71	0	742	69	0	146	25	636	4	0
Doniphan	12	1159	177	12	1110	227	44	0	384	921	0
Secesh	0	77	0	0	77	0	0	0	0	0	77
Macedonia	504	219	0	504	219	0	623	100	0	0	0
Taloka	411	761	0	703	469	0	1172	0	0	0	0
Newtonia	434	1164	0	779	818	0	152	256	1189	0	0

The results for the optimal litter application rate with respect to soil types, for well-maintained pasture are presented in Table 24. The results could be used to identify the soil types for which litter application on well maintained pasture was found optimal even for drastic reduction of phosphorus loading target. Those soils are Doniphan, Sacesh and Tonti. The results could be also used to identify the soil types for which litter application on well maintained pasture was not found optimal as the target P loading was reduced. These soils are Captina, Nixa, and Taloka.

The results for the optimal litter application rates with respect to soil types, for overgrazed pasture are presented in Table 25. The results single out two soil types where litter application was found optimal even for drastic reduction of phosphorus loading target. Those soils are Captina and Peridge. The soil type Captina was identified for the two previous land uses as the one where litter application was not optimal. For the overgrazed pasture however, the opposite conclusion holds true. The reason for this is the fact that on overgrazed pasture, the litter application on this soil type has a beneficial effect on the improvement of land cover, which significantly reduces phosphorus runoff.

The results for the optimal litter application rates by soil types for the row crop are presented in Table 26. The results show that litter application was found optimal on two soil types for moderate reduction of phosphorus loading target. These soil types are Nixa and Tonti. For the row crop, the litter application was not optimal on any soil under the more drastic reductions of phosphorus loading.

Table 25. Optimal Litter Application by Soil Type of the Agricultural Land for Overgrazed Pasture Under Policy 1.

	Current P load (46t.)			Optimal P load (26t.)			Minimum P load (20t.)	
	Litter application Rates (t/ha)			Litter application Rates (t/ha)			Litter application Rates (t/ha)	
Soil Type	0	2.6	3.2	0	2.6	3.2	0	3.2
	Land Area (ha.)			Land Area (ha.)			Land Area (ha.)	
Tonti	84	122	240	84	21	240	445	0
Claksville	1464	48	0	1483	0	30	1512	0
Captina	173	0	823	221	0	775	278	718
Nixa	738	0		738	0	0	738	0
Peridge	0	0	209	0	0	209	50	159
Britwater	82	0	0	82	0	0	82	0
Jay	49	0	0	49	0	0	49	0
Razort	124	0	6	124	0	6	131	0
Doniphan	1097	0	0	1097	0	0	1097	0
Macedonia	477	0	0	477	0	0	477	0
Parsons	73	0	0	73	0	0	73	0
Taloka	154	0	0	154	0	0	154	0
Newtonia	96	236	182	332	0	182	514	0

Table 26. Optimal Litter Application by Soil Type for Row Crop Under Policy 1.

	Current P Loading (46 t.)						Optimal P Loading (26 t.)					Minimum P Loading (20 t.)	
	Litter Application Rates (t./ha)						Litter Application Rates (t./ha)					Litter Application Rates (t./ha)	
Soil Type	0	0.32	0.65	1.1	1.56	1.95	0	0.32	0.65	1.1	1.95	0	1.95
	Land Area (ha.)						Land Area (ha.)					Land Area (ha.)	
Tonti	0	0	0	0	0	185	5	0	0	0	180	185	0
Clarksville	61	162	113	25	13	8	273	34	53	10	17	389	0
Captina	408	12	10	0	0	82	512	0	0	0	0	512	0
Nixa	0	0	0	0	0	248	36	0	0	0	213	248	0
Peridge	13	0	0	0	0	147	160	0	0	0	0	160	0
Britwater	46	0	0	0	0	19	63	0	0	0	0	63	0
Doniphan	186	24	0	16	0	0	197	13	0	16	0	226	0
Macedonia	111	0	0	0	0	0	111	0	0	0	0	111	0
Taloka	146	0	0	0	0	101	247	0	0	0	0	247	0
Newtonia	340	0	37	0	0	0	357	0	0	0	0	357	0

Table A7. in the Appendix presents the detailed results by HRUs for Policy 1 under the determined optimal phosphorus loading (26 t/year). The HRUs are sorted by their per hectare shadow prices. The HRUs at the top of the table have high per hectare shadow prices and contribute significantly to the agricultural net income, but are not excessive in phosphorus runoff. It can be seen that row crop and hay land uses again dominate in this group of HRUs. It is also noted that alum treated litter is applied to most of these HRUs with high shadow prices. At the bottom of the table are the HRUs with low (negative) shadow prices, which contribute little to the net agricultural income, but contribute significantly to the phosphorus loading. Overgrazed pasture and row crop where no litter is used and the nitrogen is replaced with commercial fertilizer dominate in this group of HRUs.

6.3. Policy 2 – Applying Litter According to the STP Criterion

6.3.1. STP Threshold of 120

The results were obtained from the linear programming runs for four levels of the STP threshold values, 120, 200, 250 and 350. For the policy that allowed litter application only to the soils that have STP lower than 120, the model calculated a value of the objective function of $3.38 million. This represents the value of the net agricultural income minus the abatement costs at the point source and the transportation costs.[12] Estimated phosphorus loading under the policy was 43,367 kg/year. This represents a 2,600 kg reduction from the current estimated phosphorus load of 46,000 kg/year. But, in comparison to Policy 1 and even the Baseline Case described above, this reduction comes at extremely high cost. The average cost of phosphorus abatement was calculated as $877/kg (the value of the objective function for the current load (46 t.) is $5.61 million, subtracting $3.38 million and dividing by 2,600 (reduced P) one obtains $877). The main

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[12] As noted before, full abatement at the point source was assumed to be instituted with this policy.

effect on the increased cost of abatement can be attributed to transportation of litter inside and outside the watershed. The intensity of transportation within the watershed was calculated at 1,218 thousand ton miles, while the intensity of transporting litter out of the watershed was 1,270 thousand ton miles.[13] This intensity of transportation was much higher than that calculated for Policy 1 (Table 20).

Despite being quite expensive, the policy of litter application according to STP was not very effective in reducing P loading. The reason for this is that the litter was applied non-discriminately with respect to phosphorus runoff from particular fields. The linear programming model chooses liter application rates according to the criteria that would minimize transportation costs within and out of the watershed. Litter would be applied on a particular HRU if the cost of transporting the litter to that HRU were less than the cost of transporting that quantity of litter out of the watershed. Another important contribution toward excessive phosphorus runoff was that nitrogen that would normally come from litter was not replaced with commercial fertilizer, once litter application was not allowed. This results in poor plant growth that reduces the quality of land cover and increases phosphorus runoff.

The results on litter application rates and the replacement of nitrogen with commercial fertilizer are shown in Table 27. The results show that a great majority of the land areas where litter application was allowed (where the initial soil test was below the threshold), received high litter application rates. On a significant portion of this land, litter is just applied to avoid shipping it out of the watershed. This produces excessive phosphorus runoff.

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[13] Ton mile is defined as the quantity of one metric ton of litter shipped at the distance of one mile.

Table 27. Litter Application Rates and Nitrogen Replacement by Land Uses for the Policy that Restricts Litter Application only to Soils with STP < 120.

	Litter applied (STP<120)			Litter not applied (STP>120)		
	Low	Medium	High	Nitrogen replacement Yes	 No	Total land
Land Use	Land Area (ha.)			Land Area (ha.)		ha.
Hay	10	0	3325	9690	375	13402
Well Maint. Past.	36	539	3477	0	19197	23250
Overgrazed Past.	52	136	1311	0	5042	6542
Row Crop	0	0	404	364	1857	2625
Total land (ha.)	98	675	8517	10054	26471	45819

Litter application rates for hay and well-maintained pasture were classified as follows: Low: 0-2 t./ha, Medium: 2- 4 t./ha, High: 4-6 t/ha. Litter application rates for overgrazed pasture were classified: Low: 0-1.1 t./ha, Medium: 1.1- 1.8 t./ha, High: 1.8-3.2 t/ha. Litter application rates for row crop were classified: Low: 0- 0.65 t./ha, Medium: 0.65- 1.3 t./ha, High: 1.3-2 t/ha.

In addition, on the land where litter application was not allowed, if nitrogen was not supplied from commercial fertilizer, the land cover was poor and there was greater potential for phosphorus runoff. This was especially apparent with the overgrazed pasture and row crop. Table 28 reports the average phosphorus runoff rates when no nitrogen is applied to the land for the four agricultural land uses.

Table 28. Average Phosphorus Runoff from Agricultural Land Uses if no Nitrogen is Applied.

	Land Uses			
	Hay	Overgrazed Past.	Well Maint. Past	Row Crop
Phosphorus runoff (Total P, kg/ha/year)	0.279	2.022	0.138	4.962

As it is apparent from the table, the row crop and overgrazed pasture have extremely high phosphorus runoff rates when nitrogen is not substituted with commercial fertilizer. On the land areas where it was not economical to replace nitrogen from litter with more expensive commercial nitrogen, the phosphorus runoff was not reduced as much as intended by the STP based policy, which altogether resulted in reduced effectiveness of this policy.

Table 29 presents the results for litter application rates and replacement of nitrogen with commercial fertilizer by soil types aggregated across agricultural land uses (litter application rates classified as described previously in Table 27.). The results by soil types do not show any significant pattern by which one could isolate particular soil types with respect to litter application rates or with respect to nitrogen replacement. For the STP based policy, the litter application rates were governed by the spatial location of the HRUs (HRUs to which it was less expensive to transport litter receive high litter application rates). On the other hand, the determination whether to replace the nitrogen with commercial fertilizer or not was mainly dependent on the crop grown relative to soil type (nitrogen was replaced where it was profitable, mainly on hay and row crops). However, Table 29 provides a good overview of the soils that tend to have high STP in the watershed. Those soils would not be available for litter application under the STP based policy. Some of the high STP soils were Captina, Nixa, Noark, Taloka and Newtonia.

Table 29. Litter Application Rates and Nitrogen Replacement by Soil Types for the Policy that Restricts Litter Application only to Soils with STP < 120.

	Litter Application Rates			Nitrogen Replacement	
	Low	Medium	High	YES	NO
Soil Type	Land Area (ha.)				
Tonti	0	52	56	1224	2090
Clarksville	21	601	4535	2264	5295
Captina	0	0	31	1977	4020
Nixa	0	0	42	1527	5427
Peridge	0	0	0	198	1164
Britwater	28	114	270	120	302
Noark	0	0	0	35	535
Jay	0	0	35	182	470
Razort	0	23	644	211	546
Doniphan	0	637	1870	804	1230
Macedonia	0	0	148	510	1219
Taloka	0	0	2	190	1480
Stigler	0	0	0	45	171
Newtonia	0	0	0	765	2358

Table 30 presents the results for litter application rates and replacement of nitrogen with commercial fertilizer by average land slopes aggregated across agricultural land uses. Inspection of the results presented in Table 30, reveals another reason for high phosphorus loading when using the STP based policy. Under this policy, unless there is an additional regulatory requirement to limit litter application on the soils that satisfy the STP criterion, considerable amounts of litter will be applied even on relatively steep slopes to save on costs to transport litter from the watershed. Since a majority of the land with steeper slopes is very susceptible to phosphorus runoff, litter application on that land leads to excessive phosphorus loading in the watershed. Also, it is very likely that land with steeper slopes would have lower STP because it did not receive as much litter as less steep land because of difficulties with application. So, a policy based on STP would indirectly create perverse incentives to apply litter to land that would otherwise remain without litter and would retain its low STP.

Table 30. Litter Application Rates and Nitrogen Replacement by Land Slopes for the Policy that Restricts Litter Application only to Soils with STP < 120.

	Litter Application Rates			Nitrogen Replacement		
Average Slope	Low	Medium	High	YES	NO	Total Land
	Land Area (ha.)					ha.
<5%	0	48	982	5295	14094	20420
5-8%	2	735	3933	4395	11440	20504
>8%	98	653	2842	364	938	4895

6.3.2. Other STP thresholds – 200, 250, 350

The STP level of 120 is often cited as a maximum level above which litter application to the agricultural land is not recommended. Hence, a STP policy designed to reduce phosphorus runoff would likely employ this threshold value. Nevertheless, an analysis was conducted for alternative values of the STP to explore the effects of varying the STP threshold level on the use of litter, transportation of litter, net income and phosphorus loading. The alternative STP thresholds were 200, 250, and 350. Table 31 presents a summary of the levels of income, phosphorus loading and transportation of litter for the three STP threshold levels. The table shows that as the threshold value for STP was raised, effectively increasing the land area where litter application was eligible, net income on the watershed level increased as well.[14] This was mainly due to a reduction in transportation of litter outside of the watershed as more litter was applied within the watershed. Phosphorus loading increased with higher levels of STP thresholds (because of the high litter application rates applied), but at decreasing rate. Alum treated litter was not used with any of the STP thresholds, reflecting the absence of the phosphorus constraint in the linear program.

Table 31. Net Income on the Watershed Level, Phosphorus Loading and Transportation of Litter for Various Threshold Levels of STP.

		STP 200	STP 250	STP 350
Land eligible for litter application	ha	12,840	19,597	26,297
Net Income on the Watershed Level	dollars	3,787,319	4,454,717	4,959,332
P loading	kg/year	50,643	57,215	57,439
Transportation out of the watershed	ton miles (0000)	731.4	0	0
Transportation within watershed	ton miles (0000)	1250	1500	1326
Use of Alum	ton	0	0	0

Table 32 presents the litter application rates and whether or not nitrogen was replaced using commercial fertilizer by agricultural land use (the litter application rates were classified as described in Table 27) for the STP values of 200, 250 and 350.

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[14] Net income on the watershed level is composed of net income to the agricultural enterprises, minus cost of abatement at the point source (it is assumed that the point source performs full abatement under this policy) and minus the cost of litter transportation.

Table 32. Litter Application Rates and Nitrogen Replacement by Threshold Values of STP.

	Litter application rates			Nitrogen Replacement	
	Low	Medium	High	YES	NO
			Land Area (ha.)		
STP200	100	1436	11304	8659	24320
STP250	578	5667	32986	6587	19635
STP350	3426	10657	12214	5032	14490

The results in Table 32 show why the total phosphorus loading leveled off at higher values of the STP threshold (57.4 t./year at STP 350, 57.2t./year at STP 250). At the higher STP threshold, the restrictions on land application of litter were significantly smaller, causing the change in the use of litter. With a low STP threshold, litter was a liability since the opportunity for land application was very restricted and excess litter had to be transported out of the watershed. Litter was "dumped" using high application rates on available land, causing high phosphorus loading. As the STP threshold increased, more land became available for litter application and the litter became a more valuable resource. Application rates reflected the value of the marginal product of litter more closely.

Detailed results by HRU for the policy allowing litter application based on the criterion STP<120 are provided in the Appendix Table A 8. The HRUs were sorted by their per hectare shadow prices. The same group of HRUs with high shadow prices as in the Baseline Case and Policy 1 are located at the top of the table. These HRUs are most profitable, providing the highest contribution to the net agricultural income, while not contributing as much to the phosphorus runoff. The bottom of the table looks somewhat different compared to the Policy 1 and the Baseline Case. Some HRUs that are located at the bottom of the table are the ones that received litter just because their STP was lower than the 120 threshold. Under the Baseline Case or Policy 1, these HRUs do not optimally receive litter (HRUs 543, 446). Other HRUs in this group are the ones for which the net income from agricultural activities was always negative, because they are situated in waterlogged areas and /or around ponds and smaller lakes. The SWAT model classified these land uses as agricultural in the process of land use aggregation, and hence the simulations only resulted in extremely low biomass and yields (HRUs 205, 444, 954 etc.). These HRUs also have very low phosphorus runoff value within the SWAT simulations. This is the reason why they were not ranked as low in the tables for the Baseline Case and Policy 1 as they were for the STP policy. These HRUs are economically inefficient, but not "environmentally inefficient". Since under the STP policy, the economic efficiency is valued more highly than the "environmental efficiency" (no phosphorus constraint), the economically more efficient HRUs have higher shadow prices than the "environmentally efficient" but economically less efficient HRUs.

In general, results obtained from the analysis of STP based litter application policy suggest that this "command and control" policy is neither effective nor economically efficient in reducing phosphorus loading in the Eucha-Spavinaw watershed.

6.4. Policy 3 – Mandatory (Uniform) Land Use Change

The results obtained from the linear programming runs for a simulated policy of mandatory land use change are provided in Table 33. The results show that this policy is more effective in preventing phosphorus runoff at low cost.

Table 33. Results from the Linear Program Runs for the Simulated Mandatory Land Use Change Policy.

Phosphorus loading (Z max)	Value of the objective function	Marginal abatement cost for P	Total abatement cost for Agricultural Enterprises	Total abatement cost to the point source	Sum of Total Abatement and Damage Costs
kg / year	dollars/watershed	dollars/kg P	dollars/year	dollars/year	dollars/year
46000	5,563,561	0.00	0	0	780,235
40000	5,563,561	0.00	0	0	669,390
35000	5,563,561	0.00	0	0	536,077
30000	5,559,250	5.07	4,311	0	384,291
25000	5,519,893	10.55	43,668	0	271,663
23637[i]	**5,503,807**	**13.54**	**59,754**	**0**	**215,332**
20000	5,451,277	14.53	67,111	45,173	218,854
18000	5,422,216	14.53	67,013	74,332	241,345

[i] socially optimal value of phosphorus loading obtained with functional approximation of the marginal abatement cost function

The value of the objective function at the maximum phosphorus loading level is just slightly lower than the values observed under the Baseline Case and Policy 1 presented in Table 8 and Table 14. This happened because the mandatory changes reduce overall net income. However, the phosphorus constraint was not binding at the maximum level of allowable phosphorus loading. This means that a policy of mandatory land use change alone could reduce phosphorus loading to approximately 31 t/year. This abatement comes exclusively from agricultural sources who only emit 20 t/year of phosphorus loading. Under the policy of mandatory land use change, the abatement at the point source did not begin until the phosphorus loading target was reduced to about 20 t/year. This suggests that mandatory land use changes would be very effective in reducing phosphorus loading from agricultural sources. This is consistent with previous findings by Storm et *al.* (2002).

The optimal level of phosphorus abatement can be found by looking for the minimum of the sum of abatement and damage costs. The optimal solution using the functional approximation of the marginal abatement costs was calculated by equating marginal abatement costs to marginal damage costs. The marginal abatement costs for this policy can be approximated as a linear function of the phosphorus load by

$$MAC_3 = 25.165 - 0.0006\,Zmax. \quad (6.3)$$

Solving for the phosphorus load by equating the marginal abatement costs and marginal damage costs (Eq. 4.12) one obtains the value of 23,637 kg/year. This is the socially optimal level of phosphorus load using this policy of mandatory land use change. The entire phosphorus abatement was done by the agricultural sources, with no abatement at the point source. Figure 19 graphically represents the marginal abatement and damage costs and the point of optimal phosphorus loading.

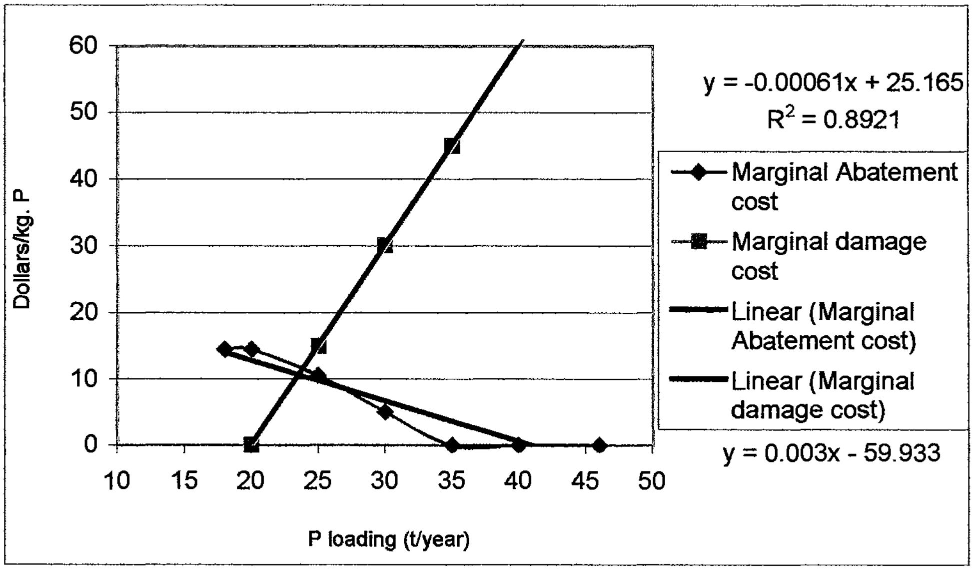

Figure 19. Marginal Abatement and Damage Costs for Policy 3.

Table 34 presents the litter application rates for the three different levels of allowed phosphorus loading on the watershed level and for the two land uses (hay and well-maintained pasture) under the policy of mandatory land use conversion. The results show that higher litter application rates were more often used on hay than on well-maintained pasture. This happened because with well maintained pasture the manure from cattle deposits most of the phosphorus back on the land while with hay more nutrients are removed from the land. The results do not suggest any significant changes in

Table 34. Litter Application Rates for Three Levels of Allowed Phosphorus Loading, for Hay and Well-maintained Pasture Land Uses under Policy 3.

Hay		Well-maintained Pasture	
Current P loading (46.t)			
Litter application rates (t./ha)	Land Area (ha.)	Litter application rates (t./ha)	Land Area (ha.)
0	13	0	19642
3.4	585	1	10149
4	6186		
4.8	6641		
6	2604		
Optimal P loading (23.6t.)			
Litter application rates (t./ha)	Land Area (ha.)	Litter application rates (t./ha)	Land Area (ha.)
0	13	0	20621
3.4	623	1	9171
4	5582		
4.8	7624		
6	2185		
Minimum P loading (18t.)			
Litter application rates (t./ha)	Land Area (ha.)	Litter application rates (t./ha)	Land Area (ha.)
0	13	0	20983
3.4	626	1	8809
4	5622		
4.8	6773		
6	2993		
Total land	16028		29792

the litter application rates as the allowed phosphorus loading was reduced. It appears that the most important change for reduction of phosphorus loading was the conversion of land from overgrazed to well-maintained pasture. The initial differences between overgrazed and well-maintained pasture were the quantity of nutrients (nitrogen) applied and the stocking rates of grazing cattle. The overgrazed pasture received less nitrogen and had a higher stocking rate than well-maintained pasture. Table 34 shows that reducing the stocking rate dominated the effect of nitrogen (litter) application when conducting the conversion from overgrazed pasture to well-maintained pasture. This suggests that reduction of the current stocking rates on overgrazed pasture could provide significant reduction of phosphorus loading.

Another observation from Table 34 is that the production of hay would likely increase if further reduction of phosphorus loading were desired. Higher litter application on hay would result in greater hay production. On one hand, this would increase the supply of hay in the region, which could cause its price to fall. On the other hand, baled hay may be an efficient way of exporting some of the nutrients out of the watershed that initially entered through purchased poultry feed.

The results on alum use under the policy of mandatory land use change are presented in Table 35. The results show that it would be socially optimal to use alum to reduce the phosphorous loading at the watershed level in combination with a mandatory land use change. The use of alum was emphasized on hay where about 80 percent of the total land received alum treated litter. The reduction in total quantity of alum treated litter at the minimum phosphorus loading came about because of the reduced opportunity for litter application on hay.

Table 35. Alum Use Under the Policy of Mandatory Land Use Change.

	Hay	Well Maint. Pasture	Alum Treated Litter
	Alum Use		
	Land Area (ha.)	Land Area (ha.)	Total Quantity (tons)
Current P load (46t.)	0	0	0
Optimal P load (23.6t.)	12445	517	25325
Minimum P load (18t.)	13585	517	19431

The results on alum use by particular soil types for both hay and well-maintained pasture are presented in Table 36. The results identify soil types where alum use was found to be more pronounced. Alum use was greatest on Newtonia, Captina, Macedonia and Tonti soils. Alum was found least used on the Razort, Stigler, Noark and Doniphan soil types.

Table 36. Alum Use by Soil Types (all land uses) for Policy of Mandatory Land Use Change.

Soil Type	Land Area of Particular Soil Type Receiving Alum Treated Litter	Total Land Area of a Particular Soil Type	Proportion of Land Area Receiving Alum Treated Litter to Total Land of Particular Soil Type
	Ha.	ha.	fraction
Tonti	1210	3421	0.35
Clarksville	3932	12716	0.31
Captina	2306	6028	0.38
Nixa	2151	6996	0.31
Peridge	356	1362	0.26
Britwater	283	834	0.34
Noark	35	570	0.06
Jay	222	687	0.32
Razort	45	1424	0.03
Doniphan	607	4541	0.13
Macedonia	678	1878	0.36
Newtonia	933	1673	0.56
Eldorado	62	215	0.29
Stigler	119	3123	0.04

The optimal level of transportation of litter within the watershed was fairly stable across the three levels of required phosphorus loading ranging from 610 to 640 thousand ton miles. Export of litter outside the watershed was not required to meet the optimal phosphorus target of 23.6 metric tons per year.

Detailed results by HRUs for the mandatory land conversion policy under the determined optimal phosphorus loading (23.6 t./year) are provided in the Appendix Table A 9. Again, the top of the table is occupied by more or less the same HRUs as in the case of all previous policies. These HRUs contribute the most to the net agricultural income and are also characterized with relatively low phosphorus runoff. The HRUs situated near ponds, smaller lakes or at waterlogged areas are again at the bottom of the table. In general, the HRUs that contribute the least to the net agricultural income have lowest shadow prices for this policy as well. Since this policy converted the most "environmentally inefficient" HRUs and transformed them to more efficient ones, the contribution to agricultural income was main determinant of the shadow price of an HRU.

In general, the policy of mandatory land use change was more economically efficient in reducing phosphorus loading in the watershed than changes in litter management alone or the STP policy alone. However, a mandatory land conversion imposed on landowners would be unpopular and very difficult to implement in practice, which renders this policy infeasible for practical implementation.

6.5. Policy 4 – Site Specific (Optimal) Land Use Change

The results obtained from the linear programming runs for a simulated policy of a site-specific land use change are presented in Table 37. The results show that significant reduction of phosphorus load can be achieved at quite low cost using this policy. For example, the phosphorus load could be reduced from current 46 tons/year to 30 tons/year at total cost of about $100,000 through a combination of land use changes and litter management practices including alum. Further reductions from both point and non-point sources could reduce total loading to 18 tons per year for an annual abatement cost of approximately $380,000 per year. The results suggest that allowing for site-specific land use changes would be a very effective and economically efficient way to reduce phosphorus loading in the watershed. At the same time this policy is more efficient than the policy with uniform land use change, which can be detected by comparing the values of the objective function for the two policies at all levels of phosphorus loading.

Table 37. Results from the Linear Program Runs for the Simulated Site Specific Land Use Change Policy.

Phosphorus loading (Z max)	Value of the objective function	Marginal abatement cost for P	Total abatement cost for Agricultural Enterprises	Total abatement cost to the point source	Sum of Total Abatement and Damage Costs
kg / year	dollars/watershed	dollars/kg P	dollars/year	dollars/year	dollars/year
46000	5,802,664	2.19	0	0	780,235
40000	5,781,731	5.28	20,933	0	690,323
35000	5,747,528	8.12	55,136	0	566,243
30000	5,701,701	10.67	100,963	0	453,257
25000	5,634,879	14.53	134,672	33,113	395,017
24526[i]	**5,627,992**	**14.53**	**134,817**	**39,855**	**338,715**
20000	5,562,011	15.16	139,446	101,207	383,257
18000	5,529,492	18.11	160,688	112,484	385,656

[i] socially optimal value of phosphorus loading obtained with functional approximation of the marginal abatement cost function

The socially optimal level of phosphorus loading for the policy of site-specific land conversion could be found at the minimum of the sum of abatement and damage costs. The optimal solution using the functional approximation of the marginal abatement costs was obtained by equating marginal abatement costs to marginal damage costs. The marginal abatement costs for this policy can be expressed as a linear function of the phosphorus load by

(6.4) $$MAC_4 = 27.357 - 0.00054\ Zmax.$$

Solving for the socially optimal phosphorus load by equating the marginal abatement cost and marginal damage costs (Eq. 4.12) one obtains the value of 24526 kilograms per year as optimal phosphorus loading under the policy of site specific (optimal) land use change. Figure 20 graphically presents the marginal abatement and damage costs and the point of optimal phosphorus loading obtained by equating them.

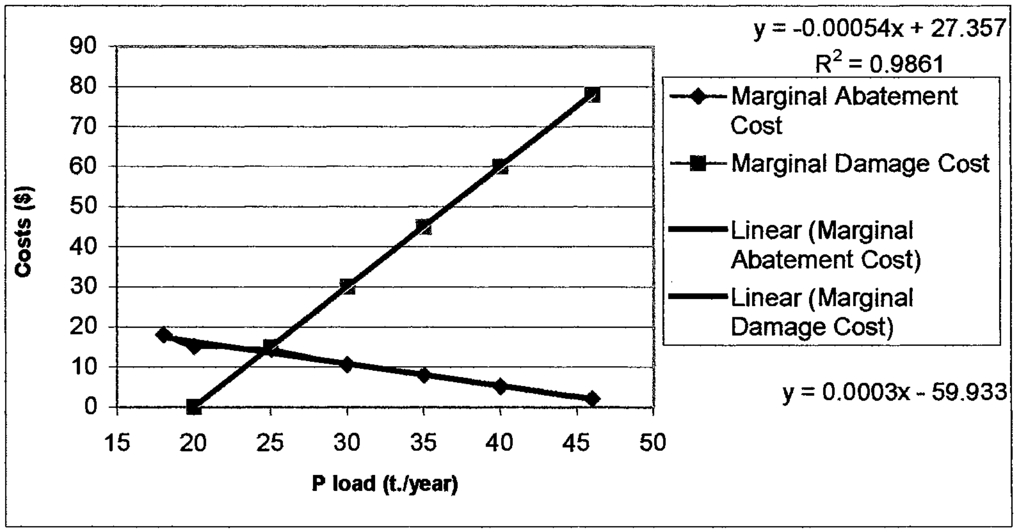

Figure 20. Marginal Abatement and Damage Costs for Site Specific Land Use Change Policy.

For this phosphorus load, the annual costs of agricultural abatement activities were around $165,000, while the costs at the point source were about $33,000. The point source would abate about 2.3 metric tons of phosphorus annually.

The simulation of this policy allowed for analysis of the optimality of land use conversion from overgrazed to well-maintained pasture and from row crop to hay. Table 38 presents the results on the optimal land area converted for the three levels of allowed phosphorus loading.

Table 38. Optimal Land Conversion of Overgrazed to Well-maintained Pasture and of Row Crop to Hay for the Three Levels of P loading for Site-Specific Land Use Change Policy.

	Max P load (46t.)		Opt. P load (24.5 t.)		Min. P load (18 t.)	
	Land converted	Land not converted	Land converted	Land not converted	Land converted	Land not converted
	ha.	ha.	ha.	ha.	ha.	ha.
Overgrazed Pasture	6537	5	6537	5	4725	1816
Row Crop	385	2240	1106	1519	1792	834

Figures 21, 22 and 23 present the spatial distribution of optimal land use conversion in the Eucha-Spavinaw watershed for the maximum (46 t), optimum (24.5 t) and minimum (18 t) phosphorus loading target.

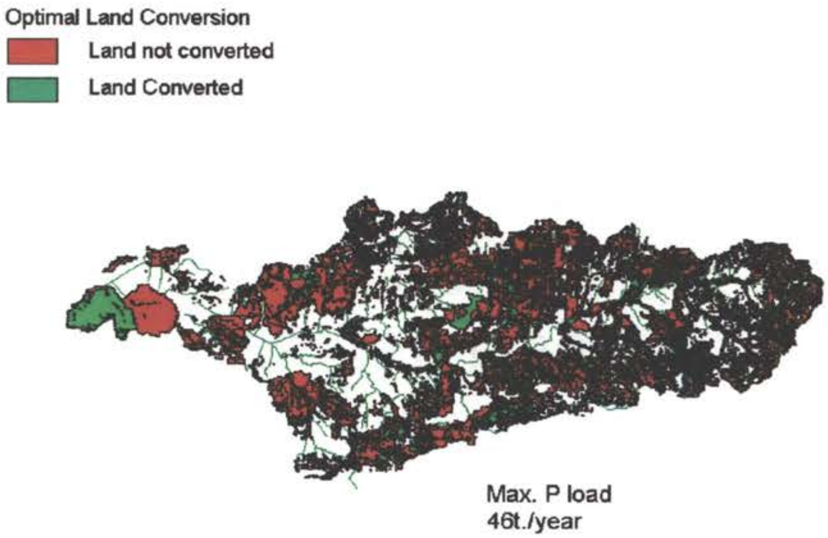

Figure 21. Spatial Distribution of Land Conversion, Policy 4, at P Loading Target of 46 t/year

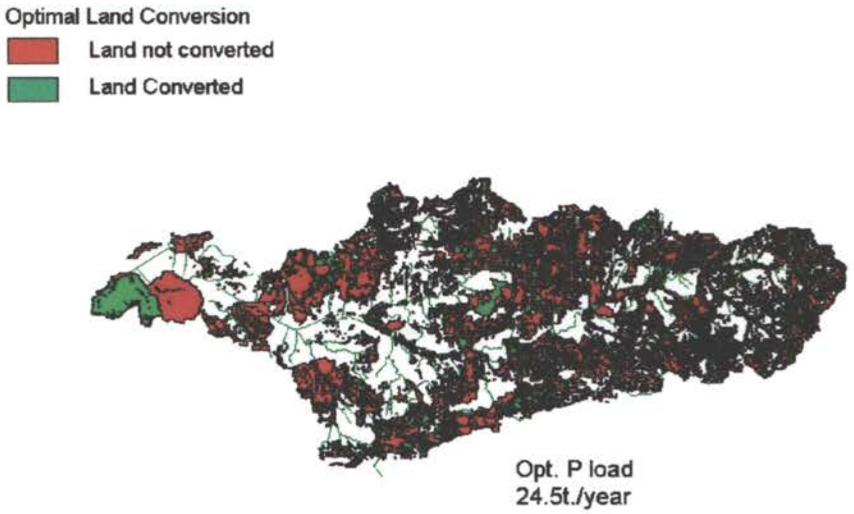

Figure 22. Spatial Distribution of Land Conversion, Policy 4, at P Loading Target of 24.5 t/year

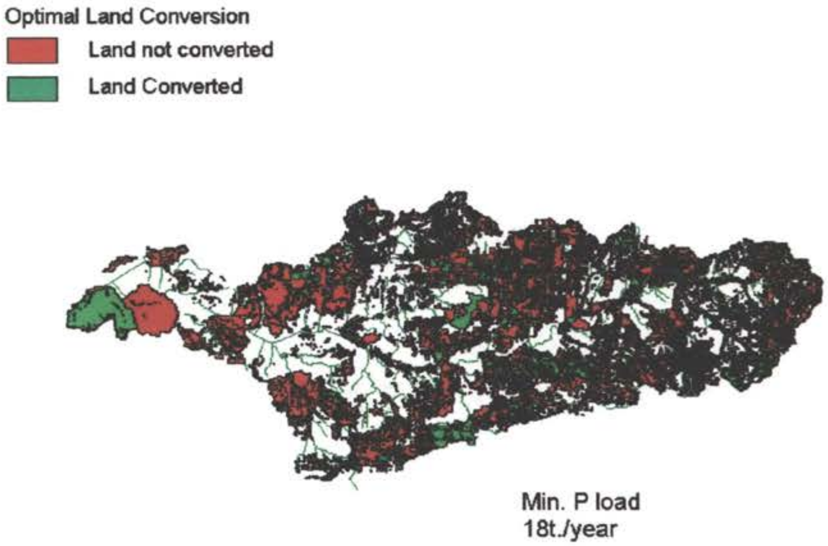

Figure 23. Spatial Distribution of Land Conversion, Policy 4, at P Loading Target of 18 t/year

Presented results show that the conversion of overgrazed pasture played a relatively more important role in reducing phosphorus loading than conversion of row crop to hay. At the optimal phosphorus loading, virtually all overgrazed pasture was converted while only about 40 percent of the row crop was converted. If the allowed phosphorus loading were further restricted to 18 tons per year, the amount of overgrazed pasture not converted would increase, while more of the of row crop would be converted to hay.

This is explained by the optimal litter application rates presented in Table 39.

Table 39. Litter Application Rates by Original Land Uses for the Three Levels of Allowed P loading, for the Site Specific Land Use Change Policy.

		Hay	Well Past	Overgrazed		Row Crop	
				Converted to Well P.	Not Converted	Converted to Hay	Not Converted
		Land Area (ha.)					
Max P loading (46t.)	Litter Application Rates						
	Low	11	22852	6446	5	0	462
	Medium	320	398	91	0	0	472
	High	13071	0	0	0	385	1306
Opt. P loading (24.5 t.)	Litter Application Rates						
	Low	11	22852	6446	5	0	840
	Medium	316	398	87	0	0	128
	High	13075	0	0	0	1106	550
Min P loading (18t.)	Litter Application Rates						
	Low	3433	20006	2749	347*	1220	736
	Medium	927	334	55	5	28	47
	High	9041	2910	1922	1464	545	51

*338 ha with N replacement

Classification of litter application rates is as follows: for hay and well-maintained pasture, low litter application rate is between 0-2 tons, medium is between 2-4 tons and high is 4-6 tons/ha. For overgrazed pasture, low: 0-1.1 t./ha, medium: 1.1- 1.8 t./ha, high: 1.8-3.2 t/ha., for row crop. low: 0- 0.65 t./ha, medium: 0.65- 1.3 t./ha, high: 1.3-2 t/ha.

The results show that at both the maximum and optimum phosphorus loadings, the overgrazed pasture was converted to well-maintained pasture by essentially reducing the cattle stocking rates. If further reduction of phosphorus load were required, then the conversion of overgrazed pasture to well-maintained pasture would require increased fertilization in addition to reduced stocking rates. Thus meeting the 18 ton phosphorus loading target would require that most overgrazed pasture receive high application of nitrogen, either from litter or from commercial fertilizer.

For this policy of site-specific land use conversion it was also important to observe alum use as the phosphorus loading targets are varied. The results are presented in the Table 40. Alum use increased as the allowed phosphorus loading was reduced. Alum use was also greater with higher litter application rates. At the optimal level of phosphorus loading, most of the hay crop was fertilized with alum treated litter.

Table 40. Alum Use on Land Area by Original Land Uses for the Three Levels of Allowed P loading, by Litter Application Rates for the Site Specific Land Use Change Policy.

	Hay	Well Past	Overgrazed		Row Crop	
			Converted to Well	Not Converted	Converted to Hay	Not Converted
Alum Used on Land Area (ha.)						
Maximum P load (46 t.)						
Litter Application Rates						
Low	0	0	0	0	0	0
Medium	0	0	0	0	0	12
High	0	0	0	0	0	252
Optimum P load (24.5 t.)						
Litter Application Rates						
Low	0	1530	48	0	0	0
Medium	295	220	12		0	43
High	11591	0	0	0	630	280
Minimum P load (18 t.)						
Litter Application Rates						
Low	367	898	75	0	0	36
Medium	499	234	55	5	28	13
High	7530	2846	1878	1300	545	34

Classification of litter application rates as defined in Table 39.

The total quantity of alum treated litter used was only 508 tons for the current phosphorus loading (46 t.), but 64.2 thousand tons for the optimal phosphorus loading (24.5 t.), and would increase to 74.1 thousand tons for the minimum phosphorus loading (18 t.).

The change in the amount of litter transport varied less dramatically as the total phosphorus limit was lowered. The litter transport within the watershed was calculated at 605 thousand ton miles for the current phosphorus loading (46 t.), 658 thousand ton miles for the optimal phosphorus loading (24.5t.), and 673 thousand ton miles for the minimum phosphorus loading (18 t.).

The optimal conversion of overgrazed pasture to well-maintained pasture and conversion of row crops to hay by soil types is summarized in Tables 41 and 42. Essentially all of the overgrazed pasture would be converted to well-maintained pasture at the optimal phosphorus loading level (24.5t.).

Table 41. Optimal Conversion of Overgrazed Pasture to Well-maintained Pasture by Soil Type for the Optimal (24.5t.) and Minimum (18 t.) P loading for the Site Specific Land Use Change Policy.

Overgrazed Pasture Conversion							
	Optimal P load (24.5 t.)			Minimum P load (18 t.)			
Soil Type	Land by Soil Type Not Converted (ha.)	Land Converted to Well M Past.(ha.)	Proportion of Land Converted	Land by Soil Type Not Converted (ha.)	Land Converted to Well M Past. (ha.)	Proportion of Land Converted	Total Land of Particular Soil Type (ha.)
Tonti	5	445	0.99	270	175	0.39	450
Clarksville	0	1512	1.00	367	1145	0.76	1512
Captina	0	996	1.00	164	832	0.84	996
Nixa	0	738	1.00	309	429	0.58	738
Peridge	0	209	1.00	38	171	0.82	209
Razort	0	131	1.00	0	131	1.00	131
Doniphan	0	1097	1.00	217	880	0.8	1097
Macedonia	0	477	1.00	144	332	0.7	477
Taloka	0	73	1.00	32	41	0.56	73
Stigler	0	154	1.00	18	136	0.88	154
Newtonia	0	514	1.00	186	328	0.64	514

At the minimum phosphorus loading level, the conversion was found not optimal (the pasture became more heavily fertilized) on Tonti, Taloka and Nixa soils. It was found optimal to convert the row crop to hay on the soil types Macedonia, Doniphan, and Captina for 18 t. and 24.5 t. phosphorus limits.

Table 42. Optimal Conversion of Row Crop to Hay by Soil Type for the Optimal (24.5t.) and Minimum (18 t.) P loading for the Site Specific Land Use Change Policy.

Row Crops Conversion							
	Optimal P load (24.5 t.)			Minimum P load (18 t.)			
Soil Type	Land by Soil Type Not Converted (ha.)	Land Converted to Hay (ha.)	Proportion of Land Converted	Land by Soil Type Not Converted (ha.)	Land Converted to Hay (ha.)	Proportion of Land Converted	Total Land of Particular Soil Type (ha.)
Captina	259	253	0.49	189	323	0.63	512
Nixa	240	8	0.03	85	163	0.66	248
Peridge	129	31	0.19	33	127	0.79	160
Tonti	185	0	0.00	12	173	0.94	185
Clarksville	274	115	0.30	89	300	0.77	389
Doniphan	13	213	0.94	16	210	0.93	226
Macedonia	0	111	1.00	17	95	0.85	111
Taloka	208	39	0.16	130	117	0.47	247
Newtonia	126	232	0.65	170	187	0.52	357

The analysis of optimal land use changes by land slope is also an important aspect to investigate. Results for the changes in land use by slopes for the optimal (24.5t.) and minimum (18 t.) phosphorus load level are presented for the overgrazed pasture and row crop in the following Table 43.[15] As expected, the results show that it is optimal to convert more of the land with steeper slopes than land with less steep slopes. However this tendency cannot be generalized. Even at very low phosphorus loading levels, there were some areas with slopes in excess of 8 percent, which were not optimally converted. For example, overgrazed pasture may be heavily fertilized with commercial nitrogen. This result may not hold if nitrogen runoff were also a concern.

Detailed results by HRU for the policy of site-specific land use change are

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[15] Results in this section are reported only for the optimal (24.5t.) and minimum (18 t.) phosphorus loading, since the results for the current (46 t.) and the optimal (24.5t.) are quite similar, especially regarding the land uses of interest (overgrazed pasture and row crop).

provided in the Appendix Table A10. The results and interpretations are fairly similar to those reported for Policy 3. An additional characteristic is that for the row crop, HRUs converted to hay tended to have lower shadow prices than the HRUs that were not converted. On the other hand, the results show that some of the overgrazed pastures could became both economically and "environmentally efficient" once the management practices were changed, in effect converting them to well maintained pasture (for example, HRU 902).

Table 43. Optimal Land Conversion of Overgrazed Pasture to Well-maintained Pasture and Row Crop to Hay, for the Optimal and Minimum P loading rate, for the Site Specific Land Use Change Policy.

		Average Slope				
		<1%	1-3%	3-5%	5-8%	>8%
Optimal P load (24.5t)		Land Area (ha.)				
Overgrazed Pasture	Land Converted to WPAS	0	1112	1741	2947	737
	Land not Converted	0	0	0	0	5
Row Crop	Land Converted to HAY	0	647	259	79	121
	Land not Converted	132	691	526	146	23
Minimum P load (18t)		Land Area (ha.)				
Overgrazed Pasture	Land Converted to WPAS	0	799	1228	2291	407
	Land not Converted	0	313	513	656	335
Row Crop	Land Converted to HAY	132	850	497	178	135
	Land not Converted	0	488	289	48	10

In general, the policy of site-specific (optimal) land use conversion was the most efficient and effective policy for reducing the phosphorus loading in the watershed, studied in this dissertation. However, this policy could only be achieved in the long run, and would have to involve some built-in incentive scheme (taxes or subsidies) to be effectively instituted.

CHAPTER VII

SUMMARY AND CONCLUSIONS

7.1. Summary of the Procedures and Results

The dissertation assessed several technologies and policies that could be used for management of phosphorus pollution from both non-point sources and the point source in the Eucha-Spavinaw watershed. The analysis used the approach that minimizes the sum of abatement and damage costs (or alternatively equates marginal abatement to marginal damage costs) to derive the socially optimal pattern and method of phosphorus abatement in the watershed. The perspective was that of a watershed manager. All costs and benefits were internalized in the optimal solutions presented. The preferences of the society, translated directly into the preferences of a hypothetical watershed manager are expressed in the form of a social well-being function. The optimal level of phosphorus abatement in the watershed would maximize this well-being function. The maximum point of the well-being function corresponds to the minimum of the sum of total abatement and damages costs and also corresponds to the point of equivalence between the marginal abatement and damage costs.

The analysis of the abatement costs was based on the costs of reducing phosphorus emissions from both point and the non-point sources of phosphorus loading in the watershed. Abatement costs at the point source (the City of Decatur, AR) were determined using engineering data. For the non-point agricultural sources, a spatial bio-physical model (SWAT) was used to simulate phosphorus loading from each agricultural enterprise at each tested poultry litter management practice. Thirteen poultry litter application rates were simulated. These consisted of various litter application rates with and without an option for nitrogen replacement with commercial fertilizer for each of the major land uses in the watershed. The possibility of using litter amended with 10 percent aluminum sulfate was also considered. Adding this possibility to the thirteen litter application rates, resulted in twenty-four simulated litter management practices. For each of these litter management practices, net agricultural income was calculated using SWAT output, enterprise budgeting, and price data.

Environmental damage costs included the cost of additional drinking water treatment for the City of Tulsa and the costs of recreational losses at the lakes Eucha and Spavinaw. These costs were estimated using the observed data and were combined to calculate total damage costs. This provided an estimate of the environmental damage costs. The dissertation does not claim that all possible damage costs are accounted for. The overall ecological values that the watershed provides, and in general the non-use values of the watershed (existence, option and bequest values) were not considered because of data and technical limitations. Nevertheless, the costs that were treated in the dissertation represent a significant proportion of the actual measurable environmental damage cost from phosphorus loading in the Eucha-Spavinaw watershed, and therefore provide a meaningful estimate of the damage costs. The marginal damage cost curve was calculated as a derivative from the total environmental damage cost curve.

A baseline case and four policy simulations that involved broiler litter management practices, land use changes, and increased phosphorus abatement at the point source were presented.[16] The baseline case examined the potential of using only reduced poultry litter application rates and point source abatement. SWAT simulations with thirteen litter management practices for each land use-soil type combination (HRU)

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[16] See Table 8 on page 82 for a summary of the policies.

in the watershed were conducted. The simulation results were included in a linear programming model, where a least-cost method of meeting phosphorus targets was determined. The first simulated policy added an option that the litter be treated with alum, as a possibility to reduce soluble phosphorus runoff. The second policy was to limit litter applications according to soil test phosphorus (STP) criterion. The third policy considered mandatory conversion of overgrazed pasture to well-maintained pasture and conversion of row crops to hay in the watershed. The fourth policy represented a combination of policies one and three, except that land conversion was optional. A summary of the baseline case and the simulated policies and their characteristics was provided in Table 8 in the text.

With respect to the time of implementation, the first policy represents a short-run solution in that it could be implemented almost immediately, the second policy short to medium run solution, while the last two policies would take longer time to implement. However, all policies and analysis are short-run with respect to phosphorus loading dynamics, since the long-term phosphorus accumulation in soils beyond current levels was not considered. Analyzing the phosphorus loading dynamics over time would require a study on its own and would have to use a different setup of the bio-physical simulation model, allowing for simulation of phosphorus dynamics. The orientation of this study was more towards a spatial detail and therefore a static equilibrium analysis was used.

For each policy, a linear programming model was used to maximize net income at the watershed level (net income from agriculture minus costs of abatement at the point source minus litter transportation costs). The linear program for each policy was run for seven distinct levels of allowed phosphorus loading in the watershed. Marginal abatement costs were obtained as shadow prices on phosphorus loading from the linear program runs. They were than approximated with a quadratic or linear function of the phosphorus loading and equated to the marginal damage costs to obtain a socially optimal level of phosphorus loading in the watershed for each simulated policy. Figure 23 presents the marginal abatement costs for the baseline case and for each policy analyzed, as well as the marginal damage costs.[17] The optimal phosphorus abatement (loading) for each individual policy is found at the point of intersection between the marginal abatement cost curve (MAC) and the damage cost curve. Figure 23 shows that as more flexible or site specific treatment methods are used, the greater is the amount of optimal abatement and the lower are the marginal costs of abatement.

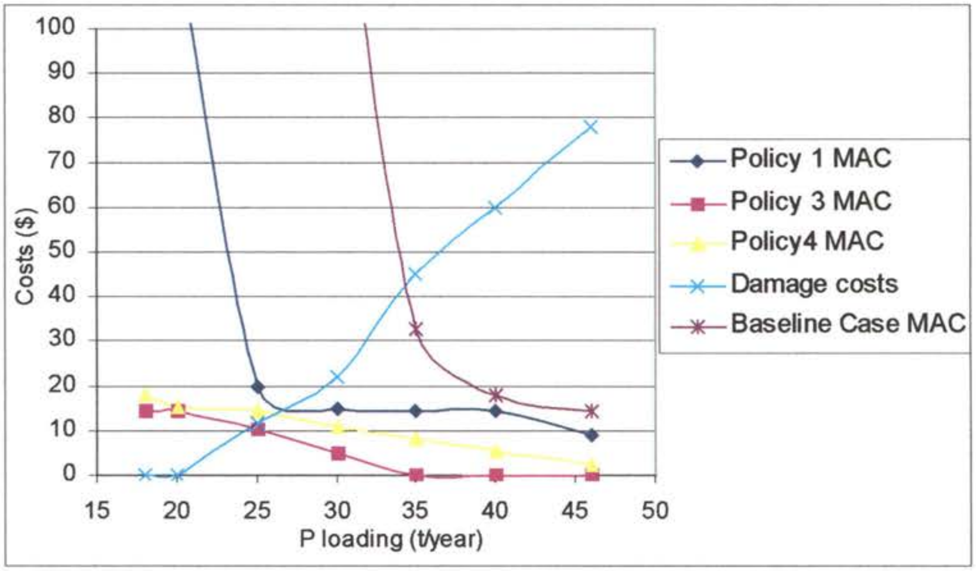

Figure 23. Marginal Abatement Cost Curves for the Baseline Case and the Individual Policies, and Marginal Damage Costs.

The linear programs were rerun for the determined optimal level of phosphorus loading, resulting in the optimal level of abatement at the point source and at each of the

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[17] Marginal damage costs were not derived for Policy 2, where there was not a binding phosphorus constraint in the linear program runs.

non-point sources. Alternatively, the socially optimal level of phosphorus abatement could be calculated by segmenting the estimated environmental damage cost function, including it in the linear program as damage costs activities and running the program. This alternative way of calculating the optimal phosphorus abatement can sometimes result in more and sometimes in less precise estimates of the actual optimal phosphorus abatement level, dependent on the curvature of the segmented damage cost function.

A summary of the steps that were undertaken in the research procedure is given in Table 44.

Table 44. Summary of the Steps taken in the Research Procedure.

	Procedure
Step 1	Run SWAT model for the 13 litter application rates. Estimate net agricultural income for each litter and land management practice. Estimate cost of phosphorus abatement at the point source. Estimate litter transportation costs.
Step 2	Estimate environmental damage costs.
Step 3	Build a linear program model to derive total and marginal abatement costs, and alternatively to solve for the optimal phosphorus loading by incorporating the segmented damage cost function in the linear program.
Step 4	Conduct functional approximation of the marginal abatement costs and equate them to the estimated marginal damage costs to obtain the socially optimal level of phosphorus loading in the watershed.

The results for the non-point sources obtained using the described procedure are identified at considerable level of spatial detail, so that they imply spatially optimal litter management practices for the agricultural enterprises in the watershed.

7.2. Conclusions

Several conclusions could be derived from the presented results. First, from the determined optimal levels of phosphorus loading to the lakes in the watershed under the various policies analyzed, it appears that a reasonable target for phosphorus loading could be set in a range of 23,000 to 26,000 kilograms per year. This range is a little higher than proposed by some previous studies, but still indicates that significant reduction of external phosphorus loading is socially optimal.[18] There may be some phosphorus abatement methods that were not included in this study (such as buffer strips, for example), whose use would potentially reduce the optimal phosphorus loading even further than found here. At the optimal phosphorus loading levels determined in this study, the costs of phosphorus abatement were not found to be excessively high, especially in the long-run. Further reductions of phosphorous loadings below these levels are attainable, but would be more costly to achieve, especially in the short-run. However, given the uncertainties and limitations of both the bio-physical model (SWAT) and the economic model, it is difficult to correctly assess an exact optimal level of allowed phosphorus loading in the watershed.

Second, the use of the STP criterion alone to regulate the litter application and phosphorus loading in the watershed seems not to be a very effective and/or efficient policy. This policy was modeled as preventing litter application on high STP soils regardless of soil type, land use, or the probability of phosphorus loss, and with no special allowances for use of chemical litter amendments (alum). In this form, the STP policy alone caused high losses of agricultural income and increased the amount of litter hauled out of the watershed. The simulated policy created perverse incentives for applying litter indiscriminately where the STP level was below the limit, just to avoid hauling it out of the watershed. Consequently, the model predicted litter would be applied to soils that were very susceptible to phosphorus runoff (steep slopes, erodable soils etc).

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[18] The recommendation presented in the report by OWRB (OWRB, 2002) of 54% reduction of external phosphorus loading amounts to the desired target of about 22 t/year of phosphorus loading to Lake Eucha.

Applying litter using the Phosphorus Risk Index (Storm and Smolen, 2001) as a criterion instead of using STP, may improve the performance of this regulatory strategy.

Third, land use change appears to be an important component of an efficient long-term solution to the problem of phosphorus pollution in the watershed. However, this would require changes in the economic structure of the agricultural production in the watershed, which would take more time to accomplish. In particular, site-specific change in land use, where there is a choice of which land area should be converted, represented a superior policy relative to the mandatory land use change. The results show that it would be optimal to convert most overgrazed pasture to well-maintained pasture, while it is optimal to convert about 40 percent of the row crops to hay. The results are derived based on the estimated land cover situation and on estimated average grazing rates. If more site specific information on grazing rates were available, the results could have been more accurate with respect to optimal conversion.

Fourth, conditioned on assumptions based on the currently available scientific information, amending poultry litter with alum appears to be effective and efficient way of reducing phosphorus loading at the watershed level. The use of alum played a significant role in all optimal solutions for the analyzed policies. The optimality of alum use was quite pronounced with high litter application rates, implying that if higher litter application rates were used, a significant reduction of phosphorus runoff could be achieved if the litter was treated with alum.

Fifth, the transportation of litter both within and out of the watershed was a significant part of the optimal solutions for phosphorus loading reduction. It is important to note again that the economic analysis in this report was from a social perspective, or from the perspective of a hypothetical watershed manager. From this perspective, the litter transportation costs are internal to the optimal decisions, and hence the transportation was a part of the optimal solutions. From a perspective of an individual agricultural producer however, the transportation costs are born privately. That is why an analysis from a pure private perspective, which would ignore a typical externality such as phosphorus pollution, would result with different findings regarding the transportation of litter. However, any solution to the phosphorus loading in the Eucha-Spavinaw watershed would require an analysis that takes into consideration both social and private objectives and would recommend policies where the discrepancies between the two are minimized. Some of these policies are subsidizing transportation of litter and/or tax credit incentives.

Sixth, significant phosphorus abatement at the point source would be optimal, especially in the short run. In the short-run, abatement at the point source could be achieved at lower cost than abatement in majority of agricultural land use areas (some agricultural enterprises would be able to abate even cheaper than the point source). Thus in the short-run, it is optimal to abate phosphorus and to drive the phosphorus concentration of the effluent from the point source to the 1 mg/l benchmark. Even though in the long-run, with land use conversion, the abatement at the agricultural sources would be marginally less expensive than the abatement at the point source, the time frame and the urgency of the problem would require significant abatement at the point source.

Finally, and possibly most important, the methodology used in this study provides a practical and robust method, assessing the optimal solutions at considerable level of spatial detail. For each unique agricultural land area (HRU) the study has assigned an optimal litter management practice for each simulated policy. The average agricultural

HRU in the study had a size of 65 hectares. At this scale it is feasible to apply optimal litter and land management practices on site-specific basis. This would enable economic efficiency, as compared to use of rules and policies on the uniform basis. The results on the spatial detail for the optimal solutions for each policy were presented for each HRU in the Appendix. In addition, for each policy, the spatial detail has been aggregated to derive results with respect to soil types and slope steepness. Using this aggregation, it is possible to draw some inference about the types of soils where litter application should be first restricted, where alum use is most beneficial, or the slopes for which the conversion of land uses is most optimal. However, these are just general inferences and by no means do they apply uniformly to a particular soil type or slope category. These aggregated results therefore may provide general guidelines, but should not be used for policy formation when disaggregated results are available. The shadow prices for each HRU and for each of the analyzed policy represent the results in disaggregated form that could be used in policy formation.

7.3. Policy Implications

Certain policy implications can be drawn from the presented results and conclusions in this dissertation. The results clearly state that a single sided "command and control" based policy (STP policy alone) is ineffective in reducing the phosphorus loading and is economically inefficient.

Policies that encourage management improvements on overgrazed pasture would be effective and efficient for reducing phosphorus loading. The improved management practices for overgrazed pasture include reducing stocking rates and better nitrogen fertilization. These changes would in the same time benefit the private land users by improving the quality and productivity of the pasture. Therefore, this recommended change could be addressed through extension work or other education based policies.

Policies that encourage site-specific conversion of row crop to hay (or other crop less susceptible to phosphorus runoff), would also contribute significantly to reduction of phosphorus loading. This land use conversion would necessarily have to be initiated through an incentive scheme involving taxes or subsidies for the individual land users, since the conversion is not beneficial from the perspective of private land users. The feasibility of using the existing conservation programs to this end was not considered in this study.

Presented results suggest that litter management technologies (such as treating litter with alum) are potentially very effective and efficient for phosphorus loading reduction. Therefore, policies that encourage agricultural producers to adopt these technologies should be considered. Education, extension work, incentive programs, and involvement of poultry integrators could play a significant role in this respect.

In the short-run, when land use conversion is not attainable, transporting the litter out of the watershed, or some other form of litter utilization within the watershed (energy generation, litter processing etc.) would be required to meet the more stringent phosphorus loading criteria. This implies that transportation of litter should be encouraged by tax incentives and/or subsidies and that various possibilities for litter processing should be welcomed.

7.4. Limitations and Directions for Further Study

As is the case with any modeling attempt, the methodology, procedures, results and conclusions presented in this dissertation are only an imperfect reflection of the real processes and problems that have been modeled. Every effort has been made to draw the modeling process and the real processes that have been modeled as close together as possible. Nevertheless, significant limitations remain of which one needs to be aware.

The limitations in this study stem from both SWAT modeling and the economic modeling. The SWAT model is a bio-physical model that is based on computer routines, approximations and simulations of biological and physical processes it models. Although SWAT is very reliable modeling tool, the uncertainty in parameter estimates is inherent, which results in the model limitations.

The economic modeling is inherently based on the neoclassical assumptions (utility maximization, profit maximization), which in themselves may not always be appropriate assumptions for the real problem that is being modeled. Also, the economic modeling used only the available data and information on both abatement and damage costs. If more data were available, the limitations of the economic model would have been lowered. The economic modeling used approximations, estimations and averaging that also involves uncertainties, which add to the limitations of the model.

There are several aspects in this dissertation for which further research would be needed. Most importantly, research on other and more poultry litter and land management practices should be conducted. There are a multitude of management practices that could be effective in the Eucha-Spavianw basin, including using buffer strips, using water treatment residuals as soil amendments, and other chemical treatment of litter to mention just a few. It is also very important to attempt to account for environmental damages in addition to the cost of water treatment to the City of Tulsa and loss of recreational values. Quantifying the ecological damages and other long-term impacts of phosphorus loading in the Eucha-Spavinaw watershed in economic terms remains a goal yet to be accomplished.

On the level of policy formation and implementation, it is needed to explore in greater detail the means of implementing the most efficient policy solution. Current incentive programs, such as the Conservation Reserve Program and EQIP (Environmental Quality Incentives Program), may need to be modified to effectively address the reduction of phosphorus pollution in the watershed. In addition, the feasibility of establishing a program for trading litter application permits and /or trading permits for soluble phosphorus runoff should also be explored. Market based mechanisms can often effectively and efficiently achieve the desired environmental criteria, but need to be carefully established on the basis of both environmental and economic findings. In general, the multidisciplinary approach, including hydrological, agricultural, biological and economic research, would be most beneficial for any future studies dealing with the problem of phosphorus pollution in the Eucha –Spavinaw.

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APPENDIX

Figure A1. A Schematic of the Design for Chemical Wastewater Treatment using Alum for City of Decatur, AR.

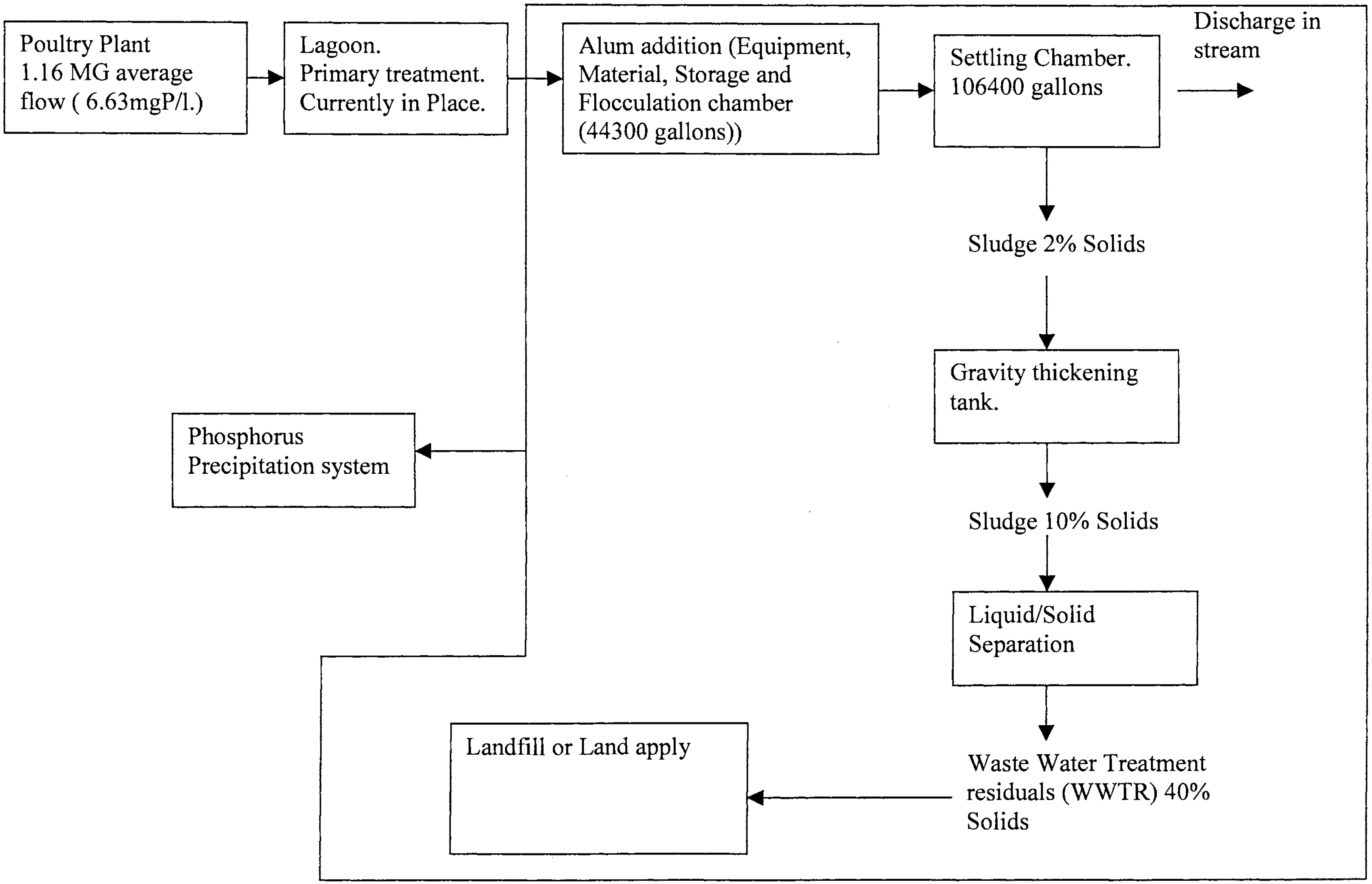

Table A.1. Costs of Various Components of the Chemical Wastewater Treatment at the Point Source.

P load in the watershed kg/year	Alum AlSO4 used (50% product) mg/l	P concentration in efluent mg/l	Alum used kg/year	Alum annual cost	Annualized cost of alum addition	Annualized cost of settling basin	Annulized cost of gravity thickening	Annualized separation costs	Annualized transportation costs	Annualized Landfiling Cost	Total annual cost	Capital (estimated initial) cost)	P removed (abatted) Kg./year
11686.02	0	6.63	0	0	0	0	0	0	0	0	0	0	0
11008.77	5	6.25	8813	$1,165	$8,754	$13,111	$12,891	$1,950	$321	$494	$38,684	$362,514	677
10365.68	10	5.88	17626	$2,329	$9,267	$13,111	$14,345	$2,339	$642	$987	$43,020	$382,409	1,320
9755.448	15	5.53	26439	$3,494	$9,674	$13,111	$16,654	$2,729	$962	$1,481	$48,105	$410,885	1,931
9176.832	20	5.21	35252	$4,659	$10,188	$13,111	$19,232	$3,119	$1,283	$1,974	$53,565	$443,668	2,509
8628.626	25	4.90	44065	$5,824	$10,552	$13,111	$20,974	$3,508	$1,604	$2,468	$58,040	$465,150	3,057
8109.663	30	4.60	52878	$6,988	$10,948	$13,111	$22,716	$3,898	$1,925	$2,961	$62,546	$486,999	3,576
7618.817	35	4.32	61691	$8,153	$11,355	$13,111	$24,458	$4,287	$2,246	$3,455	$67,064	$508,971	4,067
7155.001	40	4.06	70504	$9,318	$11,751	$13,111	$26,200	$4,677	$2,566	$3,948	$71,571	$530,820	4,531
6717.162	45	3.81	79317	$10,482	$12,179	$13,111	$27,942	$5,067	$2,887	$4,442	$76,109	$553,036	4,969
6304.286	50	3.58	88130	$11,647	$12,564	$13,111	$29,684	$5,456	$3,208	$4,935	$80,606	$574,763	5,382
5915.392	55	3.36	96943	$12,812	$12,993	$13,111	$31,426	$5,846	$3,529	$5,429	$85,144	$596,979	5,771
5549.534	60	3.15	105756	$13,977	$13,335	$13,111	$33,168	$6,236	$3,850	$5,922	$89,598	$638,216	6,136
5205.796	65	2.95	114569	$15,141	$13,849	$13,111	$34,910	$6,625	$4,170	$6,416	$94,222	$661,412	6,480
4883.297	70	2.77	123382	$16,306	$14,362	$13,111	$36,652	$7,015	$4,491	$6,909	$98,846	$684,609	6,803
4581.182	75	2.60	132195	$17,471	$14,833	$13,111	$38,394	$7,404	$4,812	$7,403	$103,428	$707,316	7,105
4298.63	80	2.44	141008	$18,635	$15,304	$13,111	$40,136	$7,794	$5,133	$7,896	$108,009	$730,022	7,387
4034.846	85	2.29	149821	$19,800	$15,668	$13,111	$41,878	$8,184	$5,453	$8,390	$112,484	$751,504	7,651
3789.063	90	2.15	158634	$20,965	$16,054	$13,111	$43,620	$8,573	$5,774	$8,883	$116,980	$773,230	7,897
3560.54	95	2.02	167447	$22,130	$16,503	$13,111	$45,362	$8,963	$6,095	$9,377	$121,540	$795,692	8,125
3348.564	100	1.90	176260	$23,294	$16,814	$13,111	$47,104	$9,353	$6,416	$9,871	$125,962	$816,561	8,337
3152.446	105	1.79	185073	$24,459	$16,875	$13,111	$48,846	$9,742	$6,737	$10,364	$130,133	$837,430	8,534
2971.52	110	1.69	193886	$25,624	$16,935	$13,111	$50,588	$10,132	$7,057	$10,858	$134,304	$858,299	8,715
2805.145	115	1.59	202699	$26,788	$16,996	$13,111	$52,330	$10,521	$7,378	$11,351	$138,476	$879,168	8,881
2652.702	120	1.50	211512	$27,953	$17,057	$13,111	$54,072	$10,911	$7,699	$11,845	$142,647	$900,037	9,033
2513.595	125	1.43	220325	$29,118	$17,117	$13,111	$55,814	$11,301	$8,020	$12,338	$146,818	$940,906	9,172
2387.247	130	1.35	229138	$30,283	$17,178	$13,111	$57,556	$11,690	$8,341	$12,832	$150,990	$961,775	9,299
2273.104	135	1.29	237951	$31,447	$17,239	$13,111	$59,298	$12,080	$8,661	$13,325	$155,161	$982,644	9,413
2170.631	140	1.23	246764	$32,612	$17,299	$13,111	$61,040	$12,470	$8,982	$13,819	$159,332	$1,003,513	9,515
2079.311	145	1.18	255577	$33,777	$17,360	$13,111	$62,782	$12,859	$9,303	$14,312	$163,504	$1,024,382	9,607
1998.647	150	1.13	264390	$34,941	$17,421	$13,111	$64,524	$13,249	$9,624	$14,806	$167,675	$1,045,252	9,687
1928.16	155	1.09	273203	$36,106	$17,481	$13,111	$66,266	$13,638	$9,945	$15,299	$171,846	$1,066,121	9,758
1867.388	160	1.06	282016	$37,271	$17,542	$13,111	$68,008	$14,028	$10,265	$15,793	$176,018	$1,086,990	9,819
1815.886	165	1.03	290829	$38,436	$17,603	$13,111	$69,750	$14,418	$10,586	$16,286.40	$180,189	$1,107,859	9,870
1773.224	170	1.01	299642	$39,600	$17,663	$13,111	$71,492	$14,807	$10,907	$16,779.93	$184,360	$1,128,728	9,913

Table A 2. Results from Estimation of the Costs to the City of Tulsa Using Monthly Phosphorus Concentration (Eq. 4.3.)

Effect	Year Dummy	Estimate	Standard Error	DF	t Value	Pr > |t|
year	1998	-50.8418	15.0636	47	-3.38	0.0015
year	1999	-30.3123	16.1748	47	-1.87	0.0671
year	2000	-41.7388	16.4152	47	-2.54	0.0144
year	2001	-64.1778	17.3454	47	-3.7	0.0006
year	2002	-58.9304	16.7389	47	-3.52	0.001
Lag2P		1147.5	353.58	47	3.25	0.0022
Lag3P		902.08	316.69	47	2.85	0.0065
Lag4P		772.36	325.14	47	2.38	0.0217

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
year	5	47	5.27	0.0006
Lag2P	1	47	10.53	0.0022
Lag3P	1	47	8.11	0.0065
Lag4P	1	47	5.64	0.0217

Table A 3. Results from Estimation of the Demand Equation for Recreation in Price Flexibility Form (Eq.4.6)

Effect	Pconc. level	Estimate	Error	DF	t Value	Pr > |t|
Q		-0.00157	0.000079	35	-19.85	<.0001
$MWTP^1$	0.037675	43.1634	1.4812	35	29.14	<.0001
$MWTP^2$	0.038232	42.4313	1.4706	35	28.85	<.0001
$MWTP^3$	0.038719	41.8975	1.4634	35	28.63	<.0001
$MWTP^4$	0.039133	41.8838	1.4633	35	28.62	<.0001
$MWTP^5$	0.039477	42.4304	1.4706	35	28.85	<.0001
$MWTP^6$	0.039749	41.347	1.4565	35	28.39	<.0001
$MWTP^7$	0.039887	39.0826	1.4333	35	27.27	<.0001
$MWTP^8$	0.03995	42.3921	1.4701	35	28.84	<.0001
$MWTP^9$	0.040042	39.6035	1.4379	35	27.54	<.0001
$MWTP^{10}$	0.04008	41.7904	1.4621	35	28.58	<.0001
$MWTP^{11}$	0.040126	41.7886	1.462	35	28.58	<.0001
$MWTP^{12}$	0.040139	41.4425	1.4577	35	28.43	<.0001

Q = number of visits per 1000 population (slope parameter estimated), $MWTP^k$ = maximum willingness-to-pay for recreation at the k^{th} phosphorus concentration level (intercept parameters estimated). Price of recreation (travel cost) was dependent variable.

Table A 4. Estimated Maximum WTP, Consumer Surplus (CS) and Change in Consumer Surplus (relative to 46000 kg/year) from Each Iso-Travel Cost Region

		Region 1		Region 2		Region 3		Region 4	
Pload (kg/year)	Estimated intercept (Max WTP)	CS	ΔCS	CS	ΔCS	CS	ΔCS	CS	ΔCS
18000	55.02	33,251	33,251	109,209	104,511	127,618	118,534	363,145	247,076
20000	53.97	26,778	26,778	97,193	92,495	114,601	105,517	340,947	224,877
25000	51.35	13,658	13,658	70,218	65,520	85,121	76,037	288,513	172,444
30000	48.73	4,913	4,913	47,617	42,919	60,016	50,932	240,454	124,385
35000	46.11	544	544	29,392	24,694	39,287	30,203	196,771	80,702
40000	43.49	0	0	15,542	10,844	22,933	13,849	157,463	41,394
46000	40.34	0	0	4,698	0	9,084	0	116,069	0

Table A 5. Values of the Socially Optimal Phosphorus Loading in the Eucha-Spavinaw Watershed for the Baseline Case, and Policies 1, 3 and 4, Calculated by Direct Linear Program Solution using the Segmented Damage Cost Function.

	Socially Optimal Phosphorus loading (Zmax)	Value of the objective function	Marginal Phosphorus Abatement Costs	Total abatement cost for Agricultural Enterprises	Total abatement cost to the point source
	kg / year	dollars/watershed	dollars/kgP	dollars/watershed	dollars/watershed
Policy					
Baseline	33980	5,048,053	43.57	374,687	159,332
Policy 1	26289	5,334,662	25.57	143,197	138,476
Policy 3	24000	5,497,400	12.48	66,161	0
Policy 4	25000	5,610,182	14.53	159,566	32,915

Table A 6. Spatial Detail for the Optimal Solution for Baseline case.

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
401	22	36.37	-94.51	9	Tonti	0.05	36.58	WWHT	1.95		3058	353.7
74	3	36.42	-94.67	15	Tonti	0.02	91.46	WWHT	1.95		4743	324.6
1038	68	36.33	-94.61	33	Tonti	0.04	36.59	WWHT	1.95		10508	321.6
381	21	36.41	-94.51	2	Tonti	0.03	60.98	WWHT	1.95		703	303.5
342	18	36.39	-94.47	10	Tonti	0.03	60.98	WWHT	1.95		2865	299.4
634	38	36.32	-94.53	45	Tonti	0.03	60.98	WWHT	1.95		13385	294.5
180	9	36.4	-94.37	12	Tonti	0.04	60.98	WWHT	1.95		3505	292.2
142	7	36.4	-94.31	13	Tonti	0.02	91.46	WWHT	1.95		3601	281.8
162	8	36.37	-94.33	21	Tonti	0.02	91.46	WWHT	1.95		5725	277.0
835	51	36.35	-94.75	1	Razort	0.01	15.24	WWHT	0.975	w/o N rep	367	254.7
282	15	34.4	-94.44	13	Tonti	0.04	60.98	WWHT	1.56		3305	251.1
324	17	36.41	-94.48	8	Tonti	0.04	60.98	WWHT	1.56		1969	250.2
577	35	36.32	-94.71	6	Razort	0.04	18.29	WWHT	0.975	w/o N rep	1538	248.8
837	51	36.35	-94.75	1	Elsah	0.01	15.24	WWHT	1.95		352	244.9
523	32	36.35	-94.77	6	Razort	0.03	18.29	WWHT	0.975	w/o N rep	1540	244.1
595	36	36.34	-94.76	6	Elsah	0.02	60.98	WWHT	1.95		1438	235.8
200	10	36.37	-94.41	5	Tonti	0.06	60.98	WWHT	0	w N rep	1084	224.4
581	35	36.32	-94.71	5	Elsah	0.04	18.29	WWHT	1.95		1155	224.2
593	36	36.34	-94.76	2	Razort	0.02	60.98	WWHT	0	w N rep	524	213.4
105	5	36.41	-94.63	1	Razort	0.04	36.58	WWHT	0	w N rep	253	201.2
756	46	36.29	-94.61	31	Taloka	0.02	60.98	WWHT	0	w N rep	6132	196.1
614	37	36.36	-94.59	3	Nixa	0.05	24.39	WWHT	1.95		481	191.9
141	7	36.4	-94.31	7	Nixa	0.02	91.46	WWHT	1.95		1391	190.9
400	22	36.37	-94.51	7	Nixa	0.05	36.58	WWHT	1.95		1263	190.2
615	37	36.36	-94.59	2	Peridge	0.05	24.39	WWHT	0	w N rep	410	186.0
179	9	36.4	-94.37	60	Nixa	0.04	60.98	WWHT	1.95		10827	179.9
926	56	36.38	-94.44	0	Elsah	0.09	60.98	WWHT	1.95		65	179.8
854	52	36.32	-94.68	1	Razort	0.10	24.39	HAY	6		200	172.9
341	18	36.39	-94.47	6	Nixa	0.03	60.98	WWHT	1.95		1109	172.8
578	35	36.32	-94.71	15	Clarksville	0.04	18.29	WWHT	0.65	w/o N rep	2624	172.1
572	35	36.32	-94.71	41	Razort	0.07	18.29	HAY	6		6964	171.1
380	21	36.41	-94.51	6	Nixa	0.03	60.98	WWHT	1.95		944	170.9
97	4	36.4	-94.57	13	Nixa	0.02	121.95	WWHT	1.95		2179	168.2
524	32	36.35	-94.77	2	Clarksville	0.03	18.29	WWHT	0.65	w/o N rep	322	167.6
612	37	36.36	-94.59	4	Clarksville	0.05	24.39	WWHT	1.95		644	164.5
121	6	36.38	-94.61	69	Taloka	0.01	121.95	WWHT	0	w N rep	11323	163.2
633	38	36.32	-94.53	31	Nixa	0.03	60.98	WWHT	1.95		5080	163.0
731	45	36.28	-94.67	158	Doniphan	0.03	91.46	HAY	6		25750	162.8
834	51	36.35	-94.75	1	Razort	0.06	15.24	HAY	4.8		172	159.8
730	45	36.28	-94.67	40	Clarksville	0.03	91.46	HAY	6		6454	159.6
507	31	36.36	-94.78	5	Healing	0.05	24.39	HAY	4	w N rep	775	159.4
592	36	36.34	-94.76	3	Razort	0.05	60.98	HAY	4.8		420	159.4
817	50	36.27	-94.81	118	Razort	0.09	24.39	HAY	4.8		18816	159.3
990	63	36.32	-94.89	4	Razort	0.08	18.29	HAY	6		583	159.3
301	16	36.35	-94.44	15	Nixa	0.05	60.98	WWHT	1.95		2329	159.2
766	47	36.39	-94.84	26	Razort	0.09	24.39	HAY	4.8		4062	158.6
504	31	36.36	-94.78	3	Razort	0.05	24.39	HAY	6		416	158.3
522	32	36.35	-94.77	22	Healing	0.05	18.29	HAY	4	w N rep	3463	158.2
520	32	36.35	-94.77	5	Razort	0.05	18.29	HAY	4.8		843	157.0
858	52	36.32	-94.68	1	Clarksville	0.09	24.39	WWHT	0.975	w/o N rep	125	155.9
693	43	36.36	-94.65	60	Newtonia	0.03	60.98	HAY	6		9361	155.7
909	55	36.27	-94.74	808	Doniphan	0.06	60.98	HAY	6		125000	154.7
73	3	36.42	-94.67	28	Newtonia	0.02	91.46	WWHT	0	w N rep	4309	154.4
713	44	36.3	-94.68	20	Doniphan	0.04	60.98	HAY	6		3106	154.3
857	52	36.32	-94.68	2	Doniphan	0.10	24.39	HAY	6		280	153.5
894	54	36.42	-94.62	6	Newtonia	0.02	91.46	WWHT	0	w N rep	927	153.0
354	19	36.35	-94.92	7	Razort	0.06	24.39	HAY	4	w N rep	1140	152.1
732	45	36.28	-94.67	83	Macedonia	0.03	91.46	HAY	6		12655	151.7

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
575	35	36.32	-94.71	38	Doniphan	0.07	18.29	HAY	6		5781	151.6
712	44	36.3	-94.68	21	Captina	0.04	60.98	HAY	6		3209	151.5
367	20	36.36	-94.89	14	Razort	0.16	24.39	HAY	4	w N rep	2087	151.3
821	50	36.27	-94.81	15	Razort	0.09	24.39	WWHT	0	w N rep	2283	151.3
259	14	36.37	-94.66	115	Newtonia	0.03	91.46	HAY	6		17317	151.1
232	13	36.41	-94.66	114	Razort	0.05	60.98	HAY	4.8		17154	150.3
710	44	36.3	-94.68	13	Clarksville	0.04	60.98	HAY	6		2022	149.9
907	55	36.27	-94.74	348	Clarksville	0.06	60.98	HAY	6		52186	149.8
755	46	36.29	-94.61	41	Captina	0.02	60.98	WWHT	0	w N rep	6126	149.6
1036	68	36.33	-94.61	13	Clarksville	0.04	36.58	WWHT	1.95		1932	149.6
579	35	36.32	-94.71	7	Clarksville	0.04	18.29	WWHT	0.325	w/o N rep	1093	149.3
281	15	34.4	-94.44	11	Nixa	0.04	60.98	WWHT	1.95		1666	149.3
668	42	36.3	-94.65	46	Doniphan	0.05	36.58	HAY	6		6838	148.6
1000	64	36.37	-94.91	6	Razort	0.11	36.58	HAY	4	w N rep	824	148.3
753	46	36.29	-94.61	184	Captina	0.03	60.98	HAY	4.8		27181	147.7
651	41	36.33	-94.65	24	Clarksville	0.07	24.39	HAY	6		3538	145.6
573	35	36.32	-94.71	87	Clarksville	0.07	18.29	HAY	6		12611	145.5
653	41	36.33	-94.65	18	Britwater	0.07	24.39	HAY	6		2535	144.8
981	62	36.33	-94.8	5	Clarksville	0.03	36.58	WWHT	0.325	w/o N rep	693	144.3
982	62	36.33	-94.8	10	Clarksville	0.03	36.58	WWHT	0.975	w/o N rep	1448	143.8
980	62	36.33	-94.8	99	Doniphan	0.05	36.58	HAY	6		14267	143.5
714	44	36.3	-94.68	33	Macedonia	0.04	60.98	HAY	4.8		4713	142.4
856	52	36.32	-94.68	2	Britwater	0.10	24.39	HAY	6		246	142.2
323	17	36.41	-94.48	12	Nixa	0.04	60.98	WWHT	1.95		1709	142.1
666	42	36.3	-94.65	35	Clarksville	0.05	36.58	HAY	6		5025	142.1
820	50	36.27	-94.81	107	Doniphan	0.09	24.39	HAY	6		15079	141.2
908	55	36.27	-94.74	228	Clarksville	0.06	60.98	HAY	6		32165	141.1
690	43	36.36	-94.65	41	Doniphan	0.03	60.98	HAY	6		5806	141.1
17	1	36.44	-94.67	52	Razort	0.07	60.98	HAY	4	w N rep	7333	140.6
752	46	36.29	-94.61	101	Clarksville	0.03	60.98	HAY	6		14177	140.3
978	62	36.33	-94.8	50	Clarksville	0.05	36.58	HAY	4.8		6968	139.9
122	6	36.38	-94.61	63	Newtonia	0.01	121.95	WWHT	0	w N rep	8766	139.3
576	35	36.32	-94.71	56	Macedonia	0.07	18.29	HAY	4.8		7763	139.0
836	51	36.35	-94.75	1	Britwater	0.01	15.24	WWHT	0	w N rep	88	138.7
711	44	36.3	-94.68	16	Clarksville	0.04	60.98	HAY	6		2204	138.5
468	28	36.36	-94.79	8	Clarksville	0.07	24.39	HAY	4.8		1129	138.4
781	48	36.4	-94.79	45	Razort	0.11	24.39	HAY	4	w N rep	6123	137.4
157	8	36.37	-94.33	58	Captina	0.03	91.46	HAY	6		8010	137.1
855	52	36.32	-94.68	5	Clarksville	0.10	24.39	HAY	6		710	136.8
652	41	36.33	-94.65	14	Clarksville	0.07	24.39	HAY	6		1933	136.5
967	61	36.35	-94.79	2	Doniphan	0.06	24.39	HAY	6		222	136.3
159	8	36.37	-94.33	69	Tonti	0.03	91.46	HAY	6		9365	136.3
574	35	36.32	-94.71	46	Clarksville	0.07	18.29	HAY	6		6200	136.2
818	50	36.27	-94.81	300	Clarksville	0.09	24.39	HAY	4.8		40798	136.1
956	60	36.37	-94.81	6	Clarksville	0.10	18.29	HAY	4.8		869	135.7
177	9	36.4	-94.37	201	Tonti	0.05	60.98	HAY	6		27246	135.6
613	37	36.36	-94.59	6	Captina	0.05	24.39	WWHT	0	w N rep	857	135.5
137	7	36.4	-94.31	143	Captina	0.03	91.46	HAY	6		19328	135.2
734	45	36.28	-94.67	16	Doniphan	0.02	91.46	WWHT	1.105	w/o N rep	2096	134.6
983	62	36.33	-94.8	13	Doniphan	0.03	36.58	WWHT	0.325	w/o N rep	1739	134.4
139	7	36.4	-94.31	73	Tonti	0.03	91.46	HAY	6		9828	134.0
209	11	36.4	-94.99	11	Razort	0.10	24.39	HAY	4	w N rep	1508	134.0
991	63	36.32	-94.89	5	Clarksville	0.08	18.29	HAY	4.8		686	133.9
992	63	36.32	-94.89	5	Britwater	0.08	18.29	HAY	4.8		612	133.6
688	43	36.36	-94.65	44	Clarksville	0.03	60.98	HAY	4.8		5874	133.5
236	13	36.41	-94.66	119	Newtonia	0.05	60.98	HAY	4.8		15935	133.5
460	27	36.36	-94.8	1	Elsah	0.13	36.58	HAY	6		156	133.2
480	29	36.34	-94.36	53	Tonti	0.06	60.98	HAY	6		7006	133.1
669	42	36.3	-94.65	40	Macedonia	0.05	36.58	HAY	4.8		5262	133.0

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
910	55	36.27	-94.74	24	Clarksville	0.04	60.98	WWHT	0.65	w/o N rep	3159	132.9
458	27	36.36	-94.8	2	Clarksville	0.13	36.58	HAY	4.8		284	132.3
339	18	36.39	-94.47	65	Tonti	0.05	60.98	HAY	6		8548	132.1
98	4	36.4	-94.57	22	Peridge	0.02	121.95	WWHT	0	w N rep	2891	132.0
235	13	36.41	-94.66	112	Doniphan	0.05	60.98	HAY	4.8		14729	131.9
667	42	36.3	-94.65	27	Clarksville	0.05	36.58	HAY	6		3574	131.7
691	43	36.36	-94.65	68	Macedonia	0.03	60.98	HAY	4.8		8878	131.4
521	32	36.35	-94.77	9	Clarksville	0.05	18.29	HAY	4.8		1139	131.4
278	15	34.4	-94.44	138	Tonti	0.05	60.98	HAY	6		18121	130.9
505	31	36.36	-94.78	7	Clarksville	0.05	24.39	HAY	4.8		865	130.8
416	23	36.36	-94.55	5	Peridge	0.05	24.39	HAY	4.8		666	130.3
966	61	36.35	-94.79	2	Clarksville	0.06	24.39	HAY	4.8		299	130.2
525	32	36.35	-94.77	4	Britwater	0.03	18.29	WWHT	0	w N rep	547	130.1
378	21	36.41	-94.51	45	Tonti	0.04	60.98	HAY	6		5861	130.1
413	23	36.36	-94.55	2	Captina	0.05	24.39	HAY	4.8		266	130.0
1051	69	36.35	-95.01	2	Healing	0.06	24.39	HAY	3.4	w/o N rep	314	130.0
979	62	36.33	-94.8	113	Clarksville	0.05	36.58	HAY	4.8		14692	129.9
197	10	36.37	-94.41	48	Tonti	0.06	60.98	HAY	6		6245	129.5
819	50	36.27	-94.81	146	Clarksville	0.09	24.39	HAY	4.8		18845	129.4
357	19	36.35	-94.92	9	Doniphan	0.06	24.39	HAY	4.8		1126	129.3
45	2	36.43	-94.7	373	Doniphan	0.04	60.98	HAY	4.8		48271	129.3
399	22	36.37	-94.51	25	Captina	0.05	36.58	WWHT	0	w N rep	3195	128.7
92	4	36.4	-94.57	130	Newtonia	0.02	121.95	HAY	4.8		16705	128.6
398	22	36.37	-94.51	29	Tonti	0.06	36.58	HAY	6		3750	128.4
120	6	36.38	-94.61	142	Newtonia	0.01	121.95	HAY	4.8		18138	128.0
257	14	36.37	-94.66	70	Macedonia	0.03	91.46	HAY	4.8		8878	127.6
957	60	36.37	-94.81	2	Clarksville	0.10	18.29	HAY	4.8		216	127.2
321	17	36.41	-94.48	70	Tonti	0.06	60.98	HAY	6		8823	126.8
893	54	36.42	-94.62	88	Newtonia	0.02	91.46	HAY	4.8		11158	126.7
550	34	36.33	-94.86	4	Clarksville	0.10	24.39	HAY	4.8		543	126.6
445	25	36.37	-94.87	2	Clarksville	0.11	24.39	HAY	4.8		288	126.5
767	47	36.39	-94.84	129	Clarksville	0.09	24.39	HAY	4.8		16241	126.4
44	2	36.43	-94.7	314	Captina	0.04	60.98	HAY	4.8		39576	126.2
355	19	36.35	-94.92	11	Clarksville	0.06	24.39	HAY	4	w N rep	1401	125.8
540	33	36.35	-94.82	19	Clarksville	0.11	24.39	HAY	4.8		2397	125.1
580	35	36.32	-94.71	7	Britwater	0.04	18.29	WWHT	0	w N rep	925	124.7
506	31	36.36	-94.78	5	Elsah	0.05	24.39	HAY	6		654	124.5
382	21	36.41	-94.51	4	Peridge	0.03	60.98	WWHT	0	w N rep	438	124.5
23	1	36.44	-94.67	3	Clarksville	0.05	60.98	WWHT	0.325	w/o N rep	339	124.2
22	1	36.44	-94.67	54	Doniphan	0.07	60.98	HAY	4.8		6673	123.8
610	37	36.36	-94.59	17	Captina	0.06	24.39	HAY	4	w N rep	2067	123.7
631	38	36.32	-94.53	90	Tonti	0.05	60.98	HAY	6		11185	123.6
689	43	36.36	-94.65	61	Clarksville	0.03	60.98	HAY	6		7554	123.5
233	13	36.41	-94.66	148	Clarksville	0.05	60.98	HAY	4.8		18203	123.4
800	49	36.37	-94.73	270	Clarksville	0.07	36.58	HAY	4.8		33258	123.2
635	38	36.32	-94.53	46	Peridge	0.03	60.98	WWHT	0	w N rep	5672	123.2
878	53	36.35	-94.57	10	Peridge	0.07	24.39	HAY	4	w N rep	1249	123.0
494	30	36.33	-94.39	9	Clarksville	0.08	36.58	HAY	6		1071	122.4
936	57	36.39	-94.94	23	Healing	0.09	18.29	HAY	3.4	w/o N rep	2862	122.4
1035	68	36.33	-94.61	73	Tonti	0.05	36.58	HAY	6		8990	122.3
276	15	34.4	-94.44	57	Captina	0.05	60.98	HAY	4	w N rep	6982	122.3
768	47	36.39	-94.84	57	Clarksville	0.09	24.39	HAY	4.8		6885	121.4
43	2	36.43	-94.7	343	Clarksville	0.04	60.98	HAY	4.8		41546	121.3
414	23	36.36	-94.55	3	Britwater	0.05	24.39	HAY	4.8		307	120.2
258	14	36.37	-94.66	67	Jay	0.03	91.46	HAY	4	w N rep	7990	120.1
376	21	36.41	-94.51	139	Captina	0.04	60.98	HAY	4	w N rep	16658	120.0
542	33	36.35	-94.82	5	Britwater	0.11	24.39	HAY	4	w N rep	623	119.8
161	8	36.37	-94.33	9	Taloka	0.02	91.46	WWHT	0	w N rep	1045	119.4
459	27	36.36	-94.8	1	Britwater	0.13	36.58	HAY	4	w N rep	129	119.4

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
541	33	36.35	-94.82	7	Clarksville	0.11	24.39	HAY	4.8		895	119.3
337	18	36.39	-94.47	89	Captina	0.05	60.98	HAY	4	w N rep	10571	119.1
1001	64	36.37	-94.91	9	Clarksville	0.11	36.58	HAY	4	w N rep	1061	119.0
238	13	36.41	-94.66	22	Clarksville	0.03	60.98	WWHT	0.325	w/o N rep	2631	118.9
175	9	36.4	-94.37	128	Captina	0.05	60.98	HAY	4	w N rep	15214	118.7
368	20	36.36	-94.89	92	Clarksville	0.16	24.39	HAY	4.8		10939	118.3
94	4	36.4	-94.57	84	Tonti	0.02	121.95	HAY	6		9959	118.3
801	49	36.37	-94.73	117	Clarksville	0.07	36.58	HAY	4.8		13799	117.8
140	7	36.4	-94.31	21	Captina	0.02	91.46	WWHT	0	w N rep	2473	117.7
91	4	36.4	-94.57	144	Captina	0.02	121.95	HAY	4	w N rep	16882	117.6
786	48	36.4	-94.79	11	Clarksville	0.07	24.39	WWHT	0	w/o N rep	1322	117.5
478	29	36.34	-94.36	37	Clarksville	0.06	60.98	HAY	6		4296	117.3
319	17	36.41	-94.48	51	Captina	0.06	60.98	HAY	4	w N rep	5975	117.2
754	46	36.29	-94.61	82	Taloka	0.03	60.98	HAY	4.8		9565	117.2
1034	68	36.33	-94.61	76	Captina	0.05	36.58	HAY	4	w N rep	8859	117.0
70	3	36.42	-94.67	88	Peridge	0.02	91.46	HAY	4	w N rep	10345	116.9
358	19	36.35	-94.92	21	Tonti	0.06	24.39	HAY	4	w N rep	2436	116.6
234	13	36.41	-94.66	109	Clarksville	0.05	60.98	HAY	4.8		12755	116.5
877	53	36.35	-94.57	6	Waben	0.07	24.39	HAY	6		755	116.5
608	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	4	w N rep	764	116.5
434	24	36.34	-94.49	59	Peridge	0.05	60.98	HAY	4	w N rep	6811	116.4
481	29	36.34	-94.36	4	Clarksville	0.06	60.98	WWHT	0	w N rep	466	116.4
356	19	36.35	-94.92	10	Clarksville	0.06	24.39	HAY	4.8		1208	116.2
67	3	36.42	-94.67	166	Captina	0.02	91.46	HAY	4	w N rep	19092	114.9
18	1	36.44	-94.67	117	Clarksville	0.07	60.98	HAY	4.8		13360	114.0
1052	69	36.35	-95.01	4	Peridge	0.06	24.39	HAY	4	w N rep	498	113.5
629	38	36.32	-94.53	110	Captina	0.05	60.98	HAY	4	w N rep	12496	113.1
913	55	36.27	-94.74	79	Doniphan	0.04	60.98	WWHT	0	w N rep	8980	113.0
432	24	36.34	-94.49	62	Captina	0.05	60.98	HAY	4	w N rep	6992	112.9
551	34	36.33	-94.86	13	Tonti	0.10	24.39	HAY	4	w N rep	1471	112.9
803	49	36.37	-94.73	28	Clarksville	0.06	36.58	WWHT	0	w N rep	3133	112.7
1032	68	36.33	-94.61	102	Clarksville	0.05	36.58	HAY	4	w N rep	11499	112.6
876	53	36.35	-94.57	12	Britwater	0.07	24.39	HAY	4	w N rep	1331	112.0
396	22	36.37	-94.51	62	Captina	0.06	36.58	HAY	4	w N rep	6963	112.0
20	1	36.44	-94.67	51	Captina	0.07	60.98	HAY	4	w N rep	5711	111.7
199	10	36.37	-94.41	10	Nixa	0.06	60.98	WWHT	1.95		1063	111.5
1048	69	36.35	-95.01	7	Captina	0.06	24.39	HAY	4	w N rep	829	111.2
210	11	36.4	-94.99	25	Clarksville	0.10	24.39	HAY	4	w N rep	2751	110.6
1013	66	36.36	-95.02	8	Clarksville	0.07	18.29	HAY	3.4	w/o N rep	826	109.8
875	53	36.35	-94.57	18	Clarksville	0.07	24.39	HAY	4.8		1994	109.2
298	16	36.35	-94.44	31	Peridge	0.07	60.98	HAY	4	w N rep	3414	109.1
395	22	36.37	-94.51	21	Clarksville	0.06	36.58	HAY	4.8		2314	109.1
295	16	36.35	-94.44	41	Clarksville	0.07	60.98	HAY	4.8		4447	109.0
300	16	36.35	-94.44	14	Newtonia	0.05	60.98	WWHT	0	w N rep	1521	108.9
782	48	36.4	-94.79	176	Clarksville	0.11	24.39	HAY	4.8		19067	108.5
609	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	4.8		804	108.3
19	1	36.44	-94.67	47	Clarksville	0.07	60.98	HAY	4.8		5046	107.9
1002	64	36.37	-94.91	5	Britwater	0.11	36.58	HAY	4	w N rep	560	107.9
934	57	36.39	-94.94	28	Clarksville	0.09	18.29	HAY	4	w N rep	3067	107.8
802	49	36.37	-94.73	217	Macedonia	0.07	36.58	HAY	4.8		23393	107.7
431	24	36.34	-94.49	52	Clarksville	0.05	60.98	HAY	4.8		5584	106.8
783	48	36.4	-94.79	54	Clarksville	0.11	24.39	HAY	4.8		5791	106.3
892	54	36.42	-94.62	15	Clarksville	0.02	91.46	HAY	4	w N rep	1610	105.9
195	10	36.37	-94.41	47	Britwater	0.06	60.98	HAY	4	w N rep	5014	105.7
71	3	36.42	-94.67	28	Captina	0.02	91.46	WWHT	0	w N rep	2944	105.5
1033	68	36.33	-94.61	136	Clarksville	0.05	36.58	HAY	4.8		14311	105.4
237	13	36.41	-94.66	27	Clarksville	0.03	60.98	WWHT	0	w N rep	2847	105.1
1049	69	36.35	-95.01	3	Britwater	0.06	24.39	HAY	4	w N rep	287	105.0
785	48	36.4	-94.79	18	Clarksville	0.07	24.39	WWHT	0	w N rep	1890	104.9

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
260	14	36.37	-94.66	14	Clarksville	0.02	91.46	WWHT	0	w N rep	1484	104.9
160	8	36.37	-94.33	39	Captina	0.02	91.46	WWHT	0	w N rep	4043	104.9
804	49	36.37	-94.73	12	Clarksville	0.06	36.58	WWHT	0.65	w/o N rep	1279	104.9
692	43	36.36	-94.65	40	Taloka	0.03	60.98	HAY	4	w N rep	4198	104.6
628	38	36.32	-94.53	61	Clarksville	0.05	60.98	HAY	4	w N rep	6410	104.5
279	15	34.4	-94.44	35	Noark	0.05	60.98	HAY	4	w N rep	3612	104.4
296	16	36.35	-94.44	37	Captina	0.07	60.98	HAY	4	w N rep	3791	103.1
96	4	36.4	-94.57	15	Newtonia	0.02	121.95	WWHT	0	w N rep	1501	101.3
1014	66	36.36	-95.02	11	Clarksville	0.07	18.29	HAY	4	w N rep	1078	101.1
735	45	36.28	-94.67	31	Macedonia	0.02	91.46	WWHT	0	w N rep	3103	99.3
68	3	36.42	-94.67	116	Jay	0.02	91.46	HAY	3.4	w/o N rep	11480	99.3
671	42	36.3	-94.65	8	Clarksville	0.05	36.58	WWHT	0	w/o N rep	817	99.2
784	48	36.4	-94.79	38	Britwater	0.11	24.39	HAY	4	w N rep	3673	96.4
806	49	36.37	-94.73	11	Doniphan	0.06	36.58	WWHT	0	w N rep	1098	96.0
670	42	36.3	-94.65	4	Clarksville	0.05	36.58	WWHT	0	w N rep	423	95.8
46	2	36.43	-94.7	38	Clarksville	0.03	60.98	WWHT	0	w N rep	3669	95.7
733	45	36.28	-94.67	10	Captina	0.02	91.46	WWHT	0	w N rep	920	95.7
935	57	36.39	-94.94	74	Britwater	0.09	18.29	HAY	3.4	w/o N rep	7067	94.9
302	16	36.35	-94.44	42	Peridge	0.05	60.98	WWHT	0	w N rep	3968	94.5
119	6	36.38	-94.61	59	Taloka	0.01	121.95	HAY	4	w N rep	5537	93.7
1037	68	36.33	-94.61	24	Captina	0.04	36.58	WWHT	0	w N rep	2152	91.0
239	13	36.41	-94.66	26	Doniphan	0.03	60.98	WWHT	0	w N rep	2302	87.3
594	36	36.34	-94.76	7	Britwater	0.02	60.98	WWHT	0	w N rep	570	86.9
495	30	36.33	-94.39	42	Nixa	0.08	36.58	HAY	4	w N rep	3646	86.0
178	9	36.4	-94.37	26	Captina	0.04	60.98	WWHT	0	w N rep	2211	86.0
436	24	36.34	-94.49	33	Nixa	0.04	60.98	WWHT	1.95		2801	85.9
715	44	36.3	-94.68	5	Clarksville	0.08	60.98	WWHT	0	w N rep	402	84.6
415	23	36.36	-94.55	4	Nixa	0.05	24.39	HAY	4	w N rep	293	81.7
716	44	36.3	-94.68	8	Clarksville	0.08	60.98	WWHT	0	w N rep	681	81.7
823	50	36.27	-94.81	33	Clarksville	0.09	24.39	WWHT	0	w N rep	2682	81.3
879	53	36.35	-94.57	7	Clarksville	0.12	24.39	WWHT	0	w N rep	571	81.2
176	9	36.4	-94.37	407	Nixa	0.05	60.98	HAY	4	w N rep	33031	81.1
694	43	36.36	-94.65	99	Taloka	0.01	60.98	WWHT	0	w N rep	7979	80.8
611	37	36.36	-94.59	7	Nixa	0.06	24.39	HAY	4	w N rep	580	79.5
397	22	36.37	-94.51	35	Nixa	0.06	36.58	HAY	4	w N rep	2781	78.7
277	15	34.4	-94.44	85	Nixa	0.05	60.98	HAY	4	w N rep	6629	78.3
338	18	36.39	-94.47	53	Nixa	0.05	60.98	HAY	4	w N rep	4106	78.0
196	10	36.37	-94.41	98	Nixa	0.06	60.98	HAY	4	w N rep	7597	77.9
377	21	36.41	-94.51	104	Nixa	0.04	60.98	HAY	4	w N rep	8072	77.7
297	16	36.35	-94.44	102	Nixa	0.07	60.98	HAY	4	w N rep	7942	77.5
379	21	36.41	-94.51	7	Captina	0.03	60.98	WWHT	0	w N rep	551	77.2
822	50	36.27	-94.81	64	Clarksville	0.09	24.39	WWHT	0	w N rep	4967	77.2
672	42	36.3	-94.65	5	Doniphan	0.05	36.58	WWHT	0	w N rep	383	76.3
25	1	36.44	-94.67	5	Taloka	0.05	60.98	WWHT	0	w N rep	390	76.1
158	8	36.37	-94.33	41	Nixa	0.03	91.46	HAY	4.8		3155	76.1
283	15	34.4	-94.44	13	Peridge	0.04	60.98	WWHT	0	w N rep	1018	76.1
320	17	36.41	-94.48	49	Nixa	0.06	60.98	HAY	4	w N rep	3692	76.1
72	3	36.42	-94.67	23	Jay	0.02	91.46	WWHT	0	w N rep	1736	75.8
479	29	36.34	-94.36	144	Nixa	0.06	60.98	HAY	4.8		10910	75.6
21	1	36.44	-94.67	45	Taloka	0.07	60.98	HAY	3.4	w/o N rep	3348	75.2
695	43	36.36	-94.65	150	Newtonia	0.01	60.98	WWHT	0	w N rep	11247	74.7
433	24	36.34	-94.49	190	Nixa	0.05	60.98	HAY	4	w N rep	14161	74.6
138	7	36.4	-94.31	32	Nixa	0.03	91.46	HAY	4	w N rep	2395	74.3
630	38	36.32	-94.53	123	Nixa	0.05	60.98	HAY	4	w N rep	9063	73.5
95	4	36.4	-94.57	13	Captina	0.02	121.95	WWHT	0	w N rep	951	73.4
845	52	36.32	-94.68	2	Razort	0.10	24.39	WPAS	1	w/o N rep	136	72.9
654	42	36.3	-94.65	69	Razort	0.05	36.58	WPAS	1	w/o N rep	5004	72.5
1015	66	36.36	-95.02	7	Nixa	0.07	18.29	HAY	3.4	w/o N rep	507	71.9
557	35	36.32	-94.71	69	Razort	0.07	18.29	WPAS	1	w/o N rep	4981	71.7

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
585	36	36.34	-94.76	0	Razort	0.05	60.98	WPAS	1	w/o N rep	13	70.9
948	60	36.37	-94.81	2	Razort	0.10	18.29	WPAS	1	w/o N rep	141	70.9
985	63	36.32	-94.89	5	Razort	0.08	18.29	WPAS	1	w/o N rep	337	70.8
513	32	36.35	-94.77	25	Healing	0.05	18.29	WPAS	0	w/o N rep	1780	70.3
511	32	36.35	-94.77	13	Razort	0.05	18.29	WPAS	0	w/o N rep	906	70.3
828	51	36.35	-94.75	1	Razort	0.06	15.24	WPAS	0	w/o N rep	88	70.3
938	58	36.35	-94.85	0	Razort	0.15	18.29	WPAS	0	w/o N rep	21	70.3
757	47	36.39	-94.84	45	Razort	0.09	24.39	WPAS	0	w/o N rep	3175	70.1
883	54	36.42	-94.62	25	Razort	0.02	91.46	WPAS	1	w/o N rep	1763	70.0
496	31	36.36	-94.78	5	Razort	0.05	24.39	WPAS	0	w/o N rep	358	70.0
808	50	36.27	-94.81	159	Razort	0.09	24.39	WPAS	0	w/o N rep	11142	70.0
995	64	36.37	-94.91	7	Razort	0.11	36.58	WPAS	0	w/o N rep	487	69.9
943	59	36.36	-94.86	2	Razort	0.17	18.29	WPAS	0	w/o N rep	145	69.8
499	31	36.36	-94.78	11	Healing	0.05	24.39	WPAS	0	w/o N rep	775	69.6
963	61	36.35	-94.79	3	Healing	0.06	24.39	WPAS	0	w/o N rep	181	69.5
5	1	36.44	-94.67	53	Razort	0.07	60.98	WPAS	0	w/o N rep	3696	69.5
361	20	36.36	-94.89	26	Razort	0.16	24.39	WPAS	0	w/o N rep	1774	69.2
407	23	36.36	-94.55	5	Healing	0.05	24.39	WPAS	1	w/o N rep	321	68.8
219	13	36.41	-94.66	255	Razort	0.05	60.98	WPAS	0	w/o N rep	17557	68.7
1016	67	36.37	-94.98	4	Razort	0.13	15.24	WPAS	0	w/o N rep	287	68.6
330	18	36.39	-94.47	53	Tonti	0.05	60.98	WPAS	1	w/o N rep	3606	68.4
773	48	36.4	-94.79	48	Razort	0.11	24.39	WPAS	0	w/o N rep	3257	68.1
203	11	36.4	-94.99	19	Razort	0.10	24.39	WPAS	0	w/o N rep	1291	67.9
167	9	36.4	-94.37	226	Tonti	0.05	60.98	WPAS	2	w/o N rep	15284	67.6
268	15	34.4	-94.44	183	Tonti	0.05	60.98	WPAS	1	w/o N rep	12291	67.3
371	21	36.41	-94.51	105	Tonti	0.04	60.98	WPAS	1	w/o N rep	7054	67.1
309	17	36.41	-94.48	105	Tonti	0.06	60.98	WPAS	1	w/o N rep	6976	66.5
299	16	36.35	-94.44	12	Captina	0.05	60.98	WWHT	0	w N rep	768	66.4
187	10	36.37	-94.41	57	Tonti	0.06	60.98	WPAS	1	w/o N rep	3797	66.4
1050	69	36.35	-95.01	3	Nixa	0.06	24.39	HAY	3.4	w/o N rep	168	66.4
622	38	36.32	-94.53	342	Tonti	0.05	60.98	WPAS	1	w/o N rep	22404	65.6
148	8	36.37	-94.33	230	Tonti	0.03	91.46	WPAS	2	w/o N rep	15022	65.2
866	53	36.35	-94.57	18	Waben	0.07	24.39	WPAS	1	w/o N rep	1182	65.2
128	7	36.4	-94.31	199	Tonti	0.03	91.46	WPAS	2	w/o N rep	12945	64.9
473	29	36.34	-94.36	166	Tonti	0.06	60.98	WPAS	2	w/o N rep	10673	64.1
464	28	36.36	-94.79	1	Elsah	0.07	24.39	WPAS	1	w/o N rep	80	63.5
48	2	36.43	-94.7	75	Doniphan	0.03	60.98	WWHT	0	w N rep	4716	62.7
586	36	36.34	-94.76	1	Elsah	0.05	60.98	WPAS	1	w/o N rep	50	61.8
340	18	36.39	-94.47	10	Captina	0.03	60.98	WWHT	0	w N rep	598	61.8
24	1	36.44	-94.67	12	Captina	0.05	60.98	WWHT	0	w N rep	766	61.7
93	4	36.4	-94.57	151	Nixa	0.02	121.95	HAY	3.4	w/o N rep	9296	61.6
498	31	36.36	-94.78	4	Elsah	0.05	24.39	WPAS	1	w/o N rep	272	60.8
962	61	36.35	-94.79	1	Elsah	0.06	24.39	WPAS	1	w/o N rep	64	60.8
69	3	36.42	-94.67	226	Nixa	0.02	91.46	HAY	3.4	w/o N rep	13670	60.6
558	35	36.32	-94.71	95	Clarksville	0.07	18.29	WPAS	1	w/o N rep	5655	59.3
846	52	36.32	-94.68	2	Clarksville	0.10	24.39	WPAS	1	w/o N rep	144	58.8
968	62	36.33	-94.8	80	Clarksville	0.05	36.58	WPAS	1	w/o N rep	4682	58.6
463	28	36.36	-94.79	3	Clarksville	0.07	24.39	WPAS	1	w/o N rep	197	58.6
741	46	36.29	-94.61	269	Clarksville	0.03	60.98	WPAS	1	w/o N rep	15775	58.5
641	41	36.33	-94.65	22	Clarksville	0.07	24.39	WPAS	1	w/o N rep	1258	58.2
269	15	34.4	-94.44	132	Noark	0.05	60.98	WPAS	0	w/o N rep	7648	58.1
310	17	36.41	-94.48	51	Noark	0.06	60.98	WPAS	0	w/o N rep	2963	58.1
829	51	36.35	-94.75	0	Clarksville	0.06	15.24	WPAS	1	w/o N rep	16	58.1
898	55	36.27	-94.74	520	Clarksville	0.06	60.98	WPAS	1	w/o N rep	30102	57.9
405	23	36.36	-94.55	13	Captina	0.05	24.39	WPAS	0	w/o N rep	743	57.8
949	60	36.37	-94.81	7	Clarksville	0.10	18.29	WPAS	1	w/o N rep	403	57.8
655	42	36.3	-94.65	96	Clarksville	0.05	36.58	WPAS	1	w/o N rep	5511	57.6
408	23	36.36	-94.55	7	Peridge	0.05	24.39	WPAS	1	w/o N rep	384	57.6
248	14	36.37	-94.66	51	Jay	0.03	91.46	WPAS	0	w/o N rep	2935	57.5

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
1021	68	36.33	-94.61	278	Clarksville	0.05	36.58	WPAS	1	w/o N rep	16002	57.5
986	63	36.32	-94.89	6	Clarksville	0.08	18.29	WPAS	1	w/o N rep	342	57.5
700	44	36.3	-94.68	62	Captina	0.04	60.98	WPAS	0	w/o N rep	3573	57.5
600	37	36.36	-94.59	52	Captina	0.06	24.39	WPAS	0	w/o N rep	2967	57.4
742	46	36.29	-94.61	277	Captina	0.03	60.98	WPAS	0	w/o N rep	15903	57.3
512	32	36.35	-94.77	27	Clarksville	0.05	18.29	WPAS	0	w/o N rep	1534	57.2
246	14	36.37	-94.66	40	Clarksville	0.03	91.46	WPAS	1	w/o N rep	2313	57.1
349	19	36.35	-94.92	27	Tonti	0.06	24.39	WPAS	0	w/o N rep	1545	57.1
168	9	36.4	-94.37	231	Noark	0.05	60.98	WPAS	0	w/o N rep	13197	57.1
113	6	36.38	-94.61	345	Newtonia	0.01	121.95	WPAS	1	w/o N rep	19705	57.1
497	31	36.36	-94.78	9	Clarksville	0.05	24.39	WPAS	1	w/o N rep	541	57.0
346	19	36.35	-94.92	34	Clarksville	0.06	24.39	WPAS	0	w/o N rep	1925	57.0
249	14	36.37	-94.66	74	Newtonia	0.03	91.46	WPAS	1	w/o N rep	4233	57.0
721	45	36.28	-94.67	177	Doniphan	0.03	91.46	WPAS	2	w/o N rep	10089	57.0
961	61	36.35	-94.79	5	Clarksville	0.06	24.39	WPAS	1	w/o N rep	290	56.8
723	45	36.28	-94.67	92	Newtonia	0.03	91.46	WPAS	1	w/o N rep	5235	56.8
31	2	36.43	-94.7	158	Captina	0.04	60.98	WPAS	0	w/o N rep	8959	56.7
758	47	36.39	-94.84	159	Clarksville	0.09	24.39	WPAS	1	w/o N rep	9014	56.7
30	2	36.43	-94.7	290	Clarksville	0.04	60.98	WPAS	1	w/o N rep	16425	56.7
912	55	36.27	-94.74	40	Britwater	0.04	60.98	WWHT	0	w N rep	2244	56.6
560	35	36.32	-94.71	44	Britwater	0.07	18.29	WPAS	0	w/o N rep	2467	56.6
809	50	36.27	-94.81	489	Clarksville	0.09	24.39	WPAS	1	w/o N rep	27638	56.6
1023	68	36.33	-94.61	198	Captina	0.05	36.58	WPAS	0	w/o N rep	11179	56.5
1040	69	36.35	-95.01	8	Captina	0.06	24.39	WPAS	0	w/o N rep	430	56.5
678	43	36.36	-94.65	87	Clarksville	0.03	60.98	WPAS	1	w/o N rep	4896	56.4
939	58	36.35	-94.85	1	Clarksville	0.15	18.29	WPAS	1	w/o N rep	43	56.4
547	34	36.33	-94.86	22	Clarksville	0.10	24.39	WPAS	0	w/o N rep	1242	56.4
601	37	36.36	-94.59	34	Peridge	0.06	24.39	WPAS	0	w/o N rep	1915	56.4
453	27	36.36	-94.8	2	Clarksville	0.13	36.58	WPAS	1	w/o N rep	101	56.3
486	30	36.33	-94.39	110	Clarksville	0.08	36.58	WPAS	2	w/o N rep	6205	56.3
369	21	36.41	-94.51	222	Captina	0.04	60.98	WPAS	0	w/o N rep	12510	56.3
987	63	36.32	-94.89	3	Britwater	0.08	18.29	WPAS	0	w/o N rep	160	56.2
951	60	36.37	-94.81	2	Britwater	0.10	18.29	WPAS	0	w/o N rep	122	56.2
561	35	36.32	-94.71	50	Doniphan	0.07	18.29	WPAS	2	w/o N rep	2789	56.1
969	62	36.33	-94.8	99	Clarksville	0.05	36.58	WPAS	0	w/o N rep	5571	56.0
559	35	36.32	-94.71	73	Clarksville	0.07	18.29	WPAS	0	w/o N rep	4101	56.0
886	54	36.42	-94.62	93	Newtonia	0.02	91.46	WPAS	1	w/o N rep	5191	55.9
1042	69	36.35	-95.01	25	Peridge	0.06	24.39	WPAS	0	w/o N rep	1412	55.9
83	4	36.4	-94.57	377	Newtonia	0.02	121.95	WPAS	1	w/o N rep	21053	55.8
950	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	0	w/o N rep	105	55.8
441	25	36.37	-94.87	13	Clarksville	0.11	24.39	WPAS	1	w/o N rep	703	55.7
810	50	36.27	-94.81	167	Clarksville	0.09	24.39	WPAS	0	w/o N rep	9284	55.7
347	19	36.35	-94.92	19	Clarksville	0.06	24.39	WPAS	0	w/o N rep	1054	55.7
532	33	36.35	-94.82	23	Clarksville	0.11	24.39	WPAS	1	w/o N rep	1274	55.7
307	17	36.41	-94.48	59	Captina	0.06	60.98	WPAS	0	w/o N rep	3292	55.7
1010	66	36.36	-95.02	10	Parsons	0.07	18.29	WPAS	0	w/o N rep	551	55.6
186	10	36.37	-94.41	77	Secesh	0.06	60.98	WPAS	1	w/o N rep	4278	55.6
56	3	36.42	-94.67	186	Captina	0.02	91.46	WPAS	0	w/o N rep	10306	55.6
701	44	36.3	-94.68	48	Britwater	0.04	60.98	WPAS	0	w/o N rep	2674	55.4
471	29	36.34	-94.36	111	Clarksville	0.06	60.98	WPAS	2	w/o N rep	6132	55.4
1007	66	36.36	-95.02	19	Clarksville	0.07	18.29	WPAS	1	w/o N rep	1030	55.4
642	41	36.33	-94.65	16	Clarksville	0.07	24.39	WPAS	0	w/o N rep	888	55.3
60	3	36.42	-94.67	176	Peridge	0.02	91.46	WPAS	0	w/o N rep	9731	55.3
129	7	36.4	-94.31	103	Noark	0.03	91.46	WPAS	0	w/o N rep	5711	55.3
681	43	36.36	-94.65	207	Newtonia	0.03	60.98	WPAS	1	w/o N rep	11454	55.3
548	34	36.33	-94.86	25	Tonti	0.10	24.39	WPAS	0	w/o N rep	1384	55.2
1024	68	36.33	-94.61	198	Doniphan	0.05	36.58	WPAS	2	w/o N rep	10907	55.2
790	49	36.37	-94.73	418	Clarksville	0.07	36.58	WPAS	0	w/o N rep	23063	55.2
101	5	36.41	-94.63	0	Britwater	0.03	36.58	WPAS	0	w/o N rep	10	55.1

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
658	42	36.3	-94.65	50	Doniphan	0.05	36.58	WPAS	2	w/o N rep	2728	55.1
328	18	36.39	-94.47	83	Captina	0.05	60.98	WPAS	0	w/o N rep	4582	55.1
919	56	36.38	-94.44	0	Britwater	0.08	60.98	WPAS	0	w/o N rep	22	55.0
847	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	0	w/o N rep	307	55.0
944	59	36.36	-94.86	4	Clarksville	0.17	18.29	WPAS	1	w/o N rep	234	54.9
970	62	36.33	-94.8	47	Doniphan	0.05	36.58	WPAS	1	w/o N rep	2560	54.9
867	53	36.35	-94.57	48	Peridge	0.07	24.39	WPAS	0	w/o N rep	2637	54.9
220	13	36.41	-94.66	325	Clarksville	0.05	60.98	WPAS	1	w/o N rep	17796	54.8
146	8	36.37	-94.33	184	Captina	0.03	91.46	WPAS	1	w/o N rep	10087	54.8
759	47	36.39	-94.84	51	Clarksville	0.09	24.39	WPAS	0	w/o N rep	2788	54.7
58	3	36.42	-94.67	256	Newtonia	0.02	91.46	WPAS	1	w/o N rep	14019	54.7
1017	67	36.37	-94.98	28	Clarksville	0.13	15.24	WPAS	1	w/o N rep	1505	54.6
126	7	36.4	-94.31	299	Captina	0.03	91.46	WPAS	1	w/o N rep	16333	54.6
422	24	36.34	-94.49	126	Captina	0.05	60.98	WPAS	0	w/o N rep	6892	54.6
996	64	36.37	-94.91	16	Clarksville	0.11	36.58	WPAS	1	w/o N rep	851	54.6
424	24	36.34	-94.49	234	Peridge	0.05	60.98	WPAS	0	w/o N rep	12747	54.4
6	1	36.44	-94.67	123	Clarksville	0.07	60.98	WPAS	0	w/o N rep	6711	54.4
7	1	36.44	-94.67	49	Captina	0.07	60.98	WPAS	0	w/o N rep	2684	54.4
884	54	36.42	-94.62	31	Clarksville	0.02	91.46	WPAS	1	w/o N rep	1707	54.3
442	25	36.37	-94.87	2	Britwater	0.11	24.39	WPAS	0	w/o N rep	119	54.3
620	38	36.32	-94.53	454	Captina	0.05	60.98	WPAS	0	w/o N rep	24632	54.3
306	17	36.41	-94.48	50	Clarksville	0.06	60.98	WPAS	2	w/o N rep	2695	54.1
864	53	36.35	-94.57	25	Clarksville	0.07	24.39	WPAS	1	w/o N rep	1349	54.1
940	58	36.35	-94.85	0	Britwater	0.15	18.29	WPAS	0	w/o N rep	26	54.0
599	37	36.36	-94.59	36	Clarksville	0.06	24.39	WPAS	1	w/o N rep	1967	54.0
656	42	36.3	-94.65	47	Clarksville	0.05	36.58	WPAS	0	w/o N rep	2534	54.0
454	27	36.36	-94.8	1	Britwater	0.13	36.58	WPAS	0	w/o N rep	54	54.0
900	55	36.27	-94.74	586	Doniphan	0.06	60.98	WPAS	2	w/o N rep	31627	54.0
657	42	36.3	-94.65	53	Britwater	0.05	36.58	WPAS	0	w/o N rep	2841	54.0
899	55	36.27	-94.74	347	Clarksville	0.06	60.98	WPAS	1	w/o N rep	18716	53.9
184	10	36.37	-94.41	63	Clarksville	0.06	60.98	WPAS	2	w/o N rep	3393	53.8
679	43	36.36	-94.65	77	Clarksville	0.03	60.98	WPAS	0	w/o N rep	4155	53.8
927	57	36.39	-94.94	48	Clarksville	0.09	18.29	WPAS	1	w/o N rep	2558	53.8
327	18	36.39	-94.47	65	Clarksville	0.05	60.98	WPAS	1	w/o N rep	3462	53.6
533	33	36.35	-94.82	4	Britwater	0.11	24.39	WPAS	0	w/o N rep	234	53.5
928	57	36.39	-94.94	114	Britwater	0.09	18.29	WPAS	0	w/o N rep	6079	53.5
643	41	36.33	-94.65	97	Britwater	0.07	24.39	WPAS	0	w/o N rep	5212	53.5
774	48	36.4	-94.79	247	Clarksville	0.11	24.39	WPAS	0	w/o N rep	13199	53.5
32	2	36.43	-94.7	186	Doniphan	0.04	60.98	WPAS	1	w/o N rep	9901	53.3
57	3	36.42	-94.67	366	Jay	0.02	91.46	WPAS	0	w/o N rep	19463	53.2
204	11	36.4	-94.99	35	Clarksville	0.10	24.39	WPAS	1	w/o N rep	1860	53.2
421	24	36.34	-94.49	171	Clarksville	0.05	60.98	WPAS	1	w/o N rep	9098	53.2
791	49	36.37	-94.73	151	Clarksville	0.07	36.58	WPAS	0	w/o N rep	8031	53.1
348	19	36.35	-94.92	12	Doniphan	0.06	24.39	WPAS	0	w/o N rep	648	53.0
362	20	36.36	-94.89	122	Clarksville	0.16	24.39	WPAS	0	w/o N rep	6471	53.0
885	54	36.42	-94.62	23	Britwater	0.02	91.46	WPAS	0	w/o N rep	1218	53.0
387	22	36.37	-94.51	172	Captina	0.06	36.58	WPAS	0	w/o N rep	9096	53.0
287	16	36.35	-94.44	195	Clarksville	0.07	60.98	WPAS	1	w/o N rep	10324	52.8
775	48	36.4	-94.79	51	Clarksville	0.11	24.39	WPAS	0	w/o N rep	2694	52.8
619	38	36.32	-94.53	233	Clarksville	0.05	60.98	WPAS	1	w/o N rep	12266	52.7
221	13	36.41	-94.66	164	Clarksville	0.05	60.98	WPAS	0	w/o N rep	8660	52.7
1022	68	36.33	-94.61	216	Clarksville	0.05	36.58	WPAS	1	w/o N rep	11387	52.6
997	64	36.37	-94.91	17	Britwater	0.11	36.58	WPAS	0	w/o N rep	869	52.4
386	22	36.37	-94.51	202	Clarksville	0.06	36.58	WPAS	1	w/o N rep	10525	52.2
1041	69	36.35	-95.01	16	Britwater	0.06	24.39	WPAS	0	w/o N rep	836	52.0
562	35	36.32	-94.71	73	Macedonia	0.07	18.29	WPAS	0	w/o N rep	3788	51.8
8	1	36.44	-94.67	44	Doniphan	0.07	60.98	WPAS	1	w/o N rep	2257	51.5
222	13	36.41	-94.66	152	Newtonia	0.05	60.98	WPAS	0	w/o N rep	7828	51.4
1039	69	36.35	-95.01	13	Clarksville	0.06	24.39	WPAS	0	w/o N rep	644	51.4

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
865	53	36.35	-94.57	45	Britwater	0.07	24.39	WPAS	1	w/o N rep	2312	50.9
1008	66	36.36	-95.02	26	Clarksville	0.07	18.29	WPAS	1	w/o N rep	1310	50.4
722	45	36.28	-94.67	100	Macedonia	0.03	91.46	WPAS	1	w/o N rep	5026	50.1
289	16	36.35	-94.44	271	Peridge	0.07	60.98	WPAS	0	w/o N rep	13500	49.9
247	14	36.37	-94.66	95	Macedonia	0.03	91.46	WPAS	1	w/o N rep	4718	49.9
984	62	36.33	-94.8	17	Jay	0.03	36.58	WWHT	0	w N rep	814	49.0
322	17	36.41	-94.48	4	Captina	0.04	60.98	WWHT	0	w N rep	198	48.8
406	23	36.36	-94.55	7	Nixa	0.05	24.39	WPAS	0	w/o N rep	319	48.7
702	44	36.3	-94.68	63	Macedonia	0.04	60.98	WPAS	1	w/o N rep	3034	48.4
370	21	36.41	-94.51	152	Nixa	0.04	60.98	WPAS	0	w/o N rep	7301	48.1
680	43	36.36	-94.65	107	Macedonia	0.03	60.98	WPAS	1	w/o N rep	5127	48.0
102	5	36.41	-94.63	0	Razort	0.03	36.58	OPAS	0	w/o N rep	4	47.7
659	42	36.3	-94.65	56	Macedonia	0.05	36.58	WPAS	1	w/o N rep	2662	47.2
267	15	34.4	-94.44	110	Nixa	0.05	60.98	WPAS	0	w/o N rep	5169	47.1
329	18	36.39	-94.47	89	Nixa	0.05	60.98	WPAS	0	w/o N rep	4203	47.0
308	17	36.41	-94.48	109	Nixa	0.06	60.98	WPAS	0	w/o N rep	5115	46.8
166	9	36.4	-94.37	728	Nixa	0.05	60.98	WPAS	0	w/o N rep	33913	46.6
621	38	36.32	-94.53	314	Nixa	0.05	60.98	WPAS	0	w/o N rep	14605	46.6
423	24	36.34	-94.49	480	Nixa	0.05	60.98	WPAS	0	w/o N rep	22235	46.4
388	22	36.37	-94.51	201	Nixa	0.06	36.58	WPAS	0	w/o N rep	9307	46.3
185	10	36.37	-94.41	123	Nixa	0.06	60.98	WPAS	0	w/o N rep	5686	46.2
487	30	36.33	-94.39	274	Nixa	0.08	36.58	WPAS	0	w/o N rep	12548	45.8
288	16	36.35	-94.44	317	Nixa	0.07	60.98	WPAS	0	w/o N rep	14419	45.5
127	7	36.4	-94.31	155	Nixa	0.03	91.46	WPAS	0	w/o N rep	7010	45.1
112	6	36.38	-94.61	227	Taloka	0.01	121.95	WPAS	0	w/o N rep	10224	45.1
147	8	36.37	-94.33	131	Nixa	0.03	91.46	WPAS	0	w/o N rep	5883	44.9
792	49	36.37	-94.73	230	Macedonia	0.07	36.58	WPAS	0	w/o N rep	10293	44.8
84	4	36.4	-94.57	174	Nixa	0.02	121.95	WPAS	0	w/o N rep	7791	44.7
59	3	36.42	-94.67	324	Nixa	0.02	91.46	WPAS	0	w/o N rep	14347	44.3
918	56	36.38	-94.44	1	Clarksville	0.08	60.98	WPAS	0	w/o N rep	26	44.3
472	29	36.34	-94.36	384	Nixa	0.06	60.98	WPAS	0	w/o N rep	16658	43.4
33	2	36.43	-94.7	184	Taloka	0.04	60.98	WPAS	0	w/o N rep	7866	42.7
911	55	36.27	-94.74	31	Captina	0.04	60.98	WWHT	0	w N rep	1306	42.5
743	46	36.29	-94.61	469	Taloka	0.03	60.98	WPAS	0	w/o N rep	19457	41.5
1009	66	36.36	-95.02	35	Nixa	0.07	18.29	WPAS	1	w/o N rep	1427	41.1
82	4	36.4	-94.57	292	Taloka	0.02	121.95	WPAS	0	w/o N rep	11879	40.6
280	15	34.4	-94.44	14	Captina	0.04	60.98	WWHT	0	w N rep	529	37.5
632	38	36.32	-94.53	80	Captina	0.03	60.98	WWHT	0	w N rep	2992	37.2
482	29	36.34	-94.36	28	Nixa	0.06	60.98	WWHT	0	w N rep	977	35.4
262	14	36.37	-94.66	19	Newtonia	0.02	91.46	WWHT	0	w N rep	621	32.3
831	51	36.35	-94.75	1	Elsah	0.06	15.24	OPAS	0	w/o N rep	28	31.1
588	36	36.34	-94.76	2	Elsah	0.05	60.98	OPAS	0	w/o N rep	62	30.4
515	32	36.35	-94.77	3	Clarksville	0.05	18.29	OPAS	0	w/o N rep	97	29.7
929	57	36.39	-94.94	4	Razort	0.09	18.29	OPAS	0	w/o N rep	112	29.6
1028	68	36.33	-94.61	23	Tonti	0.05	36.58	OPAS	3.23076		653	28.5
501	31	36.36	-94.78	2	Clarksville	0.05	24.39	OPAS	0	w/o N rep	69	28.2
972	62	36.33	-94.8	35	Clarksville	0.05	36.58	OPAS	0	w/o N rep	954	27.6
565	35	36.32	-94.71	14	Clarksville	0.07	18.29	OPAS	0	w/o N rep	391	27.5
272	15	34.4	-94.44	73	Tonti	0.05	60.98	OPAS	3.23076		1959	26.8
953	60	36.37	-94.81	0	Clarksville	0.10	18.29	OPAS	0	w/o N rep	11	26.7
563	35	36.32	-94.71	23	Razort	0.07	18.29	OPAS	3.23076		613	26.7
206	11	36.4	-94.99	3	Razort	0.10	24.39	OPAS	0	w/o N rep	75	26.0
830	51	36.35	-94.75	0	Razort	0.06	15.24	OPAS	0	w/o N rep	9	25.5
190	10	36.37	-94.41	9	Tonti	0.06	60.98	OPAS	3.23076		240	25.4
313	17	36.41	-94.48	37	Tonti	0.06	60.98	OPAS	3.23076		824	22.5
761	47	36.39	-94.84	18	Clarksville	0.09	24.39	OPAS	0	w/o N rep	404	22.3
812	50	36.27	-94.81	100	Clarksville	0.09	24.39	OPAS	0	w/o N rep	2188	22.0
514	32	36.35	-94.77	9	Clarksville	0.05	18.29	OPAS	0	w/o N rep	191	21.6
973	62	36.33	-94.8	45	Doniphan	0.05	36.58	OPAS	0	w/o N rep	956	21.2

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
602	37	36.36	-94.59	4	Clarksville	0.06	24.39	OPAS	0	w/o N rep	76	21.1
645	41	36.33	-94.65	5	Clarksville	0.07	24.39	OPAS	0	w/o N rep	113	20.8
567	35	36.32	-94.71	19	Doniphan	0.07	18.29	OPAS	0	w/o N rep	385	20.8
410	23	36.36	-94.55	10	Peridge	0.05	24.39	OPAS	3.23076		198	20.5
682	43	36.36	-94.65	85	Clarksville	0.03	60.98	OPAS	0	w/o N rep	1723	20.3
930	57	36.39	-94.94	4	Clarksville	0.09	18.29	OPAS	0	w/o N rep	77	20.2
437	24	36.34	-94.49	31	Peridge	0.04	60.98	WWHT	0	w N rep	620	20.0
198	10	36.37	-94.41	5	Britwater	0.06	60.98	WWHT	0	w N rep	90	19.6
660	42	36.3	-94.65	10	Clarksville	0.05	36.58	OPAS	0	w/o N rep	197	19.3
130	7	36.4	-94.31	55	Captina	0.03	91.46	OPAS	3.23076		1036	18.9
88	4	36.4	-94.57	34	Nixa	0.02	121.95	OPAS	0	w/o N rep	623	18.5
250	14	36.37	-94.66	33	Doniphan	0.03	91.46	OPAS	0	w/o N rep	606	18.3
606	37	36.36	-94.59	6	Peridge	0.06	24.39	OPAS	3.23076		105	18.3
1025	68	36.33	-94.61	39	Clarksville	0.05	36.58	OPAS	0	w/o N rep	712	18.2
870	53	36.35	-94.57	6	Waben	0.07	24.39	OPAS	0	w/o N rep	110	17.9
517	32	36.35	-94.77	4	Healing	0.05	18.29	OPAS	3.23076		72	17.8
605	37	36.36	-94.59	3	Nixa	0.06	24.39	OPAS	0	w/o N rep	61	17.8
131	7	36.4	-94.31	18	Nixa	0.03	91.46	OPAS	0	w/o N rep	317	17.4
150	8	36.37	-94.33	24	Nixa	0.03	91.46	OPAS	0	w/o N rep	408	17.3
500	31	36.36	-94.78	7	Clarksville	0.05	24.39	OPAS	0	w/o N rep	115	16.8
794	49	36.37	-94.73	51	Clarksville	0.07	36.58	OPAS	0	w/o N rep	852	16.7
149	8	36.37	-94.33	65	Captina	0.03	91.46	OPAS	3.23076		1077	16.6
971	62	36.33	-94.8	19	Clarksville	0.05	36.58	OPAS	0	w/o N rep	309	16.4
1044	69	36.35	-95.01	4	Nixa	0.06	24.39	OPAS	0	w/o N rep	72	16.4
10	1	36.44	-94.67	38	Clarksville	0.07	60.98	OPAS	0	w/o N rep	621	16.4
409	23	36.36	-94.55	5	Captina	0.05	24.39	OPAS	3.23076		86	16.0
240	13	36.41	-94.66	62	Newtonia	0.03	60.98	WWHT	0	w N rep	961	15.5
745	46	36.29	-94.61	75	Captina	0.03	60.98	OPAS	3.23076		1138	15.3
314	17	36.41	-94.48	18	Noark	0.06	60.98	OPAS	0	w/o N rep	273	15.2
63	3	36.42	-94.67	88	Nixa	0.02	91.46	OPAS	0	w/o N rep	1334	15.2
225	13	36.41	-94.66	62	Clarksville	0.05	60.98	OPAS	0	w/o N rep	924	14.8
564	35	36.32	-94.71	30	Clarksville	0.07	18.29	OPAS	0	w/o N rep	426	14.4
373	21	36.41	-94.51	48	Nixa	0.04	60.98	OPAS	0	w/o N rep	645	13.4
868	53	36.35	-94.57	8	Clarksville	0.07	24.39	OPAS	0	w/o N rep	108	13.4
762	47	36.39	-94.84	6	Doniphan	0.09	24.39	OPAS	0	w/o N rep	81	12.6
724	45	36.28	-94.67	75	Doniphan	0.03	91.46	OPAS	0	w/o N rep	888	11.9
474	29	36.34	-94.36	12	Clarksville	0.06	60.98	OPAS	0	w/o N rep	141	11.8
271	15	34.4	-94.44	22	Nixa	0.05	60.98	OPAS	0	w/o N rep	249	11.3
807	49	36.37	-94.73	17	Macedonia	0.06	36.58	WWHT	0	w N rep	177	10.7
813	50	36.27	-94.81	86	Doniphan	0.09	24.39	OPAS	0	w/o N rep	913	10.6
871	53	36.35	-94.57	7	Peridge	0.07	24.39	OPAS	3.23076		69	10.5
603	37	36.36	-94.59	11	Captina	0.06	24.39	OPAS	3.23076		107	10.1
778	48	36.4	-94.79	56	Clarksville	0.11	24.39	OPAS	0	w/o N rep	550	9.9
223	13	36.41	-94.66	71	Razort	0.05	60.98	OPAS	3.23076		680	9.6
332	18	36.39	-94.47	23	Nixa	0.05	60.98	OPAS	0	w/o N rep	217	9.5
952	60	36.37	-94.81	2	Clarksville	0.10	18.29	OPAS	0	w/o N rep	18	9.5
624	38	36.32	-94.53	45	Nixa	0.05	60.98	OPAS	0	w/o N rep	413	9.3
37	2	36.43	-94.7	154	Doniphan	0.04	60.98	OPAS	0	w/o N rep	1422	9.2
207	11	36.4	-94.99	20	Clarksville	0.10	24.39	OPAS	0	w/o N rep	172	8.6
902	55	36.27	-94.74	499	Doniphan	0.06	60.98	OPAS	0	w/o N rep	4270	8.6
390	22	36.37	-94.51	18	Nixa	0.06	36.58	OPAS	0	w/o N rep	152	8.4
312	17	36.41	-94.48	22	Nixa	0.06	60.98	OPAS	0	w/o N rep	178	8.3
1045	69	36.35	-95.01	3	Peridge	0.06	24.39	OPAS	3.23076		27	7.9
923	56	36.38	-94.44	0	Clarksville	0.08	60.98	HAY	0	w/o N rep	2	6.7
901	55	36.27	-94.74	133	Clarksville	0.06	60.98	OPAS	0	w/o N rep	744	5.6
488	30	36.33	-94.39	4	Clarksville	0.08	36.58	OPAS	0	w/o N rep	22	5.6
1027	68	36.33	-94.61	29	Doniphan	0.05	36.58	OPAS	0	w/o N rep	152	5.3
170	9	36.4	-94.37	149	Nixa	0.05	60.98	OPAS	0	w/o N rep	776	5.2
372	21	36.41	-94.51	59	Captina	0.04	60.98	OPAS	3.23076		288	4.9

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
848	52	36.32	-94.68	5	Clarksville	0.10	24.39	OPAS	0	w/o N rep	22	4.9
661	42	36.3	-94.65	28	Doniphan	0.05	36.58	OPAS	0	w/o N rep	133	4.8
426	24	36.34	-94.49	78	Nixa	0.05	60.98	OPAS	0	w/o N rep	371	4.8
744	46	36.29	-94.61	36	Clarksville	0.03	60.98	OPAS	0	w/o N rep	166	4.7
646	41	36.33	-94.65	3	Captina	0.07	24.39	OPAS	3.23076		12	4.2
475	29	36.34	-94.36	68	Nixa	0.06	60.98	OPAS	0	w/o N rep	249	3.6
1026	68	36.33	-94.61	33	Captina	0.05	36.58	OPAS	3.23076		118	3.6
189	10	36.37	-94.41	33	Nixa	0.06	60.98	OPAS	0	w/o N rep	103	3.1
625	38	36.32	-94.53	60	Tonti	0.05	60.98	OPAS	3.23076		173	2.9
333	18	36.39	-94.47	38	Tonti	0.05	60.98	OPAS	3.23076		91	2.4
34	2	36.43	-94.7	159	Clarksville	0.04	60.98	OPAS	0	w/o N rep	352	2.2
703	44	36.3	-94.68	17	Captina	0.04	60.98	OPAS	3.23076		27	1.7
270	15	34.4	-94.44	48	Captina	0.05	60.98	OPAS	3.23076		44	0.9
392	22	36.37	-94.51	14	Peridge	0.06	36.58	OPAS	3.23076		11	0.8
12	1	36.44	-94.67	23	Doniphan	0.07	60.98	OPAS	0	w/o N rep	17	0.7
64	3	36.42	-94.67	44	Peridge	0.02	91.46	OPAS	3.23076		22	0.5
1043	69	36.35	-95.01	7	Captina	0.06	24.39	OPAS	3.23076		0	0.0
428	24	36.34	-94.49	28	Peridge	0.05	60.98	OPAS	3.23076		-4	-0.2
760	47	36.39	-94.84	30	Clarksville	0.09	24.39	OPAS	0	w/o N rep	-10	-0.3
796	49	36.37	-94.73	41	Doniphan	0.07	36.58	OPAS	0	w/o N rep	-13	-0.3
132	7	36.4	-94.31	21	Tonti	0.03	91.46	OPAS	0	w/o N rep	-10	-0.5
490	30	36.33	-94.39	9	Nixa	0.08	36.58	OPAS	0	w/o N rep	-8	-0.9
151	8	36.37	-94.33	32	Tonti	0.03	91.46	OPAS	0	w/o N rep	-39	-1.2
311	17	36.41	-94.48	12	Captina	0.06	60.98	OPAS	3.23076		-16	-1.4
776	48	36.4	-94.79	23	Razort	0.11	24.39	OPAS	3.23076		-33	-1.4
811	50	36.27	-94.81	192	Clarksville	0.09	24.39	OPAS	0	w/o N rep	-385	-2.0
644	41	36.33	-94.65	7	Clarksville	0.07	24.39	OPAS	0	w/o N rep	-18	-2.4
535	33	36.35	-94.82	9	Clarksville	0.11	24.39	OPAS	0	w/o N rep	-24	-2.6
363	20	36.36	-94.89	6	Razort	0.16	24.39	OPAS	3.23076		-18	-2.7
226	13	36.41	-94.66	59	Doniphan	0.05	60.98	OPAS	0	w/o N rep	-197	-3.3
115	6	36.38	-94.61	125	Newtonia	0.01	121.95	OPAS	3.23076		-441	-3.5
331	18	36.39	-94.47	51	Captina	0.05	60.98	OPAS	3.23076		-189	-3.7
191	10	36.37	-94.41	17	Peridge	0.06	60.98	OPAS	3.23076		-66	-3.8
516	32	36.35	-94.77	7	Britwater	0.05	18.29	OPAS	0	w/o N rep	-28	-4.0
290	16	36.35	-94.44	53	Nixa	0.07	60.98	OPAS	0	w/o N rep	-239	-4.5
350	19	36.35	-94.92	22	Tonti	0.06	24.39	OPAS	0	w/o N rep	-138	-6.3
169	9	36.4	-94.37	61	Captina	0.05	60.98	OPAS	3.23076		-474	-7.8
85	4	36.4	-94.57	46	Captina	0.02	121.95	OPAS	3.23076		-368	-7.9
924	56	36.38	-94.44	1	Britwater	0.08	60.98	HAY	0	w/o N rep	-9	-11.8
9	1	36.44	-94.67	56	Clarksville	0.07	60.98	OPAS	0	w/o N rep	-734	-13.0
793	49	36.37	-94.73	82	Clarksville	0.07	36.58	OPAS	0	w/o N rep	-1072	-13.1
224	13	36.41	-94.66	50	Clarksville	0.05	60.98	OPAS	0	w/o N rep	-693	-14.0
489	30	36.33	-94.39	4	Captina	0.08	36.58	OPAS	3.23076		-67	-16.4
623	38	36.32	-94.53	128	Captina	0.05	60.98	OPAS	3.23076		-2264	-17.7
425	24	36.34	-94.49	46	Captina	0.05	60.98	OPAS	3.23076		-835	-18.1
389	22	36.37	-94.51	51	Captina	0.06	36.58	OPAS	3.23076		-934	-18.3
746	46	36.29	-94.61	30	Tonti	0.03	60.98	OPAS	0	w/o N rep	-556	-18.4
391	22	36.37	-94.51	18	Tonti	0.06	36.58	OPAS	0	w/o N rep	-372	-20.1
587	36	36.34	-94.76	5	Britwater	0.05	60.98	OPAS	0	w/o N rep	-100	-20.5
261	14	36.37	-94.66	48	Macedonia	0.02	91.46	WWHT	0	w N rep	-1094	-22.6
880	53	36.35	-94.57	8	Nixa	0.12	24.39	WWHT	0	w N rep	-196	-24.6
566	35	36.32	-94.71	20	Britwater	0.07	18.29	OPAS	0	w/o N rep	-498	-25.2
364	20	36.36	-94.89	36	Clarksville	0.16	24.39	OPAS	0	w/o N rep	-934	-25.8
931	57	36.39	-94.94	27	Britwater	0.09	18.29	OPAS	0	w/o N rep	-694	-25.9
171	9	36.4	-94.37	82	Tonti	0.05	60.98	OPAS	0	w/o N rep	-2182	-26.6
777	48	36.4	-94.79	82	Clarksville	0.11	24.39	OPAS	0	w/o N rep	-2187	-26.8
47	2	36.43	-94.7	58	Captina	0.03	60.98	WWHT	0	w N rep	-1588	-27.3
849	52	36.32	-94.68	6	Britwater	0.10	24.39	OPAS	0	w N rep	-152	-27.4
291	16	36.35	-94.44	80	Peridge	0.07	60.98	OPAS	3.23076		-2270	-28.2

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Per hectare shadow price ($/ha.)
568	35	36.32	-94.71	19	Macedonia	0.07	18.29	OPAS	0	w/o N rep	-558	-29.0
241	13	36.41	-94.66	25	Clarksville	0.03	60.98	WWHT	0	w N rep	-734	-29.3
954	60	36.37	-94.81	0	Water	0.10	18.29	OPAS	0	w/o N rep	-13	-32.7
538	33	36.35	-94.82	5	Water	0.11	24.39	OPAS	0	w/o N rep	-158	-32.7
543	33	36.35	-94.82	6	Water	0.11	24.39	HAY	0	w/o N rep	-231	-37.7
446	25	36.37	-94.87	2	Water	0.11	24.39	HAY	0	w/o N rep	-60	-37.7
1003	64	36.37	-94.91	2	Water	0.11	36.58	HAY	0	w/o N rep	-86	-37.7
925	56	36.38	-94.44	0	Water	0.08	60.98	HAY	0	w/o N rep	-7	-37.7
443	25	36.37	-94.87	4	Water	0.11	24.39	WPAS	0	w/o N rep	-168	-38.5
205	11	36.4	-94.99	24	Water	0.10	24.39	WPAS	0	w/o N rep	-939	-38.5
534	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0	w/o N rep	-188	-38.5
455	27	36.36	-94.8	2	Water	0.13	36.58	WPAS	0	w/o N rep	-76	-38.5
251	14	36.37	-94.66	42	Macedonia	0.03	91.46	OPAS	0	w/o N rep	-1654	-39.3
87	4	36.4	-94.57	56	Newtonia	0.02	121.95	OPAS	3.23076		-2319	-41.2
252	14	36.37	-94.66	71	Newtonia	0.03	91.46	OPAS	0	w N rep	-2973	-42.1
887	54	36.42	-94.62	45	Newtonia	0.02	91.46	OPAS	0	w N rep	-2184	-49.0
536	33	36.35	-94.82	3	Britwater	0.11	24.39	OPAS	0	w/o N rep	-171	-50.4
38	2	36.43	-94.7	112	Macedonia	0.04	60.98	OPAS	0	w N rep	-5741	-51.4
435	24	36.34	-94.49	52	Captina	0.04	60.98	WWHT	0	w N rep	-2710	-52.1
725	45	36.28	-94.67	59	Macedonia	0.03	91.46	OPAS	0	w N rep	-3125	-52.7
49	2	36.43	-94.7	39	Taloka	0.03	60.98	WWHT	0	w N rep	-2080	-53.7
684	43	36.36	-94.65	61	Newtonia	0.03	60.98	OPAS	0	w N rep	-3322	-54.7
683	43	36.36	-94.65	94	Macedonia	0.03	60.98	OPAS	0	w N rep	-5227	-55.9
62	3	36.42	-94.67	61	Newtonia	0.02	91.46	OPAS	0	w N rep	-3441	-56.9
705	44	36.3	-94.68	20	Macedonia	0.04	60.98	OPAS	0	w N rep	-1135	-58.2
114	6	36.38	-94.61	30	Taloka	0.01	121.95	OPAS	0	w N rep	-1747	-59.0
35	2	36.43	-94.7	136	Captina	0.04	60.98	OPAS	0	w N rep	-8142	-59.8
86	4	36.4	-94.57	30	Jay	0.02	121.95	OPAS	0	w N rep	-1819	-60.2
662	42	36.3	-94.65	23	Macedonia	0.05	36.58	OPAS	0	w N rep	-1515	-64.5
427	24	36.34	-94.49	28	Secesh	0.05	60.98	OPAS	0	w N rep	-1836	-65.0
61	3	36.42	-94.67	48	Captina	0.02	91.46	OPAS	0	w N rep	-3185	-65.9
673	42	36.3	-94.65	13	Macedonia	0.05	36.58	WWHT	0	w N rep	-831	-66.2
974	62	36.33	-94.8	18	Jay	0.05	36.58	OPAS	0	w N rep	-1218	-66.6
13	1	36.44	-94.67	28	Macedonia	0.07	60.98	OPAS	0	w N rep	-1923	-68.0
797	49	36.37	-94.73	80	Macedonia	0.07	36.58	OPAS	0	w N rep	-5550	-69.5
869	53	36.35	-94.57	4	Britwater	0.07	24.39	OPAS	0	w N rep	-259	-71.9
227	13	36.41	-94.66	96	Newtonia	0.05	60.98	OPAS	0	w N rep	-7245	-75.6
11	1	36.44	-94.67	37	Captina	0.07	60.98	OPAS	0	w N rep	-3025	-82.5
36	2	36.43	-94.7	91	Taloka	0.04	60.98	OPAS	0	w N rep	-7567	-83.4
188	10	36.37	-94.41	11	Britwater	0.06	60.98	OPAS	0	w N rep	-953	-84.7
704	44	36.3	-94.68	18	Taloka	0.04	60.98	OPAS	0	w N rep	-1592	-90.0
717	44	36.3	-94.68	3	Macedonia	0.08	60.98	WWHT	0	w N rep	-230	-90.6
747	46	36.29	-94.61	37	Taloka	0.03	60.98	OPAS	0	w N rep	-3375	-91.7
604	37	36.36	-94.59	4	Taloka	0.06	24.39	OPAS	0	w N rep	-369	-96.3
537	33	36.35	-94.82	2	Taloka	0.11	24.39	OPAS	0	w/o N rep	-254	-103.4
795	49	36.37	-94.73	45	Taloka	0.07	36.58	OPAS	0	w/o N rep	-5118	-113.4
805	49	36.37	-94.73	12	Taloka	0.06	36.58	WWHT	0	w N rep	-1555	-127.5

Table A 7. Spatial Detail for the Optimal Solution for Policy 1.

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
401	22	36.37	-94.51	9	Tonti	0.05	36.58	WWHT	1.95	w alum;	3069	355.0
1038	68	36.33	-94.61	33	Tonti	0.04	36.59	WWHT	1.95	w alum;	10907	333.8
74	3	36.42	-94.67	15	Tonti	0.02	91.46	WWHT	1.95	w alum;	4846	331.6
381	21	36.41	-94.51	2	Tonti	0.03	60.98	WWHT	1.95	w alum;	722	311.8
342	18	36.39	-94.47	10	Tonti	0.03	60.98	WWHT	1.95	w alum;	2953	308.5
634	38	36.32	-94.53	45	Tonti	0.03	60.98	WWHT	1.95	w alum;	13862	305.0
180	9	36.4	-94.37	12	Tonti	0.04	60.98	WWHT	1.95	w alum;	3626	302.3
142	7	36.4	-94.31	13	Tonti	0.02	91.46	WWHT	1.95	w alum;	3585	280.5
162	8	36.37	-94.33	21	Tonti	0.02	91.46	WWHT	1.95	w alum;	5774	279.4
282	15	34.4	-94.44	13	Tonti	0.04	60.98	WWHT	1.95	w alum;	3453	262.4
324	17	36.41	-94.48	8	Tonti	0.04	60.98	WWHT	1.95	w alum;	2055	261.2
835	51	36.35	-94.75	1	Razort	0.01	15.24	WWHT	1.95	w alum;	353	245.0
837	51	36.35	-94.75	1	Elsah	0.01	15.24	WWHT	1.95		343	238.6
577	35	36.32	-94.71	6	Razort	0.04	18.29	WWHT	1.11	w alum; w/o N rep	1473	238.4
523	32	36.35	-94.77	6	Razort	0.03	18.29	WWHT	1.11	w alum; w/o N rep	1465	232.1
595	36	36.34	-94.76	6	Elsah	0.02	60.98	WWHT	1.95		1388	227.6
581	35	36.32	-94.71	5	Elsah	0.04	18.29	WWHT	1.95		1125	218.3
200	10	36.37	-94.41	5	Tonti	0.06	60.98	WWHT	0.00	w N rep	1024	212.0
593	36	36.34	-94.76	2	Razort	0.02	60.98	WWHT	0.00	w N rep	508	207.1
105	5	36.41	-94.63	1	Razort	0.04	36.58	WWHT	0.00	w N rep	243	193.5
614	37	36.36	-94.59	3	Nixa	0.05	24.39	WWHT	1.95		452	180.3
756	46	36.29	-94.61	31	Taloka	0.02	60.98	WWHT	0.00	w N rep	5588	178.7
615	37	36.36	-94.59	2	Peridge	0.05	24.39	WWHT	0.00	w N rep	393	178.2
400	22	36.37	-94.51	7	Nixa	0.05	36.58	WWHT	1.95		1181	177.8
141	7	36.4	-94.31	7	Nixa	0.02	91.46	WWHT	1.95		1287	176.7
926	56	36.38	-94.44	0	Elsah	0.09	60.98	WWHT	1.95		62	171.6
854	52	36.32	-94.68	1	Razort	0.10	24.39	HAY	6.00	w alum;	191	164.9
572	35	36.32	-94.71	41	Razort	0.07	18.29	HAY	6.00	w alum;	6634	163.0
578	35	36.32	-94.71	15	Clarksville	0.04	18.29	WWHT	0.65	w/o N rep	2485	163.0
524	32	36.35	-94.77	2	Clarksville	0.03	18.29	WWHT	0.65	w/o N rep	307	159.7
179	9	36.4	-94.37	60	Nixa	0.04	60.98	WWHT	1.95	w alum;	9590	159.3
731	45	36.28	-94.67	158	Doniphan	0.03	91.46	HAY	6.00	w alum;	25108	158.8
730	45	36.28	-94.67	40	Clarksville	0.03	91.46	HAY	6.00	w alum;	6415	158.7
612	37	36.36	-94.59	4	Clarksville	0.05	24.39	WWHT	1.95	w alum;	614	156.9
592	36	36.34	-94.76	3	Razort	0.05	60.98	HAY	4.80	w alum;	407	154.4
507	31	36.36	-94.78	5	Healing	0.05	24.39	HAY	4.00	w alum;	750	154.3
834	51	36.35	-94.75	1	Razort	0.06	15.24	HAY	4.80	w alum;	166	154.2
341	18	36.39	-94.47	6	Nixa	0.03	60.98	WWHT	1.95		989	154.1
522	32	36.35	-94.77	22	Healing	0.05	18.29	HAY	4.00	w alum;	3352	153.1
732	45	36.28	-94.67	83	Macedonia	0.03	91.46	HAY	6.00	w alum;	12772	153.1
817	50	36.27	-94.81	118	Razort	0.09	24.39	HAY	4.80	w alum;	18051	152.9
504	31	36.36	-94.78	3	Razort	0.05	24.39	HAY	4.80	w alum;	400	152.2
909	55	36.27	-94.74	808	Doniphan	0.06	60.98	HAY	6.00	w alum;	122400	151.5
380	21	36.41	-94.51	6	Nixa	0.03	60.98	WWHT	1.95	w alum;	835	151.2
990	63	36.32	-94.89	4	Razort	0.08	18.29	HAY	4.80	w alum;	553	151.1
766	47	36.39	-94.84	26	Razort	0.09	24.39	HAY	4.80	w alum;	3867	151.0
520	32	36.35	-94.77	5	Razort	0.05	18.29	HAY	4.80	w alum;	812	151.0
907	55	36.27	-94.74	348	Clarksville	0.06	60.98	HAY	6.00	w alum;	52524	150.8
97	4	36.4	-94.57	13	Nixa	0.02	121.95	WWHT	1.95	w alum;	1940	149.8
712	44	36.3	-94.68	21	Captina	0.04	60.98	HAY	6.00	w alum;	3164	149.4
713	44	36.3	-94.68	20	Doniphan	0.04	60.98	HAY	6.00	w alum;	2997	148.9
858	52	36.32	-94.68	1	Clarksville	0.09	24.39	WWHT	1.30	w alum;	120	148.5
857	52	36.32	-94.68	2	Doniphan	0.10	24.39	HAY	6.00	w alum;	269	147.8
710	44	36.3	-94.68	13	Clarksville	0.04	60.98	HAY	6.00	w alum;	1992	147.7
693	43	36.36	-94.65	60	Newtonia	0.03	60.98	HAY	6.00	w alum;	8873	147.6
232	13	36.41	-94.66	114	Razort	0.05	60.98	HAY	6.00	w alum;	16793	147.1
633	38	36.32	-94.53	31	Nixa	0.03	60.98	WWHT	1.95	w alum;	4566	146.5
575	35	36.32	-94.71	38	Doniphan	0.07	18.29	HAY	6.00	w alum;	5570	146.1
367	20	36.36	-94.89	14	Razort	0.16	24.39	HAY	4.00	w alum;	2014	146.1
579	35	36.32	-94.71	7	Clarksville	0.04	18.29	WWHT	0.33	w/o N rep	1068	145.9
653	41	36.33	-94.65	18	Britwater	0.07	24.39	HAY	6.00	w alum;	2550	145.7
753	46	36.29	-94.61	184	Captina	0.03	60.98	HAY	6.00	w alum;	26789	145.6
856	52	36.32	-94.68	2	Britwater	0.10	24.39	HAY	6.00	w alum;	251	145.2
668	42	36.3	-94.65	46	Doniphan	0.05	36.58	HAY	6.00	w alum;	6669	144.9
1036	68	36.33	-94.61	13	Clarksville	0.04	36.58	WWHT	1.95	w alum;	1861	144.1
301	16	36.35	-94.44	15	Nixa	0.05	60.98	WWHT	1.95	w alum;	2100	143.6

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
651	41	36.33	-94.65	24	Clarksville	0.07	24.39	HAY	6.00	w alum;	3485	143.4
573	35	36.32	-94.71	87	Clarksville	0.07	18.29	HAY	6.00	w alum;	12427	143.4
714	44	36.3	-94.68	33	Macedonia	0.04	60.98	HAY	6.00	w alum;	4737	143.2
354	19	36.35	-94.92	7	Razort	0.06	24.39	HAY	4.00	w alum;	1073	143.1
259	14	36.37	-94.66	115	Newtonia	0.03	91.46	HAY	6.00	w alum;	16378	142.9
666	42	36.3	-94.65	35	Clarksville	0.05	36.58	HAY	6.00	w alum;	5032	142.3
73	3	36.42	-94.67	28	Newtonia	0.02	91.46	WWHT	0.00	w N rep	3954	141.7
894	54	36.42	-94.62	6	Newtonia	0.02	91.46	WWHT	0.00	w N rep	857	141.4
1000	64	36.37	-94.91	6	Razort	0.11	36.58	HAY	4.00	w alum;	785	141.4
908	55	36.27	-94.74	228	Clarksville	0.06	60.98	HAY	6.00	w alum;	32158	141.1
752	46	36.29	-94.61	101	Clarksville	0.03	60.98	HAY	6.00	w alum;	14172	140.3
576	35	36.32	-94.71	56	Macedonia	0.07	18.29	HAY	6.00	w alum;	7793	139.6
755	46	36.29	-94.61	41	Captina	0.02	60.98	WWHT	0.00	w N rep	5677	138.7
690	43	36.36	-94.65	41	Doniphan	0.03	60.98	HAY	6.00	w alum;	5688	138.2
982	62	36.33	-94.8	10	Clarksville	0.03	36.58	WWHT	0.98	w/o N rep	1384	137.4
121	6	36.38	-94.61	69	Taloka	0.01	121.95	WWHT	0.00	w N rep	9525	137.3
980	62	36.33	-94.8	99	Doniphan	0.05	36.58	HAY	6.00	w alum;	13644	137.3
978	62	36.33	-94.8	50	Clarksville	0.05	36.58	HAY	4.80	w alum;	6833	137.2
17	1	36.44	-94.67	52	Razort	0.07	60.98	HAY	4.00	w alum;	7143	137.0
711	44	36.3	-94.68	16	Clarksville	0.04	60.98	HAY	6.00	w alum;	2175	136.7
669	42	36.3	-94.65	40	Macedonia	0.05	36.58	HAY	6.00	w alum;	5394	136.4
157	8	36.37	-94.33	58	Captina	0.03	91.46	HAY	6.00	w alum;	7946	136.0
820	50	36.27	-94.81	107	Doniphan	0.09	24.39	HAY	4.80	w alum;	14494	135.7
468	28	36.36	-94.79	8	Clarksville	0.07	24.39	HAY	4.80	w alum;	1106	135.6
781	48	36.4	-94.79	45	Razort	0.11	24.39	HAY	4.00	w alum;	6025	135.2
855	52	36.32	-94.68	5	Clarksville	0.10	24.39	HAY	6.00	w alum;	699	134.6
818	50	36.27	-94.81	300	Clarksville	0.09	24.39	HAY	4.80	w alum;	40330	134.6
652	41	36.33	-94.65	14	Clarksville	0.07	24.39	HAY	6.00	w alum;	1903	134.4
574	35	36.32	-94.71	46	Clarksville	0.07	18.29	HAY	6.00	w alum;	6104	134.0
688	43	36.36	-94.65	44	Clarksville	0.03	60.98	HAY	6.00	w alum;	5880	133.6
981	62	36.33	-94.8	5	Clarksville	0.03	36.58	WWHT	0.33	w/o N rep	640	133.4
992	63	36.32	-94.89	5	Britwater	0.08	18.29	HAY	4.80	w alum;	611	133.4
956	60	36.37	-94.81	6	Clarksville	0.10	18.29	HAY	4.80	w alum;	853	133.3
159	8	36.37	-94.33	69	Tonti	0.03	91.46	HAY	6.00	w alum;	9150	133.2
691	43	36.36	-94.65	68	Macedonia	0.03	60.98	HAY	4.80	w alum;	8984	133.0
821	50	36.27	-94.81	15	Razort	0.09	24.39	WWHT	0.00	w N rep	2002	132.7
967	61	36.35	-94.79	2	Doniphan	0.06	24.39	HAY	4.80	w alum;	216	132.6
177	9	36.4	-94.37	201	Tonti	0.05	60.98	HAY	6.00	w alum;	26602	132.4
667	42	36.3	-94.65	27	Clarksville	0.05	36.58	HAY	6.00	w alum;	3586	132.2
137	7	36.4	-94.31	143	Captina	0.03	91.46	HAY	6.00	w alum;	18870	132.0
836	51	36.35	-94.75	1	Britwater	0.01	15.24	WWHT	0.00	w N rep	84	131.9
480	29	36.34	-94.36	53	Tonti	0.06	60.98	HAY	6.00	w alum;	6933	131.8
458	27	36.36	-94.8	2	Clarksville	0.13	36.58	HAY	4.80	w alum;	282	131.7
236	13	36.41	-94.66	119	Newtonia	0.05	60.98	HAY	6.00	w alum;	15677	131.3
991	63	36.32	-94.89	5	Clarksville	0.08	18.29	HAY	4.80	w alum;	672	131.2
235	13	36.41	-94.66	112	Doniphan	0.05	60.98	HAY	6.00	w alum;	14626	131.0
521	32	36.35	-94.77	9	Clarksville	0.05	18.29	HAY	4.80	w alum;	1131	130.5
139	7	36.4	-94.31	73	Tonti	0.03	91.46	HAY	6.00	w alum;	9567	130.5
122	6	36.38	-94.61	63	Newtonia	0.01	121.95	WWHT	0.00	w N rep	8202	130.4
505	31	36.36	-94.78	7	Clarksville	0.05	24.39	HAY	4.80	w alum;	861	130.2
966	61	36.35	-94.79	2	Clarksville	0.06	24.39	HAY	4.80	w alum;	297	129.6
197	10	36.37	-94.41	48	Tonti	0.06	60.98	HAY	6.00	w alum;	6227	129.1
257	14	36.37	-94.66	70	Macedonia	0.03	91.46	HAY	4.80	w alum;	8965	128.8
209	11	36.4	-94.99	11	Razort	0.10	24.39	HAY	4.00	w alum;	1446	128.5
734	45	36.28	-94.67	16	Doniphan	0.02	91.46	WWHT	1.11	w alum; w/o N rep	1998	128.4
44	2	36.43	-94.7	314	Captina	0.04	60.98	HAY	4.80	w alum;	40046	127.7
339	18	36.39	-94.47	65	Tonti	0.05	60.98	HAY	6.00	w alum;	8259	127.6
979	62	36.33	-94.8	113	Clarksville	0.05	36.58	HAY	4.80	w alum;	14397	127.3
754	46	36.29	-94.61	82	Taloka	0.03	60.98	HAY	4.80	w alum;	10377	127.1
258	14	36.37	-94.66	67	Jay	0.03	91.46	HAY	4.00	w alum;	8454	127.1
819	50	36.27	-94.81	146	Clarksville	0.09	24.39	HAY	4.80	w alum;	18495	127.0
45	2	36.43	-94.7	373	Doniphan	0.04	60.98	HAY	4.80	w alum;	47301	126.7
278	15	34.4	-94.44	138	Tonti	0.05	60.98	HAY	6.00	w alum;	17478	126.2
459	27	36.36	-94.8	1	Britwater	0.13	36.58	HAY	4.80	w alum;	136	126.2
233	13	36.41	-94.66	148	Clarksville	0.05	60.98	HAY	4.80	w alum;	18566	125.8
416	23	36.36	-94.55	5	Peridge	0.05	24.39	HAY	4.80	w alum;	643	125.8
550	34	36.33	-94.86	4	Clarksville	0.10	24.39	HAY	4.80	w alum;	539	125.7

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
767	47	36.39	-94.84	129	Clarksville	0.09	24.39	HAY	4.80	w alum;	16135	125.5
910	55	36.27	-94.74	24	Clarksville	0.04	60.98	WWHT	0.65	w alum; w/o N rep	2983	125.5
413	23	36.36	-94.55	2	Captina	0.05	24.39	HAY	4.80	w alum;	256	125.4
983	62	36.33	-94.8	13	Doniphan	0.03	36.58	WWHT	0.33	w/o N rep	1619	125.2
542	33	36.35	-94.82	5	Britwater	0.11	24.39	HAY	4.80	w alum;	651	125.1
540	33	36.35	-94.82	19	Clarksville	0.11	24.39	HAY	4.80	w alum;	2397	125.1
398	22	36.37	-94.51	29	Tonti	0.06	36.58	HAY	6.00	w alum;	3650	125.0
957	60	36.37	-94.81	2	Clarksville	0.10	18.29	HAY	4.80	w alum;	212	124.4
689	43	36.36	-94.65	61	Clarksville	0.03	60.98	HAY	6.00	w alum;	7607	124.4
445	25	36.37	-94.87	2	Clarksville	0.11	24.39	HAY	4.80	w alum;	283	124.2
800	49	36.37	-94.73	270	Clarksville	0.07	36.58	HAY	4.80	w alum;	33539	124.2
378	21	36.41	-94.51	45	Tonti	0.04	60.98	HAY	6.00	w alum;	5595	124.2
460	27	36.36	-94.8	1	Elsah	0.13	36.58	HAY	6.00	w alum;	145	124.1
613	37	36.36	-94.59	6	Captina	0.05	24.39	WWHT	0.00	w N rep	780	123.5
494	30	36.33	-94.39	9	Clarksville	0.08	36.58	HAY	6.00	w alum;	1079	123.4
281	15	34.4	-94.44	11	Nixa	0.04	60.98	WWHT	1.95	w alum;	1374	123.1
92	4	36.4	-94.57	130	Newtonia	0.02	121.95	HAY	4.80	w alum;	15927	122.6
355	19	36.35	-94.92	11	Clarksville	0.06	24.39	HAY	4.00	w alum;	1362	122.2
321	17	36.41	-94.48	70	Tonti	0.06	60.98	HAY	6.00	w alum;	8503	122.2
357	19	36.35	-94.92	9	Doniphan	0.06	24.39	HAY	4.80	w alum;	1063	122.1
43	2	36.43	-94.7	343	Clarksville	0.04	60.98	HAY	4.80	w alum;	41793	122.0
1051	69	36.35	-95.01	2	Healing	0.06	24.39	HAY	4.00	w alum;	294	121.9
631	38	36.32	-94.53	90	Tonti	0.05	60.98	HAY	6.00	w alum;	11016	121.8
120	6	36.38	-94.61	142	Newtonia	0.01	121.95	HAY	4.80	w alum;	17236	121.6
22	1	36.44	-94.67	54	Doniphan	0.07	60.98	HAY	4.80	w alum;	6547	121.5
525	32	36.35	-94.77	4	Britwater	0.03	18.29	WWHT	0.00	w N rep	510	121.3
893	54	36.42	-94.62	88	Newtonia	0.02	91.46	HAY	4.80	w alum;	10624	120.7
692	43	36.36	-94.65	40	Taloka	0.03	60.98	HAY	4.80	w alum;	4834	120.5
276	15	34.4	-94.44	57	Captina	0.05	60.98	HAY	4.80	w alum;	6879	120.5
478	29	36.34	-94.36	37	Clarksville	0.06	60.98	HAY	6.00	w alum;	4407	120.3
23	1	36.44	-94.67	3	Clarksville	0.05	60.98	WWHT	0.00	w/o N rep	327	120.0
610	37	36.36	-94.59	17	Captina	0.06	24.39	HAY	4.00	w alum;	2003	119.8
878	53	36.35	-94.57	10	Peridge	0.07	24.39	HAY	4.00	w alum;	1216	119.8
368	20	36.36	-94.89	92	Clarksville	0.16	24.39	HAY	4.80	w alum;	11063	119.7
768	47	36.39	-94.84	57	Clarksville	0.09	24.39	HAY	4.80	w alum;	6781	119.6
936	57	36.39	-94.94	23	Healing	0.09	18.29	HAY	4.00	w alum;	2788	119.2
414	23	36.36	-94.55	3	Britwater	0.05	24.39	HAY	4.80	w alum;	305	119.2
506	31	36.36	-94.78	5	Elsah	0.05	24.39	HAY	6.00	w alum;	624	118.9
541	33	36.35	-94.82	7	Clarksville	0.11	24.39	HAY	4.80	w alum;	886	118.2
234	13	36.41	-94.66	109	Clarksville	0.05	60.98	HAY	4.80	w alum;	12939	118.2
175	9	36.4	-94.37	128	Captina	0.05	60.98	HAY	4.80	w alum;	15132	118.1
337	18	36.39	-94.47	89	Captina	0.05	60.98	HAY	4.80	w alum;	10454	117.8
801	49	36.37	-94.73	117	Clarksville	0.07	36.58	HAY	4.80	w alum;	13784	117.7
376	21	36.41	-94.51	139	Captina	0.04	60.98	HAY	4.80	w alum;	16320	117.6
91	4	36.4	-94.57	144	Captina	0.02	121.95	HAY	4.00	w alum;	16851	117.4
1001	64	36.37	-94.91	9	Clarksville	0.11	36.58	HAY	4.00	w alum;	1046	117.3
70	3	36.42	-94.67	88	Peridge	0.02	91.46	HAY	4.00	w alum;	10369	117.2
1035	68	36.33	-94.61	73	Tonti	0.05	36.58	HAY	6.00	w alum;	8609	117.1
434	24	36.34	-94.49	59	Peridge	0.05	60.98	HAY	4.80	w alum;	6832	116.8
94	4	36.4	-94.57	84	Tonti	0.02	121.95	HAY	6.00	w alum;	9801	116.5
551	34	36.33	-94.86	13	Tonti	0.10	24.39	HAY	4.00	w alum;	1515	116.2
358	19	36.35	-94.92	21	Tonti	0.06	24.39	HAY	4.00	w alum;	2421	116.0
580	35	36.32	-94.71	7	Britwater	0.04	18.29	WWHT	0.00	w N rep	859	115.8
18	1	36.44	-94.67	117	Clarksville	0.07	60.98	HAY	4.80	w alum;	13570	115.7
67	3	36.42	-94.67	166	Captina	0.02	91.46	HAY	4.00	w alum;	19221	115.7
20	1	36.44	-94.67	51	Captina	0.07	60.98	HAY	4.00	w alum;	5902	115.4
319	17	36.41	-94.48	51	Captina	0.06	60.98	HAY	4.80	w alum;	5877	115.3
802	49	36.37	-94.73	217	Macedonia	0.07	36.58	HAY	4.80	w alum;	25034	115.2
323	17	36.41	-94.48	12	Nixa	0.04	60.98	WWHT	1.95	w alum;	1379	114.7
1034	68	36.33	-94.61	76	Captina	0.05	36.58	HAY	4.00	w alum;	8684	114.7
608	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	4.00	w alum;	751	114.4
432	24	36.34	-94.49	62	Captina	0.05	60.98	HAY	4.00	w alum;	7035	113.6
629	38	36.32	-94.53	110	Captina	0.05	60.98	HAY	4.00	w alum;	12540	113.5
399	22	36.37	-94.51	25	Captina	0.05	36.58	WWHT	0.00	w N rep	2815	113.4
876	53	36.35	-94.57	12	Britwater	0.07	24.39	HAY	4.80	w alum;	1341	112.9
396	22	36.37	-94.51	62	Captina	0.06	36.58	HAY	4.00	w alum;	7012	112.8
298	16	36.35	-94.44	31	Peridge	0.07	60.98	HAY	4.80	w alum;	3526	112.7

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
356	19	36.35	-94.92	10	Clarksville	0.06	24.39	HAY	4.00	w alum;	1172	112.7
1002	64	36.37	-94.91	5	Britwater	0.11	36.58	HAY	4.00	w alum;	585	112.6
295	16	36.35	-94.44	41	Clarksville	0.07	60.98	HAY	4.80	w alum;	4591	112.5
195	10	36.37	-94.41	47	Britwater	0.06	60.98	HAY	4.80	w alum;	5315	112.1
782	48	36.4	-94.79	176	Clarksville	0.11	24.39	HAY	4.80	w alum;	19606	111.6
1032	68	36.33	-94.61	102	Clarksville	0.05	36.58	HAY	4.00	w alum;	11385	111.5
98	4	36.4	-94.57	22	Peridge	0.02	121.95	WWHT	0.00	w N rep	2441	111.5
210	11	36.4	-94.99	25	Clarksville	0.10	24.39	HAY	4.00	w alum;	2757	110.8
395	22	36.37	-94.51	21	Clarksville	0.06	36.58	HAY	4.80	w alum;	2343	110.5
877	53	36.35	-94.57	6	Waben	0.07	24.39	HAY	4.80	w alum;	714	110.2
431	24	36.34	-94.49	52	Clarksville	0.05	60.98	HAY	4.80	w alum;	5738	109.7
238	13	36.41	-94.66	22	Clarksville	0.03	60.98	WWHT	0.33	w/o N rep	2422	109.5
1052	69	36.35	-95.01	4	Peridge	0.06	24.39	HAY	4.00	w alum;	478	109.0
913	55	36.27	-94.74	79	Doniphan	0.04	60.98	WWHT	0.00	w N rep	8621	108.5
481	29	36.34	-94.36	4	Clarksville	0.06	60.98	WWHT	0.00	w N rep	434	108.5
19	1	36.44	-94.67	47	Clarksville	0.07	60.98	HAY	4.80	w alum;	5065	108.3
875	53	36.35	-94.57	18	Clarksville	0.07	24.39	HAY	4.80	w alum;	1970	107.9
296	16	36.35	-94.44	37	Captina	0.07	60.98	HAY	4.80	w alum;	3947	107.4
892	54	36.42	-94.62	15	Clarksville	0.02	91.46	HAY	4.00	w alum;	1631	107.3
786	48	36.4	-94.79	11	Clarksville	0.07	24.39	WWHT	0.00	w/o N rep	1207	107.2
784	48	36.4	-94.79	38	Britwater	0.11	24.39	HAY	4.80	w alum;	4079	107.0
1048	69	36.35	-95.01	7	Captina	0.06	24.39	HAY	4.00	w alum;	798	107.0
934	57	36.39	-94.94	28	Clarksville	0.09	18.29	HAY	4.00	w alum;	3039	106.9
628	38	36.32	-94.53	61	Clarksville	0.05	60.98	HAY	4.80	w alum;	6554	106.8
68	3	36.42	-94.67	116	Jay	0.02	91.46	HAY	4.00	w alum;	12350	106.8
783	48	36.4	-94.79	54	Clarksville	0.11	24.39	HAY	4.80	w alum;	5812	106.7
609	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	4.80	w alum;	791	106.6
1013	66	36.36	-95.02	8	Clarksville	0.07	18.29	HAY	4.00	w alum;	801	106.4
803	49	36.37	-94.73	28	Clarksville	0.06	36.58	WWHT	0.00	w N rep	2912	104.8
1033	68	36.33	-94.61	136	Clarksville	0.05	36.58	HAY	4.80	w alum;	14204	104.6
635	38	36.32	-94.53	46	Peridge	0.03	60.98	WWHT	0.00	w N rep	4796	104.2
119	6	36.38	-94.61	59	Taloka	0.01	121.95	HAY	4.00	w alum;	6148	104.0
1049	69	36.35	-95.01	3	Britwater	0.06	24.39	HAY	4.00	w alum;	283	103.5
279	15	34.4	-94.44	35	Noark	0.05	60.98	HAY	4.00	w alum;	3575	103.3
382	21	36.41	-94.51	4	Peridge	0.03	60.98	WWHT	0.00	w N rep	364	103.2
935	57	36.39	-94.94	74	Britwater	0.09	18.29	HAY	4.00	w alum;	7468	100.3
21	1	36.44	-94.67	45	Taloka	0.07	60.98	HAY	4.00	w alum;	4440	99.8
260	14	36.37	-94.66	14	Clarksville	0.02	91.46	WWHT	0.00	w N rep	1388	98.1
1014	66	36.36	-95.02	11	Clarksville	0.07	18.29	HAY	4.00	w alum;	1042	97.7
237	13	36.41	-94.66	27	Clarksville	0.03	60.98	WWHT	0.00	w N rep	2634	97.2
804	49	36.37	-94.73	12	Clarksville	0.06	36.58	WWHT	0.65	w alum; w/o N rep	1169	95.9
785	48	36.4	-94.79	18	Clarksville	0.07	24.39	WWHT	0.00	w N rep	1709	94.9
495	30	36.33	-94.39	42	Nixa	0.08	36.58	HAY	6.00	w alum;	4003	94.4
140	7	36.4	-94.31	21	Captina	0.02	91.46	WWHT	0.00	w N rep	1976	94.0
671	42	36.3	-94.65	8	Clarksville	0.05	36.58	WWHT	0.00	w N rep	760	92.2
806	49	36.37	-94.73	11	Doniphan	0.06	36.58	WWHT	0.00	w N rep	1030	90.0
46	2	36.43	-94.7	38	Clarksville	0.03	60.98	WWHT	0.00	w N rep	3424	89.3
176	9	36.4	-94.37	407	Nixa	0.05	60.98	HAY	4.80	w alum;	36139	88.7
479	29	36.34	-94.36	144	Nixa	0.06	60.98	HAY	6.00	w alum;	12772	88.5
300	16	36.35	-94.44	14	Newtonia	0.05	60.98	WWHT	0.00	w N rep	1234	88.4
735	45	36.28	-94.67	31	Macedonia	0.02	91.46	WWHT	0.00	w N rep	2759	88.3
158	8	36.37	-94.33	41	Nixa	0.03	91.46	HAY	6.00	w alum;	3630	87.6
297	16	36.35	-94.44	102	Nixa	0.07	60.98	HAY	4.00	w alum;	8927	87.1
196	10	36.37	-94.41	98	Nixa	0.06	60.98	HAY	4.00	w alum;	8495	87.1
397	22	36.37	-94.51	35	Nixa	0.06	36.58	HAY	4.00	w alum;	3054	86.5
415	23	36.36	-94.55	4	Nixa	0.05	24.39	HAY	4.00	w alum;	309	86.3
96	4	36.4	-94.57	15	Newtonia	0.02	121.95	WWHT	0.00	w N rep	1278	86.2
670	42	36.3	-94.65	4	Clarksville	0.05	36.58	WWHT	0.00	w N rep	374	84.7
338	18	36.39	-94.47	53	Nixa	0.05	60.98	HAY	4.80	w alum;	4452	84.6
277	15	34.4	-94.44	85	Nixa	0.05	60.98	HAY	4.00	w alum;	7156	84.5
161	8	36.37	-94.33	9	Taloka	0.02	91.46	WWHT	0.00	w N rep	737	84.2
611	37	36.36	-94.59	7	Nixa	0.06	24.39	HAY	4.00	w alum;	613	83.9
138	7	36.4	-94.31	32	Nixa	0.03	91.46	HAY	6.00	w alum;	2700	83.7
433	24	36.34	-94.49	190	Nixa	0.05	60.98	HAY	4.00	w alum;	15879	83.7
377	21	36.41	-94.51	104	Nixa	0.04	60.98	HAY	4.00	w alum;	8685	83.6
199	10	36.37	-94.41	10	Nixa	0.06	60.98	WWHT	1.95	w alum;	795	83.4
733	45	36.28	-94.67	10	Captina	0.02	91.46	WWHT	0.00	w N rep	802	83.3

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
71	3	36.42	-94.67	28	Captina	0.02	91.46	WWHT	0.00	w N rep	2303	82.5
320	17	36.41	-94.48	49	Nixa	0.06	60.98	HAY	4.00	w alum;	3988	82.2
630	38	36.32	-94.53	123	Nixa	0.05	60.98	HAY	4.00	w alum;	10132	82.1
239	13	36.41	-94.66	26	Doniphan	0.03	60.98	WWHT	0.00	w N rep	2125	80.6
160	8	36.37	-94.33	39	Captina	0.02	91.46	WWHT	0.00	w N rep	3037	78.8
823	50	36.27	-94.81	33	Clarksville	0.09	24.39	WWHT	0.00	w N rep	2498	75.7
716	44	36.3	-94.68	8	Clarksville	0.08	60.98	WWHT	0.00	w N rep	630	75.5
1015	66	36.36	-95.02	7	Nixa	0.07	18.29	HAY	4.00	w alum;	517	73.4
93	4	36.4	-94.57	151	Nixa	0.02	121.95	HAY	4.00	w alum;	10960	72.6
69	3	36.42	-94.67	226	Nixa	0.02	91.46	HAY	4.00	w alum;	16146	71.5
1037	68	36.33	-94.61	24	Captina	0.04	36.58	WWHT	0.00	w N rep	1671	70.6
1050	69	36.35	-95.01	3	Nixa	0.06	24.39	HAY	4.00	w alum;	178	70.4
845	52	36.32	-94.68	2	Razort	0.10	24.39	WPAS	0.00	w/o N rep	131	70.2
985	63	36.32	-94.89	5	Razort	0.08	18.29	WPAS	0.00	w/o N rep	334	70.1
557	35	36.32	-94.71	69	Razort	0.07	18.29	WPAS	0.00	w/o N rep	4868	70.0
948	60	36.37	-94.81	2	Razort	0.10	18.29	WPAS	0.00	w/o N rep	139	69.9
511	32	36.35	-94.77	13	Razort	0.05	18.29	WPAS	0.00	w/o N rep	899	69.8
828	51	36.35	-94.75	1	Razort	0.06	15.24	WPAS	0.00	w/o N rep	88	69.8
938	58	36.35	-94.85	0	Razort	0.15	18.29	WPAS	0.00	w/o N rep	20	69.8
585	36	36.34	-94.76	0	Razort	0.05	60.98	WPAS	0.00	w/o N rep	13	69.8
513	32	36.35	-94.77	25	Healing	0.05	18.29	WPAS	0.00	w/o N rep	1763	69.7
654	42	36.3	-94.65	69	Razort	0.05	36.58	WPAS	1.00	w alum; w/o N rep	4804	69.6
757	47	36.39	-94.84	45	Razort	0.09	24.39	WPAS	0.00	w/o N rep	3151	69.6
496	31	36.36	-94.78	5	Razort	0.05	24.39	WPAS	0.00	w/o N rep	355	69.4
808	50	36.27	-94.81	159	Razort	0.09	24.39	WPAS	0.00	w/o N rep	11051	69.4
995	64	36.37	-94.91	7	Razort	0.11	36.58	WPAS	0.00	w/o N rep	483	69.3
715	44	36.3	-94.68	5	Clarksville	0.08	60.98	WWHT	0.00	w N rep	329	69.2
943	59	36.36	-94.86	2	Razort	0.17	18.29	WPAS	0.00	w/o N rep	144	69.2
879	53	36.35	-94.57	7	Clarksville	0.12	24.39	WWHT	0.00	w N rep	484	68.9
499	31	36.36	-94.78	11	Healing	0.05	24.39	WPAS	0.00	w/o N rep	766	68.7
963	61	36.35	-94.79	3	Healing	0.06	24.39	WPAS	0.00	w/o N rep	178	68.7
5	1	36.44	-94.67	53	Razort	0.07	60.98	WPAS	0.00	w/o N rep	3651	68.7
302	16	36.35	-94.44	42	Peridge	0.05	60.98	WWHT	0.00	w N rep	2881	68.6
361	20	36.36	-94.89	26	Razort	0.16	24.39	WPAS	0.00	w/o N rep	1755	68.4
594	36	36.34	-94.76	7	Britwater	0.02	60.98	WWHT	0.00	w N rep	447	68.2
1016	67	36.37	-94.98	4	Razort	0.13	15.24	WPAS	0.00	w/o N rep	285	68.1
407	23	36.36	-94.55	5	Healing	0.05	24.39	WPAS	0.00	w/o N rep	317	67.9
883	54	36.42	-94.62	25	Razort	0.02	91.46	WPAS	0.00	w/o N rep	1712	67.9
219	13	36.41	-94.66	255	Razort	0.05	60.98	WPAS	0.00	w/o N rep	17339	67.9
203	11	36.4	-94.99	19	Razort	0.10	24.39	WPAS	0.00	w/o N rep	1279	67.2
773	48	36.4	-94.79	48	Razort	0.11	24.39	WPAS	0.00	w/o N rep	3209	67.1
672	42	36.3	-94.65	5	Doniphan	0.05	36.58	WWHT	0.00	w N rep	336	66.9
330	18	36.39	-94.47	53	Tonti	0.05	60.98	WPAS	1.00	w/o N rep	3423	64.9
695	43	36.36	-94.65	150	Newtonia	0.01	60.98	WWHT	0.00	w N rep	9686	64.4
268	15	34.4	-94.44	183	Tonti	0.05	60.98	WPAS	1.00	w/o N rep	11663	63.9
371	21	36.41	-94.51	105	Tonti	0.04	60.98	WPAS	1.00	w/o N rep	6707	63.8
167	9	36.4	-94.37	226	Tonti	0.05	60.98	WPAS	1.00	w/o N rep	14386	63.6
309	17	36.41	-94.48	105	Tonti	0.06	60.98	WPAS	1.00	w/o N rep	6607	63.0
187	10	36.37	-94.41	57	Tonti	0.06	60.98	WPAS	1.00	w alum; w/o N rep	3603	63.0
622	38	36.32	-94.53	342	Tonti	0.05	60.98	WPAS	1.00	w alum; w/o N rep	21321	62.4
148	8	36.37	-94.33	230	Tonti	0.03	91.46	WPAS	1.00	w/o N rep	14333	62.2
866	53	36.35	-94.57	18	Waben	0.07	24.39	WPAS	1.00	w alum; w/o N rep	1127	62.2
128	7	36.4	-94.31	199	Tonti	0.03	91.46	WPAS	1.00	w/o N rep	12291	61.7
822	50	36.27	-94.81	64	Clarksville	0.09	24.39	WWHT	0.00	w N rep	3935	61.1
464	28	36.36	-94.79	1	Elsah	0.07	24.39	WPAS	1.00	w/o N rep	77	60.6
473	29	36.34	-94.36	166	Tonti	0.06	60.98	WPAS	2.00	w alum; w/o N rep	10069	60.5
586	36	36.34	-94.76	1	Elsah	0.05	60.98	WPAS	1.00	w alum; w/o N rep	48	59.4
498	31	36.36	-94.78	4	Elsah	0.05	24.39	WPAS	1.00	w alum; w/o N rep	261	58.2
962	61	36.35	-94.79	1	Elsah	0.06	24.39	WPAS	1.00	w alum; w/o N rep	61	58.1
436	24	36.34	-94.49	33	Nixa	0.04	60.98	WWHT	1.95	w alum;	1888	57.9
558	35	36.32	-94.71	95	Clarksville	0.07	18.29	WPAS	1.00	w alum; w/o N rep	5491	57.6
269	15	34.4	-94.44	132	Noark	0.05	60.98	WPAS	0.00	w/o N rep	7531	57.2
310	17	36.41	-94.48	51	Noark	0.06	60.98	WPAS	0.00	w/o N rep	2917	57.2
846	52	36.32	-94.68	2	Clarksville	0.10	24.39	WPAS	1.00	w alum; w/o N rep	140	57.0
968	62	36.33	-94.8	80	Clarksville	0.05	36.58	WPAS	1.00	w alum; w/o N rep	4542	56.9
829	51	36.35	-94.75	0	Clarksville	0.06	15.24	WPAS	0.00	w/o N rep	15	56.8
986	63	36.32	-94.89	6	Clarksville	0.08	18.29	WPAS	0.00	w/o N rep	337	56.7

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
405	23	36.36	-94.55	13	Captina	0.05	24.39	WPAS	0.00	w/o N rep	728	56.7
898	55	36.27	-94.74	520	Clarksville	0.06	60.98	WPAS	1.00	w alum; w/o N rep	29460	56.6
512	32	36.35	-94.77	27	Clarksville	0.05	18.29	WPAS	0.00	w/o N rep	1519	56.6
178	9	36.4	-94.37	26	Captina	0.04	60.98	WWHT	0.00	w N rep	1455	56.6
48	2	36.43	-94.7	75	Doniphan	0.03	60.98	WWHT	0.00	w N rep	4250	56.6
463	28	36.36	-94.79	3	Clarksville	0.07	24.39	WPAS	0.00	w/o N rep	190	56.5
346	19	36.35	-94.92	34	Clarksville	0.06	24.39	WPAS	0.00	w/o N rep	1905	56.4
741	46	36.29	-94.61	269	Clarksville	0.03	60.98	WPAS	1.00	w alum; w/o N rep	15164	56.3
949	60	36.37	-94.81	7	Clarksville	0.10	18.29	WPAS	0.00	w/o N rep	392	56.2
497	31	36.36	-94.78	9	Clarksville	0.05	24.39	WPAS	0.00	w/o N rep	533	56.2
600	37	36.36	-94.59	52	Captina	0.06	24.39	WPAS	0.00	w/o N rep	2902	56.2
349	19	36.35	-94.92	27	Tonti	0.06	24.39	WPAS	0.00	w/o N rep	1520	56.2
961	61	36.35	-94.79	5	Clarksville	0.06	24.39	WPAS	0.00	w/o N rep	286	56.1
168	9	36.4	-94.37	231	Noark	0.05	60.98	WPAS	0.00	w/o N rep	12976	56.1
641	41	36.33	-94.65	22	Clarksville	0.07	24.39	WPAS	1.00	w alum; w/o N rep	1212	56.1
742	46	36.29	-94.61	277	Captina	0.03	60.98	WPAS	0.00	w/o N rep	15551	56.1
700	44	36.3	-94.68	62	Captina	0.04	60.98	WPAS	0.00	w/o N rep	3484	56.0
809	50	36.27	-94.81	489	Clarksville	0.09	24.39	WPAS	0.00	w/o N rep	27292	55.9
408	23	36.36	-94.55	7	Peridge	0.05	24.39	WPAS	0.00	w/o N rep	372	55.8
560	35	36.32	-94.71	44	Britwater	0.07	18.29	WPAS	0.00	w/o N rep	2429	55.7
547	34	36.33	-94.86	22	Clarksville	0.10	24.39	WPAS	0.00	w/o N rep	1226	55.7
655	42	36.3	-94.65	96	Clarksville	0.05	36.58	WPAS	1.00	w alum; w/o N rep	5319	55.6
969	62	36.33	-94.8	99	Clarksville	0.05	36.58	WPAS	0.00	w/o N rep	5527	55.6
248	14	36.37	-94.66	51	Jay	0.03	91.46	WPAS	0.00	w/o N rep	2835	55.6
559	35	36.32	-94.71	73	Clarksville	0.07	18.29	WPAS	0.00	w/o N rep	4068	55.5
987	63	36.32	-94.89	3	Britwater	0.08	18.29	WPAS	0.00	w/o N rep	157	55.4
758	47	36.39	-94.84	159	Clarksville	0.09	24.39	WPAS	0.00	w/o N rep	8805	55.4
31	2	36.43	-94.7	158	Captina	0.04	60.98	WPAS	0.00	w/o N rep	8737	55.3
950	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	0.00	w/o N rep	104	55.3
601	37	36.36	-94.59	34	Peridge	0.06	24.39	WPAS	0.00	w/o N rep	1877	55.3
246	14	36.37	-94.66	40	Clarksville	0.03	91.46	WPAS	1.00	w alum; w/o N rep	2237	55.3
951	60	36.37	-94.81	2	Britwater	0.10	18.29	WPAS	0.00	w/o N rep	119	55.2
810	50	36.27	-94.81	167	Clarksville	0.09	24.39	WPAS	0.00	w/o N rep	9197	55.2
347	19	36.35	-94.92	19	Clarksville	0.06	24.39	WPAS	0.00	w/o N rep	1044	55.2
1040	69	36.35	-95.01	8	Captina	0.06	24.39	WPAS	0.00	w/o N rep	420	55.2
453	27	36.36	-94.8	2	Clarksville	0.13	36.58	WPAS	0.00	w/o N rep	99	55.1
30	2	36.43	-94.7	290	Clarksville	0.04	60.98	WPAS	0.00	w/o N rep	15954	55.1
1023	68	36.33	-94.61	198	Captina	0.05	36.58	WPAS	0.00	w/o N rep	10890	55.0
249	14	36.37	-94.66	74	Newtonia	0.03	91.46	WPAS	0.00	w/o N rep	4080	54.9
939	58	36.35	-94.85	1	Clarksville	0.15	18.29	WPAS	0.00	w/o N rep	42	54.8
532	33	36.35	-94.82	23	Clarksville	0.11	24.39	WPAS	0.00	w/o N rep	1254	54.8
369	21	36.41	-94.51	222	Captina	0.04	60.98	WPAS	0.00	w/o N rep	12175	54.8
1021	68	36.33	-94.61	278	Clarksville	0.05	36.58	WPAS	1.00	w alum; w/o N rep	15241	54.7
642	41	36.33	-94.65	16	Clarksville	0.07	24.39	WPAS	0.00	w/o N rep	878	54.7
1042	69	36.35	-95.01	25	Peridge	0.06	24.39	WPAS	0.00	w/o N rep	1381	54.7
441	25	36.37	-94.87	13	Clarksville	0.11	24.39	WPAS	0.00	w/o N rep	690	54.7
1010	66	36.36	-95.02	10	Parsons	0.07	18.29	WPAS	0.00	w/o N rep	540	54.5
129	7	36.4	-94.31	103	Noark	0.03	91.46	WPAS	0.00	w/o N rep	5628	54.5
678	43	36.36	-94.65	87	Clarksville	0.03	60.98	WPAS	1.00	w alum; w/o N rep	4723	54.5
486	30	36.33	-94.39	110	Clarksville	0.08	36.58	WPAS	2.00	w alum; w/o N rep	5999	54.4
721	45	36.28	-94.67	177	Doniphan	0.03	91.46	WPAS	2.00	w alum; w/o N rep	9625	54.3
113	6	36.38	-94.61	345	Newtonia	0.01	121.95	WPAS	0.00	w/o N rep	18748	54.3
471	29	36.34	-94.36	111	Clarksville	0.06	60.98	WPAS	2.00	w alum; w/o N rep	5995	54.2
790	49	36.37	-94.73	418	Clarksville	0.07	36.58	WPAS	0.00	w/o N rep	22636	54.1
759	47	36.39	-94.84	51	Clarksville	0.09	24.39	WPAS	0.00	w/o N rep	2759	54.1
701	44	36.3	-94.68	48	Britwater	0.04	60.98	WPAS	0.00	w/o N rep	2610	54.1
56	3	36.42	-94.67	186	Captina	0.02	91.46	WPAS	0.00	w/o N rep	10030	54.1
101	5	36.41	-94.63	0	Britwater	0.03	36.58	WPAS	0.00	w/o N rep	10	54.0
548	34	36.33	-94.86	25	Tonti	0.10	24.39	WPAS	0.00	w/o N rep	1354	54.0
307	17	36.41	-94.48	59	Captina	0.06	60.98	WPAS	0.00	w/o N rep	3194	54.0
944	59	36.36	-94.86	4	Clarksville	0.17	18.29	WPAS	0.00	w/o N rep	230	54.0
60	3	36.42	-94.67	176	Peridge	0.02	91.46	WPAS	0.00	w/o N rep	9490	53.9
847	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	0.00	w/o N rep	301	53.9
919	56	36.38	-94.44	0	Britwater	0.08	60.98	WPAS	0.00	w/o N rep	21	53.8
723	45	36.28	-94.67	92	Newtonia	0.03	91.46	WPAS	1.00	w alum; w/o N rep	4947	53.7
146	8	36.37	-94.33	184	Captina	0.03	91.46	WPAS	1.00	w alum; w/o N rep	9874	53.6
996	64	36.37	-94.91	16	Clarksville	0.11	36.58	WPAS	0.00	w/o N rep	835	53.6

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
328	18	36.39	-94.47	83	Captina	0.05	60.98	WPAS	0.00	w/o N rep	4448	53.5
6	1	36.44	-94.67	123	Clarksville	0.07	60.98	WPAS	0.00	w/o N rep	6586	53.4
867	53	36.35	-94.57	48	Peridge	0.07	24.39	WPAS	0.00	w/o N rep	2566	53.4
561	35	36.32	-94.71	50	Doniphan	0.07	18.29	WPAS	1.00	w alum; w/o N rep	2651	53.3
656	42	36.3	-94.65	47	Clarksville	0.05	36.58	WPAS	0.00	w/o N rep	2500	53.3
126	7	36.4	-94.31	299	Captina	0.03	91.46	WPAS	1.00	w alum; w/o N rep	15932	53.3
886	54	36.42	-94.62	93	Newtonia	0.02	91.46	WPAS	1.00	w alum; w/o N rep	4933	53.2
220	13	36.41	-94.66	325	Clarksville	0.05	60.98	WPAS	1.00	w alum; w/o N rep	17238	53.1
442	25	36.37	-94.87	2	Britwater	0.11	24.39	WPAS	0.00	w/o N rep	116	53.1
83	4	36.4	-94.57	377	Newtonia	0.02	121.95	WPAS	1.00	w alum; w/o N rep	20002	53.0
679	43	36.36	-94.65	77	Clarksville	0.03	60.98	WPAS	0.00	w/o N rep	4095	53.0
681	43	36.36	-94.65	207	Newtonia	0.03	60.98	WPAS	0.00	w/o N rep	10952	52.8
940	58	36.35	-94.85	0	Britwater	0.15	18.29	WPAS	0.00	w/o N rep	25	52.8
422	24	36.34	-94.49	126	Captina	0.05	60.98	WPAS	0.00	w/o N rep	6653	52.7
424	24	36.34	-94.49	234	Peridge	0.05	60.98	WPAS	0.00	w/o N rep	12336	52.7
184	10	36.37	-94.41	63	Clarksville	0.06	60.98	WPAS	2.00	w alum; w/o N rep	3321	52.7
970	62	36.33	-94.8	47	Doniphan	0.05	36.58	WPAS	1.00	w alum; w/o N rep	2458	52.7
348	19	36.35	-94.92	12	Doniphan	0.06	24.39	WPAS	0.00	w/o N rep	643	52.7
884	54	36.42	-94.62	31	Clarksville	0.02	91.46	WPAS	1.00	w alum; w/o N rep	1651	52.5
899	55	36.27	-94.74	347	Clarksville	0.06	60.98	WPAS	1.00	w alum; w/o N rep	18245	52.5
454	27	36.36	-94.8	1	Britwater	0.13	36.58	WPAS	0.00	w/o N rep	52	52.5
1007	66	36.36	-95.02	19	Clarksville	0.07	18.29	WPAS	1.00	w alum; w/o N rep	976	52.5
7	1	36.44	-94.67	49	Captina	0.07	60.98	WPAS	0.00	w/o N rep	2588	52.5
657	42	36.3	-94.65	53	Britwater	0.05	36.58	WPAS	0.00	w/o N rep	2763	52.5
791	49	36.37	-94.73	151	Clarksville	0.07	36.58	WPAS	0.00	w/o N rep	7916	52.3
620	38	36.32	-94.53	454	Captina	0.05	60.98	WPAS	0.00	w/o N rep	23735	52.3
533	33	36.35	-94.82	4	Britwater	0.11	24.39	WPAS	0.00	w/o N rep	229	52.3
658	42	36.3	-94.65	50	Doniphan	0.05	36.58	WPAS	2.00	w alum; w/o N rep	2588	52.2
774	48	36.4	-94.79	247	Clarksville	0.11	24.39	WPAS	0.00	w/o N rep	12895	52.2
643	41	36.33	-94.65	97	Britwater	0.07	24.39	WPAS	1.00	w alum; w/o N rep	5084	52.2
775	48	36.4	-94.79	51	Clarksville	0.11	24.39	WPAS	0.00	w/o N rep	2652	52.0
306	17	36.41	-94.48	50	Clarksville	0.06	60.98	WPAS	1.00	w alum; w/o N rep	2589	52.0
362	20	36.36	-94.89	122	Clarksville	0.16	24.39	WPAS	1.00	w alum; w/o N rep	6341	52.0
599	37	36.36	-94.59	36	Clarksville	0.06	24.39	WPAS	1.00	w alum; w/o N rep	1892	52.0
864	53	36.35	-94.57	25	Clarksville	0.07	24.39	WPAS	1.00	w alum; w/o N rep	1295	51.9
694	43	36.36	-94.65	99	Taloka	0.01	60.98	WWHT	0.00	w N rep	5122	51.9
928	57	36.39	-94.94	114	Britwater	0.09	18.29	WPAS	0.00	w/o N rep	5897	51.9
900	55	36.27	-94.74	586	Doniphan	0.06	60.98	WPAS	1.00	w alum; w/o N rep	30409	51.9
885	54	36.42	-94.62	23	Britwater	0.02	91.46	WPAS	0.00	w/o N rep	1191	51.8
221	13	36.41	-94.66	164	Clarksville	0.05	60.98	WPAS	0.00	w/o N rep	8520	51.8
421	24	36.34	-94.49	171	Clarksville	0.05	60.98	WPAS	1.00	w alum; w/o N rep	8849	51.7
327	18	36.39	-94.47	65	Clarksville	0.05	60.98	WPAS	1.00	w alum; w/o N rep	3337	51.7
58	3	36.42	-94.67	256	Newtonia	0.02	91.46	WPAS	1.00	w alum; w/o N rep	13243	51.6
186	10	36.37	-94.41	77	Secesh	0.06	60.98	WPAS	1.00	w/o N rep	3960	51.5
1024	68	36.33	-94.61	198	Doniphan	0.05	36.58	WPAS	1.00	w/o N rep	10165	51.4
1017	67	36.37	-94.98	28	Clarksville	0.13	15.24	WPAS	1.00	w alum; w/o N rep	1416	51.4
619	38	36.32	-94.53	233	Clarksville	0.05	60.98	WPAS	1.00	w alum; w/o N rep	11936	51.3
287	16	36.35	-94.44	195	Clarksville	0.07	60.98	WPAS	1.00	w alum; w/o N rep	10025	51.3
32	2	36.43	-94.7	186	Doniphan	0.04	60.98	WPAS	1.00	w alum; w/o N rep	9508	51.2
387	22	36.37	-94.51	172	Captina	0.06	36.58	WPAS	0.00	w/o N rep	8737	50.9
927	57	36.39	-94.94	48	Clarksville	0.09	18.29	WPAS	1.00	w alum; w/o N rep	2417	50.8
997	64	36.37	-94.91	17	Britwater	0.11	36.58	WPAS	0.00	w/o N rep	842	50.8
1022	68	36.33	-94.61	216	Clarksville	0.05	36.58	WPAS	1.00	w alum; w/o N rep	10959	50.7
1041	69	36.35	-95.01	16	Britwater	0.06	24.39	WPAS	0.00	w/o N rep	814	50.7
57	3	36.42	-94.67	366	Jay	0.02	91.46	WPAS	0.00	w/o N rep	18515	50.7
1039	69	36.35	-95.01	13	Clarksville	0.06	24.39	WPAS	0.00	w/o N rep	634	50.6
562	35	36.32	-94.71	73	Macedonia	0.07	18.29	WPAS	0.00	w/o N rep	3698	50.6
204	11	36.4	-94.99	35	Clarksville	0.10	24.39	WPAS	1.00	w alum; w/o N rep	1766	50.5
386	22	36.37	-94.51	202	Clarksville	0.06	36.58	WPAS	1.00	w alum; w/o N rep	10168	50.5
865	53	36.35	-94.57	45	Britwater	0.07	24.39	WPAS	1.00	w alum; w/o N rep	2260	49.8
222	13	36.41	-94.66	152	Newtonia	0.05	60.98	WPAS	0.00	w/o N rep	7568	49.7
8	1	36.44	-94.67	44	Doniphan	0.07	60.98	WPAS	1.00	w alum; w/o N rep	2168	49.5
247	14	36.37	-94.66	95	Macedonia	0.03	91.46	WPAS	0.00	w/o N rep	4576	48.4
25	1	36.44	-94.67	5	Taloka	0.05	60.98	WWHT	0.00	w N rep	247	48.3
1008	66	36.36	-95.02	26	Clarksville	0.07	18.29	WPAS	1.00	w alum; w/o N rep	1247	48.0
406	23	36.36	-94.55	7	Nixa	0.05	24.39	WPAS	0.00	w/o N rep	311	47.5
289	16	36.35	-94.44	271	Peridge	0.07	60.98	WPAS	0.00	w/o N rep	12790	47.3

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
379	21	36.41	-94.51	7	Captina	0.03	60.98	WWHT	0.00	w N rep	337	47.2
95	4	36.4	-94.57	13	Captina	0.02	121.95	WWHT	0.00	w N rep	607	46.9
722	45	36.28	-94.67	100	Macedonia	0.03	91.46	WPAS	1.00	w alum; w/o N rep	4688	46.7
370	21	36.41	-94.51	152	Nixa	0.04	60.98	WPAS	0.00	w/o N rep	7093	46.7
283	15	34.4	-94.44	13	Peridge	0.04	60.98	WWHT	0.00	w N rep	618	46.2
702	44	36.3	-94.68	63	Macedonia	0.04	60.98	WPAS	1.00	w alum; w/o N rep	2890	46.1
680	43	36.36	-94.65	107	Macedonia	0.03	60.98	WPAS	0.00	w/o N rep	4897	45.9
267	15	34.4	-94.44	110	Nixa	0.05	60.98	WPAS	0.00	w/o N rep	5013	45.6
329	18	36.39	-94.47	89	Nixa	0.05	60.98	WPAS	0.00	w/o N rep	4075	45.6
308	17	36.41	-94.48	109	Nixa	0.06	60.98	WPAS	0.00	w/o N rep	4954	45.3
166	9	36.4	-94.37	728	Nixa	0.05	60.98	WPAS	0.00	w/o N rep	32805	45.1
621	38	36.32	-94.53	314	Nixa	0.05	60.98	WPAS	0.00	w/o N rep	14125	45.0
423	24	36.34	-94.49	480	Nixa	0.05	60.98	WPAS	0.00	w/o N rep	21479	44.8
388	22	36.37	-94.51	201	Nixa	0.06	36.58	WPAS	0.00	w/o N rep	8988	44.7
185	10	36.37	-94.41	123	Nixa	0.06	60.98	WPAS	0.00	w/o N rep	5486	44.5
24	1	36.44	-94.67	12	Captina	0.05	60.98	WWHT	0.00	w N rep	547	44.1
487	30	36.33	-94.39	274	Nixa	0.08	36.58	WPAS	0.00	w/o N rep	12078	44.0
659	42	36.3	-94.65	56	Macedonia	0.05	36.58	WPAS	1.00	w alum; w/o N rep	2483	44.0
72	3	36.42	-94.67	23	Jay	0.02	91.46	WWHT	0.00	w N rep	1007	44.0
127	7	36.4	-94.31	155	Nixa	0.03	91.46	WPAS	0.00	w/o N rep	6807	43.8
288	16	36.35	-94.44	317	Nixa	0.07	60.98	WPAS	0.00	w/o N rep	13859	43.8
147	8	36.37	-94.33	131	Nixa	0.03	91.46	WPAS	0.00	w/o N rep	5707	43.6
918	56	36.38	-94.44	1	Clarksville	0.08	60.98	WPAS	0.00	w/o N rep	26	43.3
84	4	36.4	-94.57	174	Nixa	0.02	121.95	WPAS	0.00	w/o N rep	7514	43.1
102	5	36.41	-94.63	0	Razort	0.03	36.58	OPAS	0.00	w/o N rep	4	42.9
112	6	36.38	-94.61	227	Taloka	0.01	121.95	WPAS	0.00	w/o N rep	9671	42.6
59	3	36.42	-94.67	324	Nixa	0.02	91.46	WPAS	0.00	w/o N rep	13801	42.6
792	49	36.37	-94.73	230	Macedonia	0.07	36.58	WPAS	0.00	w/o N rep	9721	42.3
472	29	36.34	-94.36	384	Nixa	0.06	60.98	WPAS	0.00	w/o N rep	16006	41.7
1009	66	36.36	-95.02	35	Nixa	0.07	18.29	WPAS	1.00	w alum; w/o N rep	1408	40.6
33	2	36.43	-94.7	184	Taloka	0.04	60.98	WPAS	0.00	w/o N rep	7209	39.1
743	46	36.29	-94.61	469	Taloka	0.03	60.98	WPAS	1.00	w alum; w/o N rep	17959	38.3
82	4	36.4	-94.57	292	Taloka	0.02	121.95	WPAS	0.00	w/o N rep	10865	37.2
299	16	36.35	-94.44	12	Captina	0.05	60.98	WWHT	0.00	w N rep	421	36.4
340	18	36.39	-94.47	10	Captina	0.03	60.98	WWHT	0.00	w N rep	345	35.7
912	55	36.27	-94.74	40	Britwater	0.04	60.98	WWHT	0.00	w N rep	1356	34.2
831	51	36.35	-94.75	1	Elsah	0.06	15.24	OPAS	0.00	w/o N rep	27	29.8
588	36	36.34	-94.76	2	Elsah	0.05	60.98	OPAS	0.00	w/o N rep	59	29.0
515	32	36.35	-94.77	3	Clarksville	0.05	18.29	OPAS	0.00	w/o N rep	92	28.1
501	31	36.36	-94.78	2	Clarksville	0.05	24.39	OPAS	0.00	w/o N rep	64	26.2
972	62	36.33	-94.8	35	Clarksville	0.05	36.58	OPAS	0.00	w/o N rep	882	25.5
565	35	36.32	-94.71	14	Clarksville	0.07	18.29	OPAS	0.00	w/o N rep	361	25.4
953	60	36.37	-94.81	0	Clarksville	0.10	18.29	OPAS	0.00	w/o N rep	10	24.4
929	57	36.39	-94.94	4	Razort	0.09	18.29	OPAS	0.00	w/o N rep	91	24.0
984	62	36.33	-94.8	17	Jay	0.03	36.58	WWHT	0.00	w N rep	381	22.9
830	51	36.35	-94.75	0	Razort	0.06	15.24	OPAS	0.00	w/o N rep	8	21.2
206	11	36.4	-94.99	3	Razort	0.10	24.39	OPAS	0.00	w/o N rep	55	19.2
761	47	36.39	-94.84	18	Clarksville	0.09	24.39	OPAS	0.00	w/o N rep	344	19.0
812	50	36.27	-94.81	100	Clarksville	0.09	24.39	OPAS	0.00	w/o N rep	1850	18.6
514	32	36.35	-94.77	9	Clarksville	0.05	18.29	OPAS	0.00	w/o N rep	161	18.1
973	62	36.33	-94.8	45	Doniphan	0.05	36.58	OPAS	0.00	w/o N rep	795	17.6
602	37	36.36	-94.59	4	Clarksville	0.06	24.39	OPAS	0.00	w/o N rep	63	17.5
645	41	36.33	-94.65	5	Clarksville	0.07	24.39	OPAS	0.00	w/o N rep	93	17.1
567	35	36.32	-94.71	19	Doniphan	0.07	18.29	OPAS	0.00	w/o N rep	317	17.1
682	43	36.36	-94.65	85	Clarksville	0.03	60.98	OPAS	0.00	w/o N rep	1402	16.5
1028	68	36.33	-94.61	23	Tonti	0.05	36.58	OPAS	3.23		359	15.7
660	42	36.3	-94.65	10	Clarksville	0.05	36.58	OPAS	0.00	w/o N rep	156	15.3
482	29	36.34	-94.36	28	Nixa	0.06	60.98	WWHT	0.00	w N rep	418	15.1
911	55	36.27	-94.74	31	Captina	0.04	60.98	WWHT	0.00	w N rep	454	14.8
563	35	36.32	-94.71	23	Razort	0.07	18.29	OPAS	0.00	w/o N rep	332	14.5
88	4	36.4	-94.57	34	Nixa	0.02	121.95	OPAS	0.00	w/o N rep	482	14.3
930	57	36.39	-94.94	4	Clarksville	0.09	18.29	OPAS	0.00	w/o N rep	54	14.2
250	14	36.37	-94.66	33	Doniphan	0.03	91.46	OPAS	0.00	w/o N rep	466	14.1
1025	68	36.33	-94.61	39	Clarksville	0.05	36.58	OPAS	0.00	w/o N rep	545	13.9
262	14	36.37	-94.66	19	Newtonia	0.02	91.46	WWHT	0.00	w N rep	261	13.6
870	53	36.35	-94.57	6	Waben	0.07	24.39	OPAS	0.00	w/o N rep	83	13.6
605	37	36.36	-94.59	3	Nixa	0.06	24.39	OPAS	0.00	w/o N rep	46	13.4

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
131	7	36.4	-94.31	18	Nixa	0.03	91.46	OPAS	0.00	w/o N rep	236	13.0
150	8	36.37	-94.33	24	Nixa	0.03	91.46	OPAS	0.00	w/o N rep	303	12.9
322	17	36.41	-94.48	4	Captina	0.04	60.98	WWHT	0.00	w N rep	50	12.4
500	31	36.36	-94.78	7	Clarksville	0.05	24.39	OPAS	0.00	w/o N rep	84	12.2
794	49	36.37	-94.73	51	Clarksville	0.07	36.58	OPAS	0.00	w/o N rep	616	12.1
971	62	36.33	-94.8	19	Clarksville	0.05	36.58	OPAS	0.00	w/o N rep	221	11.8
1044	69	36.35	-95.01	4	Nixa	0.06	24.39	OPAS	0.00	w/o N rep	52	11.7
10	1	36.44	-94.67	38	Clarksville	0.07	60.98	OPAS	0.00	w/o N rep	443	11.7
272	15	34.4	-94.44	73	Tonti	0.05	60.98	OPAS	3.23		821	11.2
564	35	36.32	-94.71	30	Clarksville	0.07	18.29	OPAS	3.23	w alum;	325	11.0
314	17	36.41	-94.48	18	Noark	0.06	60.98	OPAS	0.00	w/o N rep	184	10.2
63	3	36.42	-94.67	88	Nixa	0.02	91.46	OPAS	0.00	w/o N rep	898	10.2
190	10	36.37	-94.41	9	Tonti	0.06	60.98	OPAS	3.23		95	10.0
225	13	36.41	-94.66	62	Clarksville	0.05	60.98	OPAS	0.00	w/o N rep	609	9.8
632	38	36.32	-94.53	80	Captina	0.03	60.98	WWHT	0.00	w N rep	746	9.3
373	21	36.41	-94.51	48	Nixa	0.04	60.98	OPAS	0.00	w/o N rep	386	8.0
868	53	36.35	-94.57	8	Clarksville	0.07	24.39	OPAS	0.00	w/o N rep	65	8.0
762	47	36.39	-94.84	6	Doniphan	0.09	24.39	OPAS	0.00	w/o N rep	45	7.0
313	17	36.41	-94.48	37	Tonti	0.06	60.98	OPAS	3.23		231	6.3
724	45	36.28	-94.67	75	Doniphan	0.03	91.46	OPAS	0.00	w/o N rep	458	6.1
474	29	36.34	-94.36	12	Clarksville	0.06	60.98	OPAS	0.00	w/o N rep	72	6.0
271	15	34.4	-94.44	22	Nixa	0.05	60.98	OPAS	0.00	w/o N rep	120	5.4
923	56	36.38	-94.44	0	Clarksville	0.08	60.98	HAY	0.00	w/o N rep	1	5.2
813	50	36.27	-94.81	86	Doniphan	0.09	24.39	OPAS	0.00	w/o N rep	396	4.6
517	32	36.35	-94.77	4	Healing	0.05	18.29	OPAS	3.23		16	4.0
778	48	36.4	-94.79	56	Clarksville	0.11	24.39	OPAS	0.00	w/o N rep	204	3.7
410	23	36.36	-94.55	10	Peridge	0.05	24.39	OPAS	3.23		34	3.5
332	18	36.39	-94.47	23	Nixa	0.05	60.98	OPAS	0.00	w/o N rep	74	3.3
952	60	36.37	-94.81	2	Clarksville	0.10	18.29	OPAS	0.00	w/o N rep	6	3.2
624	38	36.32	-94.53	45	Nixa	0.05	60.98	OPAS	0.00	w/o N rep	131	2.9
37	2	36.43	-94.7	154	Doniphan	0.04	60.98	OPAS	0.00	w/o N rep	440	2.9
902	55	36.27	-94.74	499	Doniphan	0.06	60.98	OPAS	0.00	w/o N rep	1019	2.0
390	22	36.37	-94.51	18	Nixa	0.06	36.58	OPAS	0.00	w/o N rep	33	1.8
130	7	36.4	-94.31	55	Captina	0.03	91.46	OPAS	3.23		97	1.8
312	17	36.41	-94.48	22	Nixa	0.06	60.98	OPAS	0.00	w/o N rep	37	1.7
606	37	36.36	-94.59	6	Peridge	0.06	24.39	OPAS	3.23		5	0.9
207	11	36.4	-94.99	20	Clarksville	0.10	24.39	OPAS	0.00	w/o N rep	-2	-0.1
745	46	36.29	-94.61	75	Captina	0.03	60.98	OPAS	3.23		-77	-1.0
149	8	36.37	-94.33	65	Captina	0.03	91.46	OPAS	3.23		-83	-1.3
280	15	34.4	-94.44	14	Captina	0.04	60.98	WWHT	0.00	w N rep	-22	-1.5
488	30	36.33	-94.39	4	Clarksville	0.08	36.58	OPAS	0.00	w/o N rep	-6	-1.6
901	55	36.27	-94.74	133	Clarksville	0.06	60.98	OPAS	0.00	w/o N rep	-245	-1.8
1027	68	36.33	-94.61	29	Doniphan	0.05	36.58	OPAS	0.00	w/o N rep	-56	-1.9
409	23	36.36	-94.55	5	Captina	0.05	24.39	OPAS	3.23		-11	-2.0
170	9	36.4	-94.37	149	Nixa	0.05	60.98	OPAS	0.00	w/o N rep	-308	-2.1
848	52	36.32	-94.68	5	Clarksville	0.10	24.39	OPAS	0.00	w/o N rep	-11	-2.5
661	42	36.3	-94.65	28	Doniphan	0.05	36.58	OPAS	0.00	w/o N rep	-70	-2.6
426	24	36.34	-94.49	78	Nixa	0.05	60.98	OPAS	0.00	w/o N rep	-206	-2.6
744	46	36.29	-94.61	36	Clarksville	0.03	60.98	OPAS	0.00	w/o N rep	-99	-2.8
132	7	36.4	-94.31	21	Tonti	0.03	91.46	OPAS	2.58	w alum;	-85	-4.0
475	29	36.34	-94.36	68	Nixa	0.06	60.98	OPAS	0.00	w/o N rep	-276	-4.0
189	10	36.37	-94.41	33	Nixa	0.06	60.98	OPAS	0.00	w/o N rep	-151	-4.6
223	13	36.41	-94.66	71	Razort	0.05	60.98	OPAS	0.00	w/o N rep	-341	-4.8
34	2	36.43	-94.7	159	Clarksville	0.04	60.98	OPAS	0.00	w/o N rep	-916	-5.8
12	1	36.44	-94.67	23	Doniphan	0.07	60.98	OPAS	0.00	w/o N rep	-177	-7.6
760	47	36.39	-94.84	30	Clarksville	0.09	24.39	OPAS	0.00	w/o N rep	-268	-8.9
796	49	36.37	-94.73	41	Doniphan	0.07	36.58	OPAS	0.00	w/o N rep	-367	-8.9
871	53	36.35	-94.57	7	Peridge	0.07	24.39	OPAS	3.23		-59	-9.0
603	37	36.36	-94.59	11	Captina	0.06	24.39	OPAS	3.23		-97	-9.2
490	30	36.33	-94.39	9	Nixa	0.08	36.58	OPAS	0.00	w/o N rep	-90	-9.6
240	13	36.41	-94.66	62	Newtonia	0.03	60.98	WWHT	0.00	w N rep	-602	-9.7
151	8	36.37	-94.33	32	Tonti	0.03	91.46	OPAS	0.00	w/o N rep	-317	-10.0
811	50	36.27	-94.81	192	Clarksville	0.09	24.39	OPAS	0.00	w/o N rep	-2105	-11.0
1045	69	36.35	-95.01	3	Peridge	0.06	24.39	OPAS	3.23		-38	-11.0
644	41	36.33	-94.65	7	Clarksville	0.07	24.39	OPAS	0.00	w/o N rep	-84	-11.5
535	33	36.35	-94.82	9	Clarksville	0.11	24.39	OPAS	0.00	w/o N rep	-106	-11.8
226	13	36.41	-94.66	59	Doniphan	0.05	60.98	OPAS	0.00	w/o N rep	-747	-12.6

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
516	32	36.35	-94.77	7	Britwater	0.05	18.29	OPAS	0.00	w/o N rep	-96	-13.4
646	41	36.33	-94.65	3	Captina	0.07	24.39	OPAS	3.23		-39	-13.8
290	16	36.35	-94.44	53	Nixa	0.07	60.98	OPAS	0.00	w/o N rep	-746	-14.1
333	18	36.39	-94.47	38	Tonti	0.05	60.98	OPAS	3.23	w alum;	-565	-14.9
1026	68	36.33	-94.61	33	Captina	0.05	36.58	OPAS	3.23		-488	-15.0
372	21	36.41	-94.51	59	Captina	0.04	60.98	OPAS	3.23		-909	-15.4
350	19	36.35	-94.92	22	Tonti	0.06	24.39	OPAS	0.00	w/o N rep	-355	-16.3
776	48	36.4	-94.79	23	Razort	0.11	24.39	OPAS	0.00	w/o N rep	-376	-16.4
625	38	36.32	-94.53	60	Tonti	0.05	60.98	OPAS	3.23		-1005	-16.7
703	44	36.3	-94.68	17	Captina	0.04	60.98	OPAS	3.23		-283	-17.2
924	56	36.38	-94.44	1	Britwater	0.08	60.98	HAY	0.00	w/o N rep	-12	-17.2
437	24	36.34	-94.49	31	Peridge	0.04	60.98	WWHT	0.00	w N rep	-618	-19.9
64	3	36.42	-94.67	44	Peridge	0.02	91.46	OPAS	3.23		-893	-20.2
1043	69	36.35	-95.01	7	Captina	0.06	24.39	OPAS	3.23		-137	-20.7
807	49	36.37	-94.73	17	Macedonia	0.06	36.58	WWHT	0.00	w N rep	-345	-20.7
428	24	36.34	-94.49	28	Peridge	0.05	60.98	OPAS	3.23		-585	-20.9
270	15	34.4	-94.44	48	Captina	0.05	60.98	OPAS	3.23		-1013	-20.9
392	22	36.37	-94.51	14	Peridge	0.06	36.58	OPAS	3.23		-296	-21.0
198	10	36.37	-94.41	5	Britwater	0.06	60.98	WWHT	0.00	w N rep	-97	-21.2
363	20	36.36	-94.89	6	Razort	0.16	24.39	OPAS	3.23		-142	-22.2
115	6	36.38	-94.61	125	Newtonia	0.01	121.95	OPAS	3.23	w alum;	-2789	-22.2
311	17	36.41	-94.48	12	Captina	0.06	60.98	OPAS	3.23		-276	-23.4
9	1	36.44	-94.67	56	Clarksville	0.07	60.98	OPAS	0.00	w/o N rep	-1385	-24.5
793	49	36.37	-94.73	82	Clarksville	0.07	36.58	OPAS	0.00	w/o N rep	-2020	-24.6
224	13	36.41	-94.66	50	Clarksville	0.05	60.98	OPAS	0.00	w/o N rep	-1277	-25.7
191	10	36.37	-94.41	17	Peridge	0.06	60.98	OPAS	3.23		-446	-26.0
331	18	36.39	-94.47	51	Captina	0.05	60.98	OPAS	3.23		-1368	-26.9
849	52	36.32	-94.68	6	Britwater	0.10	24.39	OPAS	0.00	w N rep	-167	-30.2
391	22	36.37	-94.51	18	Tonti	0.06	36.58	OPAS	3.23	w alum;	-561	-30.4
746	46	36.29	-94.61	30	Tonti	0.03	60.98	OPAS	0.00	w/o N rep	-942	-31.2
85	4	36.4	-94.57	46	Captina	0.02	121.95	OPAS	3.23		-1450	-31.3
169	9	36.4	-94.37	61	Captina	0.05	60.98	OPAS	3.23		-1957	-32.3
954	60	36.37	-94.81	0	Water	0.10	18.29	OPAS	0.00	w/o N rep	-13	-32.7
538	33	36.35	-94.82	5	Water	0.11	24.39	OPAS	0.00	w/o N rep	-158	-32.7
587	36	36.34	-94.76	5	Britwater	0.05	60.98	OPAS	0.00	w/o N rep	-165	-33.8
543	33	36.35	-94.82	6	Water	0.11	24.39	HAY	0.00	w/o N rep	-232	-37.7
446	25	36.37	-94.87	2	Water	0.11	24.39	HAY	0.00	w/o N rep	-60	-37.7
1003	64	36.37	-94.91	2	Water	0.11	36.58	HAY	0.00	w/o N rep	-86	-37.8
925	56	36.38	-94.44	0	Water	0.08	60.98	HAY	0.00	w/o N rep	-7	-37.8
443	25	36.37	-94.87	4	Water	0.11	24.39	WPAS	0.00	w/o N rep	-168	-38.6
205	11	36.4	-94.99	24	Water	0.10	24.39	WPAS	0.00	w/o N rep	-940	-38.6
534	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0.00	w/o N rep	-188	-38.6
455	27	36.36	-94.8	2	Water	0.13	36.58	WPAS	0.00	w/o N rep	-76	-38.6
566	35	36.32	-94.71	20	Britwater	0.07	18.29	OPAS	0.00	w/o N rep	-783	-39.5
171	9	36.4	-94.37	82	Tonti	0.05	60.98	OPAS	3.23	w alum;	-3238	-39.5
364	20	36.36	-94.89	36	Clarksville	0.16	24.39	OPAS	0.00	w/o N rep	-1461	-40.3
777	48	36.4	-94.79	82	Clarksville	0.11	24.39	OPAS	0.00	w/o N rep	-3406	-41.8
623	38	36.32	-94.53	128	Captina	0.05	60.98	OPAS	3.23		-5385	-42.1
425	24	36.34	-94.49	46	Captina	0.05	60.98	OPAS	3.23		-1984	-43.0
931	57	36.39	-94.94	27	Britwater	0.09	18.29	OPAS	0.00	w/o N rep	-1158	-43.2
489	30	36.33	-94.39	4	Captina	0.08	36.58	OPAS	3.23		-181	-44.1
568	35	36.32	-94.71	19	Macedonia	0.07	18.29	OPAS	0.00	w/o N rep	-852	-44.3
389	22	36.37	-94.51	51	Captina	0.06	36.58	OPAS	3.23		-2275	-44.5
251	14	36.37	-94.66	42	Macedonia	0.03	91.46	OPAS	0.00	w N rep	-2013	-47.8
252	14	36.37	-94.66	71	Newtonia	0.03	91.46	OPAS	0.00	w N rep	-3382	-47.9
87	4	36.4	-94.57	56	Newtonia	0.02	121.95	OPAS	3.23	w alum;	-3000	-53.3
261	14	36.37	-94.66	48	Macedonia	0.02	91.46	WWHT	0.00	w N rep	-2586	-53.4
880	53	36.35	-94.57	8	Nixa	0.12	24.39	WWHT	0.00	w N rep	-437	-54.8
291	16	36.35	-94.44	80	Peridge	0.07	60.98	OPAS	3.23		-4490	-55.9
887	54	36.42	-94.62	45	Newtonia	0.02	91.46	OPAS	0.00	w N rep	-2532	-56.8
38	2	36.43	-94.7	112	Macedonia	0.04	60.98	OPAS	0.00	w N rep	-6677	-59.8
725	45	36.28	-94.67	59	Macedonia	0.03	91.46	OPAS	0.00	w N rep	-3641	-61.4
684	43	36.36	-94.65	61	Newtonia	0.03	60.98	OPAS	0.00	w N rep	-3878	-63.9
47	2	36.43	-94.7	58	Captina	0.03	60.98	WWHT	0.00	w N rep	-3730	-64.0
683	43	36.36	-94.65	94	Macedonia	0.03	60.98	OPAS	0.00	w N rep	-6108	-65.3
62	3	36.42	-94.67	61	Newtonia	0.02	91.46	OPAS	0.00	w N rep	-4024	-66.5
241	13	36.41	-94.66	25	Clarksville	0.03	60.98	WWHT	0.00	w N rep	-1694	-67.7

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price	Per hectare shadow price ($/ha.)
705	44	36.3	-94.68	20	Macedonia	0.04	60.98	OPAS	0.00	w N rep	-1330	-68.2
114	6	36.38	-94.61	30	Taloka	0.01	121.95	OPAS	0.00	w N rep	-2047	-69.2
536	33	36.35	-94.82	3	Britwater	0.11	24.39	OPAS	0.00	w N rep	-236	-69.4
35	2	36.43	-94.7	136	Captina	0.04	60.98	OPAS	0.00	w N rep	-9608	-70.6
86	4	36.4	-94.57	30	Jay	0.02	121.95	OPAS	0.00	w N rep	-2156	-71.4
662	42	36.3	-94.65	23	Macedonia	0.05	36.58	OPAS	0.00	w N rep	-1783	-75.9
427	24	36.34	-94.49	28	Secesh	0.05	60.98	OPAS	0.00	w N rep	-2162	-76.5
61	3	36.42	-94.67	48	Captina	0.02	91.46	OPAS	0.00	w N rep	-3753	-77.6
974	62	36.33	-94.8	18	Jay	0.05	36.58	OPAS	0.00	w N rep	-1436	-78.5
13	1	36.44	-94.67	28	Macedonia	0.07	60.98	OPAS	0.00	w N rep	-2269	-80.3
797	49	36.37	-94.73	80	Macedonia	0.07	36.58	OPAS	0.00	w N rep	-6556	-82.1
869	53	36.35	-94.57	4	Britwater	0.07	24.39	OPAS	0.00	w N rep	-306	-85.1
227	13	36.41	-94.66	96	Newtonia	0.05	60.98	OPAS	0.00	w N rep	-8486	-88.6
11	1	36.44	-94.67	37	Captina	0.07	60.98	OPAS	0.00	w N rep	-3598	-98.1
188	10	36.37	-94.41	11	Britwater	0.06	60.98	OPAS	0.00	w N rep	-1134	-100.8
36	2	36.43	-94.7	91	Taloka	0.04	60.98	OPAS	0.00	w N rep	-9381	-103.3
49	2	36.43	-94.7	39	Taloka	0.03	60.98	WWHT	0.00	w N rep	-4089	-105.5
435	24	36.34	-94.49	52	Captina	0.04	60.98	WWHT	0.00	w N rep	-5554	-106.9
747	46	36.29	-94.61	37	Taloka	0.03	60.98	OPAS	0.00	w N rep	-4029	-109.4
704	44	36.3	-94.68	18	Taloka	0.04	60.98	OPAS	0.00	w N rep	-1949	-110.2
673	42	36.3	-94.65	13	Macedonia	0.05	36.58	WWHT	0.00	w N rep	-1414	-112.6
604	37	36.36	-94.59	4	Taloka	0.06	24.39	OPAS	0.00	w N rep	-441	-115.1
537	33	36.35	-94.82	2	Taloka	0.11	24.39	OPAS	0.00	w N rep	-309	-125.8
717	44	36.3	-94.68	3	Macedonia	0.08	60.98	WWHT	0.00	w N rep	-364	-143.5
795	49	36.37	-94.73	45	Taloka	0.07	36.58	OPAS	0.00	w N rep	-6565	-145.4
805	49	36.37	-94.73	12	Taloka	0.06	36.58	WWHT	0.00	w N rep	-2418	-198.2

Table A 8. Spatial Detail for the Optimal Solution for Policy 2 (Litter applied if STP<120).

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
835	51	36.35	-94.75	1	Razort	0.01	15.24	WWHT	1.95		498	345.7
523	32	36.35	-94.77	6	Razort	0.03	18.29	WWHT	1.95		2168	343.5
593	36	36.34	-94.76	2	Razort	0.02	60.98	WWHT	1.95		837	340.8
577	35	36.32	-94.71	6	Razort	0.04	18.29	WWHT	1.95		2097	339.4
821	50	36.27	-94.81	15	Razort	0.09	24.39	WWHT	1.95		4998	331.3
854	52	36.32	-94.68	1	Razort	0.10	24.39	HAY	6		368	318.2
572	35	36.32	-94.71	41	Razort	0.07	18.29	HAY	6		12872	316.3
507	31	36.36	-94.78	5	Healing	0.05	24.39	HAY	6		1521	313.0
504	31	36.36	-94.78	3	Razort	0.05	24.39	HAY	6		815	310.3
834	51	36.35	-94.75	1	Razort	0.06	15.24	HAY	6		333	309.0
592	36	36.34	-94.76	3	Razort	0.05	60.98	HAY	6		814	308.8
766	47	36.39	-94.84	26	Razort	0.09	24.39	HAY	6		7900	308.6
907	55	36.27	-94.74	348	Clarksville	0.06	60.98	HAY	6		107200	307.7
856	52	36.32	-94.68	2	Britwater	0.10	24.39	HAY	6		532	307.3
367	20	36.36	-94.89	14	Razort	0.16	24.39	HAY	6		4233	307.0
817	50	36.27	-94.81	118	Razort	0.09	24.39	HAY	6		36237	306.9
522	32	36.35	-94.77	22	Healing	0.05	18.29	HAY	6		6693	305.6
909	55	36.27	-94.74	808	Doniphan	0.06	60.98	HAY	6		246500	305.1
520	32	36.35	-94.77	5	Razort	0.05	18.29	HAY	6		1629	303.1
459	27	36.36	-94.8	1	Britwater	0.13	36.58	HAY	6		326	303.1
990	63	36.32	-94.89	4	Razort	0.08	18.29	HAY	6		1109	302.7
576	35	36.32	-94.71	56	Macedonia	0.07	18.29	HAY	6		16800	300.9
857	52	36.32	-94.68	2	Doniphan	0.10	24.39	HAY	6		547	300.2
575	35	36.32	-94.71	38	Doniphan	0.07	18.29	HAY	6		11383	298.6
573	35	36.32	-94.71	87	Clarksville	0.07	18.29	HAY	6		25836	298.2
837	51	36.35	-94.75	1	Elsah	0.01	15.24	WWHT	1.95		428	297.7
595	36	36.34	-94.76	6	Elsah	0.02	60.98	WWHT	1.95		1814	297.4
1000	64	36.37	-94.91	6	Razort	0.11	36.58	HAY	6		1648	296.6
162	8	36.37	-94.33	21	Tonti	0.02	91.46	WWHT	0	w N rep	6097	295.0
354	19	36.35	-94.92	7	Razort	0.06	24.39	HAY	6		2210	294.8
908	55	36.27	-94.74	228	Clarksville	0.06	60.98	HAY	6		67175	294.8
468	28	36.36	-94.79	8	Clarksville	0.07	24.39	HAY	6		2400	294.0
542	33	36.35	-94.82	5	Britwater	0.11	24.39	HAY	6		1528	293.8
458	27	36.36	-94.8	2	Clarksville	0.13	36.58	HAY	6		629	293.5
956	60	36.37	-94.81	6	Clarksville	0.10	18.29	HAY	6		1870	292.2
992	63	36.32	-94.89	5	Britwater	0.08	18.29	HAY	6		1337	291.9
967	61	36.35	-94.79	2	Doniphan	0.06	24.39	HAY	6		474	290.6
978	62	36.33	-94.8	50	Clarksville	0.05	36.58	HAY	6		14459	290.3
818	50	36.27	-94.81	300	Clarksville	0.09	24.39	HAY	6		86928	290.0
505	31	36.36	-94.78	7	Clarksville	0.05	24.39	HAY	6		1910	289.0
980	62	36.33	-94.8	99	Doniphan	0.05	36.58	HAY	6		28715	288.9
820	50	36.27	-94.81	107	Doniphan	0.09	24.39	HAY	6		30838	288.7
142	7	36.4	-94.31	13	Tonti	0.02	91.46	WWHT	0	w N rep	3686	288.4
966	61	36.35	-94.79	2	Clarksville	0.06	24.39	HAY	6		662	288.3
855	52	36.32	-94.68	5	Clarksville	0.10	24.39	HAY	6		1494	287.7
574	35	36.32	-94.71	46	Clarksville	0.07	18.29	HAY	6		13083	287.3
767	47	36.39	-94.84	129	Clarksville	0.09	24.39	HAY	6		36775	286.1
1002	64	36.37	-94.91	5	Britwater	0.11	36.58	HAY	6		1480	285.1
756	46	36.29	-94.61	31	Taloka	0.02	60.98	WWHT	0	w/o N rep	8881	283.9
368	20	36.36	-94.89	92	Clarksville	0.16	24.39	HAY	6		26239	283.9
991	63	36.32	-94.89	5	Clarksville	0.08	18.29	HAY	6		1451	283.3
521	32	36.35	-94.77	9	Clarksville	0.05	18.29	HAY	6		2453	283.1
836	51	36.35	-94.75	1	Britwater	0.01	15.24	WWHT	1.95		179	283.0
445	25	36.37	-94.87	2	Clarksville	0.11	24.39	HAY	6		644	283.0

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
540	33	36.35	-94.82	19	Clarksville	0.11	24.39	HAY	6		5409	282.3
957	60	36.37	-94.81	2	Clarksville	0.10	18.29	HAY	6		479	281.9
121	6	36.38	-94.61	69	Taloka	0.01	121.95	WWHT	0	w/o N rep	19489	280.9
594	36	36.34	-94.76	7	Britwater	0.02	60.98	WWHT	1.95		1839	280.7
525	32	36.35	-94.77	4	Britwater	0.03	18.29	WWHT	1.95		1180	280.6
634	38	36.32	-94.53	45	Tonti	0.03	60.98	WWHT	0	w N rep	12720	279.8
819	50	36.27	-94.81	146	Clarksville	0.09	24.39	HAY	6		40738	279.8
401	22	36.37	-94.51	9	Tonti	0.05	36.58	WWHT	0	w N rep	2416	279.5
979	62	36.33	-94.8	113	Clarksville	0.05	36.58	HAY	6		31597	279.4
550	34	36.33	-94.86	4	Clarksville	0.10	24.39	HAY	6		1197	279.3
580	35	36.32	-94.71	7	Britwater	0.04	18.29	WWHT	1.95		2070	279.2
460	27	36.36	-94.8	1	Elsah	0.13	36.58	HAY	6		326	279.1
200	10	36.37	-94.41	5	Tonti	0.06	60.98	WWHT	0	w N rep	1342	277.9
342	18	36.39	-94.47	10	Tonti	0.03	60.98	WWHT	0	w N rep	2659	277.8
355	19	36.35	-94.92	11	Clarksville	0.06	24.39	HAY	6		3092	277.5
381	21	36.41	-94.51	2	Tonti	0.03	60.98	WWHT	0	w N rep	642	277.4
768	47	36.39	-94.84	57	Clarksville	0.09	24.39	HAY	6		15713	277.0
357	19	36.35	-94.92	9	Doniphan	0.06	24.39	HAY	6		2407	276.5
180	9	36.4	-94.37	12	Tonti	0.04	60.98	WWHT	0	w N rep	3316	276.5
1038	68	36.33	-94.61	33	Tonti	0.04	36.59	WWHT	0	w N rep	9028	276.3
581	35	36.32	-94.71	5	Elsah	0.04	18.29	WWHT	1.95		1423	276.3
1001	64	36.37	-94.91	9	Clarksville	0.11	36.58	HAY	6		2457	275.6
209	11	36.4	-94.99	11	Razort	0.10	24.39	HAY	6		3099	275.4
506	31	36.36	-94.78	5	Elsah	0.05	24.39	HAY	6		1444	274.8
282	15	34.4	-94.44	13	Tonti	0.04	60.98	WWHT	0	w N rep	3615	274.6
324	17	36.41	-94.48	8	Tonti	0.04	60.98	WWHT	0	w N rep	2160	274.5
551	34	36.33	-94.86	13	Tonti	0.10	24.39	HAY	6		3577	274.5
936	57	36.39	-94.94	23	Healing	0.09	18.29	HAY	6		6411	274.2
74	3	36.42	-94.67	15	Tonti	0.02	91.46	WWHT	0	w N rep	3989	273.0
541	33	36.35	-94.82	7	Clarksville	0.11	24.39	HAY	6		2044	272.6
358	19	36.35	-94.92	21	Tonti	0.06	24.39	HAY	6		5680	272.0
161	8	36.37	-94.33	9	Taloka	0.02	91.46	WWHT	0	w N rep	2367	270.3
935	57	36.39	-94.94	74	Britwater	0.09	18.29	HAY	6		19918	267.5
356	19	36.35	-94.92	10	Clarksville	0.06	24.39	HAY	6		2774	266.8
934	57	36.39	-94.94	28	Clarksville	0.09	18.29	HAY	6		7393	260.0
210	11	36.4	-94.99	25	Clarksville	0.10	24.39	HAY	6		6436	258.7
1013	66	36.36	-95.02	8	Clarksville	0.07	18.29	HAY	6		1936	257.1
912	55	36.27	-94.74	40	Britwater	0.04	60.98	WWHT	1.95		10164	256.5
105	5	36.41	-94.63	1	Razort	0.04	36.58	WWHT	0	w/o N rep	323	256.5
578	35	36.32	-94.71	15	Clarksville	0.04	18.29	WWHT	1.95		3835	251.6
1014	66	36.36	-95.02	11	Clarksville	0.07	18.29	HAY	6		2632	246.7
72	3	36.42	-94.67	23	Jay	0.02	91.46	WWHT	0	w/o N rep	5573	243.4
524	32	36.35	-94.77	2	Clarksville	0.03	18.29	WWHT	1.95		460	239.3
858	52	36.32	-94.68	1	Clarksville	0.09	24.39	WWHT	1.95		193	239.2
926	56	36.38	-94.44	0	Elsah	0.09	60.98	WWHT	1.95		86	238.7
984	62	36.33	-94.8	17	Jay	0.03	36.58	WWHT	1.95		3879	233.2
981	62	36.33	-94.8	5	Clarksville	0.03	36.58	WWHT	1.95		1119	233.0
98	4	36.4	-94.57	22	Peridge	0.02	121.95	WWHT	0	w/o N rep	5018	229.1
822	50	36.27	-94.81	64	Clarksville	0.09	24.39	WWHT	1.95		14745	229.1
615	37	36.36	-94.59	2	Peridge	0.05	24.39	WWHT	0	w/o N rep	505	229.1
382	21	36.41	-94.51	4	Peridge	0.03	60.98	WWHT	0	w/o N rep	799	227.0
694	43	36.36	-94.65	99	Taloka	0.01	60.98	WWHT	0	w/o N rep	22328	226.2
911	55	36.27	-94.74	31	Captina	0.04	60.98	WWHT	1.95		6939	225.5
1015	66	36.36	-95.02	7	Nixa	0.07	18.29	HAY	6		1573	223.3
25	1	36.44	-94.67	5	Taloka	0.05	60.98	WWHT	0	w/o N rep	1139	222.3

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
302	16	36.35	-94.44	42	Peridge	0.05	60.98	WWHT	0	w/o N rep	9272	220.7
399	22	36.37	-94.51	25	Captina	0.05	36.58	WWHT	0	w/o N rep	5452	219.7
140	7	36.4	-94.31	21	Captina	0.02	91.46	WWHT	0	w N rep	4608	219.3
283	15	34.4	-94.44	13	Peridge	0.04	60.98	WWHT	0	w/o N rep	2926	218.8
160	8	36.37	-94.33	39	Captina	0.02	91.46	WWHT	0	w N rep	8358	216.8
178	9	36.4	-94.37	26	Captina	0.04	60.98	WWHT	0	w/o N rep	5540	215.5
635	38	36.32	-94.53	46	Peridge	0.03	60.98	WWHT	0	w/o N rep	9913	215.3
613	37	36.36	-94.59	6	Captina	0.05	24.39	WWHT	0	w/o N rep	1340	212.0
95	4	36.4	-94.57	13	Captina	0.02	121.95	WWHT	0	w/o N rep	2734	211.0
379	21	36.41	-94.51	7	Captina	0.03	60.98	WWHT	0	w/o N rep	1496	209.7
73	3	36.42	-94.67	28	Newtonia	0.02	91.46	WWHT	0	w N rep	5833	209.0
198	10	36.37	-94.41	5	Britwater	0.06	60.98	WWHT	0	w/o N rep	952	207.9
322	17	36.41	-94.48	4	Captina	0.04	60.98	WWHT	0	w/o N rep	840	207.6
280	15	34.4	-94.44	14	Captina	0.04	60.98	WWHT	0	w/o N rep	2926	207.4
805	49	36.37	-94.73	12	Taloka	0.06	36.58	WWHT	0	w/o N rep	2520	206.6
437	24	36.34	-94.49	31	Peridge	0.04	60.98	WWHT	0	w/o N rep	6411	206.4
71	3	36.42	-94.67	28	Captina	0.02	91.46	WWHT	0	w/o N rep	5735	205.5
299	16	36.35	-94.44	12	Captina	0.05	60.98	WWHT	0	w/o N rep	2357	203.8
894	54	36.42	-94.62	6	Newtonia	0.02	91.46	WWHT	0	w N rep	1229	202.8
755	46	36.29	-94.61	41	Captina	0.02	60.98	WWHT	0	w/o N rep	8233	201.1
910	55	36.27	-94.74	24	Clarksville	0.04	60.98	WWHT	1.95		4747	199.7
982	62	36.33	-94.8	10	Clarksville	0.03	36.58	WWHT	1.95		2005	199.0
913	55	36.27	-94.74	79	Doniphan	0.04	60.98	WWHT	1.95		15815	199.0
579	35	36.32	-94.71	7	Clarksville	0.04	18.29	WWHT	1.95		1453	198.7
340	18	36.39	-94.47	10	Captina	0.03	60.98	WWHT	0	w/o N rep	1920	198.3
300	16	36.35	-94.44	14	Newtonia	0.05	60.98	WWHT	0	w N rep	2750	196.9
983	62	36.33	-94.8	13	Doniphan	0.03	36.58	WWHT	1.95		2517	194.7
49	2	36.43	-94.7	39	Taloka	0.03	60.98	WWHT	0	w/o N rep	7496	193.4
1037	68	36.33	-94.61	24	Captina	0.04	36.58	WWHT	0	w/o N rep	4481	189.5
435	24	36.34	-94.49	52	Captina	0.04	60.98	WWHT	0	w/o N rep	9827	189.1
823	50	36.27	-94.81	33	Clarksville	0.09	24.39	WWHT	1.95		6185	187.5
733	45	36.28	-94.67	10	Captina	0.02	91.46	WWHT	0	w/o N rep	1774	184.3
715	44	36.3	-94.68	5	Clarksville	0.08	60.98	WWHT	0	w/o N rep	863	181.8
785	48	36.4	-94.79	18	Clarksville	0.07	24.39	WWHT	0	w/o N rep	3248	180.3
96	4	36.4	-94.57	15	Newtonia	0.02	121.95	WWHT	0	w/o N rep	2664	179.7
803	49	36.37	-94.73	28	Clarksville	0.06	36.58	WWHT	0	w/o N rep	4957	178.4
122	6	36.38	-94.61	63	Newtonia	0.01	121.95	WWHT	0	w N rep	11183	177.8
670	42	36.3	-94.65	4	Clarksville	0.05	36.58	WWHT	0	w/o N rep	781	176.8
241	13	36.41	-94.66	25	Clarksville	0.03	60.98	WWHT	0	w/o N rep	4396	175.6
24	1	36.44	-94.67	12	Captina	0.05	60.98	WWHT	0	w/o N rep	2156	173.6
673	42	36.3	-94.65	13	Macedonia	0.05	36.58	WWHT	0	w/o N rep	2168	172.6
237	13	36.41	-94.66	27	Clarksville	0.03	60.98	WWHT	0	w/o N rep	4664	172.2
632	38	36.32	-94.53	80	Captina	0.03	60.98	WWHT	0	w/o N rep	13700	170.2
481	29	36.34	-94.36	4	Clarksville	0.06	60.98	WWHT	0	w/o N rep	679	169.6
260	14	36.37	-94.66	14	Clarksville	0.02	91.46	WWHT	0	w/o N rep	2370	167.5
735	45	36.28	-94.67	31	Macedonia	0.02	91.46	WWHT	0	w/o N rep	5194	166.3
807	49	36.37	-94.73	17	Macedonia	0.06	36.58	WWHT	0	w/o N rep	2743	164.6
240	13	36.41	-94.66	62	Newtonia	0.03	60.98	WWHT	0	w/o N rep	10048	162.3
786	48	36.4	-94.79	11	Clarksville	0.07	24.39	WWHT	0	w/o N rep	1815	161.3
734	45	36.28	-94.67	16	Doniphan	0.02	91.46	WWHT	0	w/o N rep	2461	158.1
46	2	36.43	-94.7	38	Clarksville	0.03	60.98	WWHT	0	w/o N rep	6015	156.9
717	44	36.3	-94.68	3	Macedonia	0.08	60.98	WWHT	0	w/o N rep	396	156.2
695	43	36.36	-94.65	150	Newtonia	0.01	60.98	WWHT	0	w/o N rep	23486	156.1
671	42	36.3	-94.65	8	Clarksville	0.05	36.58	WWHT	0	w/o N rep	1283	155.6
1036	68	36.33	-94.61	13	Clarksville	0.04	36.58	WWHT	0	w/o N rep	1970	152.6

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
47	2	36.43	-94.7	58	Captina	0.03	60.98	WWHT	0	w/o N rep	8823	151.4
262	14	36.37	-94.66	19	Newtonia	0.02	91.46	WWHT	0	w/o N rep	2894	150.8
261	14	36.37	-94.66	48	Macedonia	0.02	91.46	WWHT	0	w/o N rep	7209	148.8
612	37	36.36	-94.59	4	Clarksville	0.05	24.39	WWHT	0	w/o N rep	580	148.0
716	44	36.3	-94.68	8	Clarksville	0.08	60.98	WWHT	0	w/o N rep	1232	147.7
806	49	36.37	-94.73	11	Doniphan	0.06	36.58	WWHT	0	w/o N rep	1687	147.4
879	53	36.35	-94.57	7	Clarksville	0.12	24.39	WWHT	0	w/o N rep	1035	147.3
672	42	36.3	-94.65	5	Doniphan	0.05	36.58	WWHT	0	w/o N rep	725	144.3
238	13	36.41	-94.66	22	Clarksville	0.03	60.98	WWHT	0	w/o N rep	3171	143.3
482	29	36.34	-94.36	28	Nixa	0.06	60.98	WWHT	0	w/o N rep	3856	139.7
23	1	36.44	-94.67	3	Clarksville	0.05	60.98	WWHT	0	w/o N rep	380	139.4
141	7	36.4	-94.31	7	Nixa	0.02	91.46	WWHT	0	w/o N rep	1013	139.0
898	55	36.27	-94.74	520	Clarksville	0.06	60.98	WPAS	6		70722	136.0
900	55	36.27	-94.74	586	Doniphan	0.06	60.98	WPAS	6		79340	135.4
845	52	36.32	-94.68	2	Razort	0.10	24.39	WPAS	6		250	134.5
804	49	36.37	-94.73	12	Clarksville	0.06	36.58	WWHT	0	w/o N rep	1636	134.1
239	13	36.41	-94.66	26	Doniphan	0.03	60.98	WWHT	0	w/o N rep	3531	134.0
281	15	34.4	-94.44	11	Nixa	0.04	60.98	WWHT	0	w/o N rep	1486	133.1
323	17	36.41	-94.48	12	Nixa	0.04	60.98	WWHT	0	w/o N rep	1601	133.1
557	35	36.32	-94.71	69	Razort	0.07	18.29	WPAS	6		9221	132.7
179	9	36.4	-94.37	60	Nixa	0.04	60.98	WWHT	0	w/o N rep	7968	132.4
199	10	36.37	-94.41	10	Nixa	0.06	60.98	WWHT	0	w/o N rep	1263	132.3
847	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	6		738	132.1
614	37	36.36	-94.59	3	Nixa	0.05	24.39	WWHT	0	w/o N rep	329	131.4
496	31	36.36	-94.78	5	Razort	0.05	24.39	WPAS	6		669	130.9
560	35	36.32	-94.71	44	Britwater	0.07	18.29	WPAS	6		5697	130.7
380	21	36.41	-94.51	6	Nixa	0.03	60.98	WWHT	0	w/o N rep	718	129.9
948	60	36.37	-94.81	2	Razort	0.10	18.29	WPAS	6		257	129.9
880	53	36.35	-94.57	8	Nixa	0.12	24.39	WWHT	0	w/o N rep	1033	129.5
499	31	36.36	-94.78	11	Healing	0.05	24.39	WPAS	6		1442	129.4
828	51	36.35	-94.75	1	Razort	0.06	15.24	WPAS	6		163	129.4
585	36	36.34	-94.76	0	Razort	0.05	60.98	WPAS	6		23	129.2
963	61	36.35	-94.79	3	Healing	0.06	24.39	WPAS	6		335	128.8
301	16	36.35	-94.44	15	Nixa	0.05	60.98	WWHT	0	w/o N rep	1872	128.1
454	27	36.36	-94.8	1	Britwater	0.13	36.58	WPAS	6		127	128.0
48	2	36.43	-94.7	75	Doniphan	0.03	60.98	WWHT	0	w/o N rep	9611	127.9
846	52	36.32	-94.68	2	Clarksville	0.10	24.39	WPAS	6		313	127.6
561	35	36.32	-94.71	50	Doniphan	0.07	18.29	WPAS	6		6331	127.3
341	18	36.39	-94.47	6	Nixa	0.03	60.98	WWHT	0	w/o N rep	816	127.1
757	47	36.39	-94.84	45	Razort	0.09	24.39	WPAS	6		5752	127.0
951	60	36.37	-94.81	2	Britwater	0.10	18.29	WPAS	6		274	126.8
558	35	36.32	-94.71	95	Clarksville	0.07	18.29	WPAS	6		12074	126.6
562	35	36.32	-94.71	73	Macedonia	0.07	18.29	WPAS	6		9230	126.3
464	28	36.36	-94.79	1	Elsah	0.07	24.39	WPAS	6		160	126.2
436	24	36.34	-94.49	33	Nixa	0.04	60.98	WWHT	0	w/o N rep	4113	126.2
899	55	36.27	-94.74	347	Clarksville	0.06	60.98	WPAS	6		43780	126.0
400	22	36.37	-94.51	7	Nixa	0.05	36.58	WWHT	0	w/o N rep	835	125.8
498	31	36.36	-94.78	4	Elsah	0.05	24.39	WPAS	6		561	125.3
97	4	36.4	-94.57	13	Nixa	0.02	121.95	WWHT	0	w/o N rep	1621	125.1
463	28	36.36	-94.79	3	Clarksville	0.07	24.39	WPAS	6		419	124.7
962	61	36.35	-94.79	1	Elsah	0.06	24.39	WPAS	6		132	124.7
563	35	36.32	-94.71	23	Razort	0.07	18.29	OPAS	3.2308		2865	124.6
453	27	36.36	-94.8	2	Clarksville	0.13	36.58	WPAS	6		223	124.3
808	50	36.27	-94.81	159	Razort	0.09	24.39	WPAS	6		19771	124.2
938	58	36.35	-94.85	0	Razort	0.15	18.29	WPAS	6		36	124.0

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
830	51	36.35	-94.75	0	Razort	0.06	15.24	OPAS	3.2308		45	123.9
564	35	36.32	-94.71	30	Clarksville	0.07	18.29	OPAS	3.2308		3657	123.8
586	36	36.34	-94.76	1	Elsah	0.05	60.98	WPAS	6		101	123.7
511	32	36.35	-94.77	13	Razort	0.05	18.29	WPAS	6		1592	123.5
943	59	36.36	-94.86	2	Razort	0.17	18.29	WPAS	6		257	123.5
949	60	36.37	-94.81	7	Clarksville	0.10	18.29	WPAS	6		859	123.1
361	20	36.36	-94.89	26	Razort	0.16	24.39	WPAS	6		3149	122.8
940	58	36.35	-94.85	0	Britwater	0.15	18.29	WPAS	6		59	122.7
829	51	36.35	-94.75	0	Clarksville	0.06	15.24	WPAS	6		33	122.5
497	31	36.36	-94.78	9	Clarksville	0.05	24.39	WPAS	6		1161	122.3
513	32	36.35	-94.77	25	Healing	0.05	18.29	WPAS	6		3085	121.9
985	63	36.32	-94.89	5	Razort	0.08	18.29	WPAS	6		580	121.8
961	61	36.35	-94.79	5	Clarksville	0.06	24.39	WPAS	6		621	121.7
442	25	36.37	-94.87	2	Britwater	0.11	24.39	WPAS	6		265	121.4
758	47	36.39	-94.84	159	Clarksville	0.09	24.39	WPAS	6		19232	121.0
970	62	36.33	-94.8	47	Doniphan	0.05	36.58	WPAS	6		5644	121.0
533	33	36.35	-94.82	4	Britwater	0.11	24.39	WPAS	6		529	120.8
517	32	36.35	-94.77	4	Healing	0.05	18.29	OPAS	3.2308		489	120.6
987	63	36.32	-94.89	3	Britwater	0.08	18.29	WPAS	6		342	120.6
363	20	36.36	-94.89	6	Razort	0.16	24.39	OPAS	3.2308		768	120.2
633	38	36.32	-94.53	31	Nixa	0.03	60.98	WWHT	0	w/o N rep	3742	120.1
968	62	36.33	-94.8	80	Clarksville	0.05	36.58	WPAS	6		9549	119.6
939	58	36.35	-94.85	1	Clarksville	0.15	18.29	WPAS	6		91	119.1
566	35	36.32	-94.71	20	Britwater	0.07	18.29	OPAS	3.2308		2357	119.0
944	59	36.36	-94.86	4	Clarksville	0.17	18.29	WPAS	6		506	118.8
760	47	36.39	-94.84	30	Clarksville	0.09	24.39	OPAS	3.2308		3558	118.3
712	44	36.3	-94.68	21	Captina	0.04	60.98	HAY	0	w N rep	2495	117.8
929	57	36.39	-94.94	4	Razort	0.09	18.29	OPAS	3.2308		447	117.7
441	25	36.37	-94.87	13	Clarksville	0.11	24.39	WPAS	6		1483	117.6
362	20	36.36	-94.89	122	Clarksville	0.16	24.39	WPAS	6		14337	117.5
559	35	36.32	-94.71	73	Clarksville	0.07	18.29	WPAS	6		8595	117.3
974	62	36.33	-94.8	18	Jay	0.05	36.58	OPAS	3.2308		2145	117.2
971	62	36.33	-94.8	19	Clarksville	0.05	36.58	OPAS	3.2308		2204	117.2
532	33	36.35	-94.82	23	Clarksville	0.11	24.39	WPAS	6		2675	116.9
512	32	36.35	-94.77	27	Clarksville	0.05	18.29	WPAS	6		3123	116.4
809	50	36.27	-94.81	489	Clarksville	0.09	24.39	WPAS	6		56799	116.2
206	11	36.4	-94.99	3	Razort	0.10	24.39	OPAS	3.2308		332	115.5
849	52	36.32	-94.68	6	Britwater	0.10	24.39	OPAS	3.2308		638	115.1
986	63	36.32	-94.89	6	Clarksville	0.08	18.29	WPAS	6		684	115.0
995	64	36.37	-94.91	7	Razort	0.11	36.58	WPAS	6		800	114.7
536	33	36.35	-94.82	3	Britwater	0.11	24.39	OPAS	3.2308		390	114.7
950	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	6		213	113.3
997	64	36.37	-94.91	17	Britwater	0.11	36.58	WPAS	6		1871	112.8
759	47	36.39	-94.84	51	Clarksville	0.09	24.39	WPAS	6		5664	111.1
547	34	36.33	-94.86	22	Clarksville	0.10	24.39	WPAS	6		2445	111.1
350	19	36.35	-94.92	22	Tonti	0.06	24.39	OPAS	3.2308		2417	110.7
753	46	36.29	-94.61	184	Captina	0.03	60.98	HAY	0	w N rep	20349	110.6
996	64	36.37	-94.91	16	Clarksville	0.11	36.58	WPAS	6		1711	109.8
348	19	36.35	-94.92	12	Doniphan	0.06	24.39	WPAS	6		1339	109.7
969	62	36.33	-94.8	99	Clarksville	0.05	36.58	WPAS	6		10893	109.6
346	19	36.35	-94.92	34	Clarksville	0.06	24.39	WPAS	6		3660	108.4
810	50	36.27	-94.81	167	Clarksville	0.09	24.39	WPAS	3.4	w/o N rep	17900	107.4
927	57	36.39	-94.94	48	Clarksville	0.09	18.29	WPAS	3	w/o N rep	5090	107.0
928	57	36.39	-94.94	114	Britwater	0.09	18.29	WPAS	3.4	w/o N rep	12111	106.6
548	34	36.33	-94.86	25	Tonti	0.10	24.39	WPAS	3.4	w/o N rep	2669	106.5

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
1017	67	36.37	-94.98	28	Clarksville	0.13	15.24	WPAS	3	w/o N rep	2912	105.7
1010	66	36.36	-95.02	10	Parsons	0.07	18.29	WPAS	3	w/o N rep	1040	105.0
1016	67	36.37	-94.98	4	Razort	0.13	15.24	WPAS	3	w/o N rep	439	104.9
204	11	36.4	-94.99	35	Clarksville	0.10	24.39	WPAS	3	w/o N rep	3665	104.9
1007	66	36.36	-95.02	19	Clarksville	0.07	18.29	WPAS	3	w/o N rep	1938	104.2
203	11	36.4	-94.99	19	Razort	0.10	24.39	WPAS	3	w/o N rep	1979	104.1
349	19	36.35	-94.92	27	Tonti	0.06	24.39	WPAS	3	w/o N rep	2815	104.0
347	19	36.35	-94.92	19	Clarksville	0.06	24.39	WPAS	3	w/o N rep	1953	103.2
1008	66	36.36	-95.02	26	Clarksville	0.07	18.29	WPAS	3.4	w/o N rep	2668	102.7
376	21	36.41	-94.51	139	Captina	0.04	60.98	HAY	0	w N rep	13916	100.2
893	54	36.42	-94.62	88	Newtonia	0.02	91.46	HAY	0	w N rep	8789	99.8
175	9	36.4	-94.37	128	Captina	0.05	60.98	HAY	0	w N rep	12600	98.3
276	15	34.4	-94.44	57	Captina	0.05	60.98	HAY	0	w N rep	5605	98.2
319	17	36.41	-94.48	51	Captina	0.06	60.98	HAY	0	w N rep	5003	98.2
44	2	36.43	-94.7	314	Captina	0.04	60.98	HAY	0	w N rep	30637	97.7
1009	66	36.36	-95.02	35	Nixa	0.07	18.29	WPAS	4	w N rep	3388	97.7
693	43	36.36	-94.65	60	Newtonia	0.03	60.98	HAY	0	w N rep	5851	97.3
236	13	36.41	-94.66	119	Newtonia	0.05	60.98	HAY	0	w N rep	11521	96.5
732	45	36.28	-94.67	83	Macedonia	0.03	91.46	HAY	0	w N rep	8034	96.3
396	22	36.37	-94.51	62	Captina	0.06	36.58	HAY	0	w N rep	5978	96.1
20	1	36.44	-94.67	51	Captina	0.07	60.98	HAY	0	w N rep	4865	95.1
413	23	36.36	-94.55	2	Captina	0.05	24.39	HAY	0	w N rep	194	94.9
610	37	36.36	-94.59	17	Captina	0.06	24.39	HAY	0	w N rep	1586	94.9
416	23	36.36	-94.55	5	Peridge	0.05	24.39	HAY	0	w N rep	484	94.7
878	53	36.35	-94.57	10	Peridge	0.07	24.39	HAY	0	w N rep	960	94.5
730	45	36.28	-94.67	40	Clarksville	0.03	91.46	HAY	0	w N rep	3819	94.5
337	18	36.39	-94.47	89	Captina	0.05	60.98	HAY	0	w N rep	8371	94.3
1051	69	36.35	-95.01	2	Healing	0.06	24.39	HAY	0	w N rep	228	94.3
434	24	36.34	-94.49	59	Peridge	0.05	60.98	HAY	0	w N rep	5489	93.8
259	14	36.37	-94.66	115	Newtonia	0.03	91.46	HAY	0	w N rep	10722	93.6
157	8	36.37	-94.33	58	Captina	0.03	91.46	HAY	0	w N rep	5462	93.5
92	4	36.4	-94.57	130	Newtonia	0.02	121.95	HAY	0	w N rep	12124	93.3
1048	69	36.35	-95.01	7	Captina	0.06	24.39	HAY	0	w N rep	695	93.2
67	3	36.42	-94.67	166	Captina	0.02	91.46	HAY	0	w N rep	15445	93.0
432	24	36.34	-94.49	62	Captina	0.05	60.98	HAY	0	w N rep	5747	92.8
1052	69	36.35	-95.01	4	Peridge	0.06	24.39	HAY	0	w N rep	406	92.5
629	38	36.32	-94.53	110	Captina	0.05	60.98	HAY	0	w N rep	10181	92.2
1034	68	36.33	-94.61	76	Captina	0.05	36.58	HAY	0	w N rep	6976	92.1
70	3	36.42	-94.67	88	Peridge	0.02	91.46	HAY	0	w N rep	8057	91.1
653	41	36.33	-94.65	18	Britwater	0.07	24.39	HAY	0	w N rep	1584	90.5
714	44	36.3	-94.68	33	Macedonia	0.04	60.98	HAY	0	w N rep	2994	90.5
91	4	36.4	-94.57	144	Captina	0.02	121.95	HAY	0	w N rep	12740	88.7
232	13	36.41	-94.66	114	Razort	0.05	60.98	HAY	0	w N rep	10046	88.0
710	44	36.3	-94.68	13	Clarksville	0.04	60.98	HAY	0	w N rep	1185	87.9
651	41	36.33	-94.65	24	Clarksville	0.07	24.39	HAY	0	w N rep	2133	87.8
535	33	36.35	-94.82	9	Clarksville	0.11	24.39	OPAS	2.5846		789	87.8
137	7	36.4	-94.31	143	Captina	0.03	91.46	HAY	0	w N rep	12534	87.7
298	16	36.35	-94.44	31	Peridge	0.07	60.98	HAY	0	w N rep	2733	87.4
296	16	36.35	-94.44	37	Captina	0.07	60.98	HAY	0	w N rep	3198	87.0
120	6	36.38	-94.61	142	Newtonia	0.01	121.95	HAY	0	w N rep	12168	85.9
68	3	36.42	-94.67	116	Jay	0.02	91.46	HAY	0	w N rep	9885	85.5
669	42	36.3	-94.65	40	Macedonia	0.05	36.58	HAY	0	w N rep	3379	85.4
752	46	36.29	-94.61	101	Clarksville	0.03	60.98	HAY	0	w N rep	8390	83.0
17	1	36.44	-94.67	52	Razort	0.07	60.98	HAY	0	w N rep	4329	83.0
666	42	36.3	-94.65	35	Clarksville	0.05	36.58	HAY	0	w N rep	2917	82.5

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
21	1	36.44	-94.67	45	Taloka	0.07	60.98	HAY	0	w N rep	3667	82.4
781	48	36.4	-94.79	45	Razort	0.11	24.39	HAY	0	w N rep	3664	82.2
731	45	36.28	-94.67	158	Doniphan	0.03	91.46	HAY	0	w N rep	12903	81.6
811	50	36.27	-94.81	192	Clarksville	0.09	24.39	OPAS	2.5846		15515	81.0
258	14	36.37	-94.66	67	Jay	0.03	91.46	HAY	0	w N rep	5244	78.8
802	49	36.37	-94.73	217	Macedonia	0.07	36.58	HAY	0	w N rep	17008	78.3
784	48	36.4	-94.79	38	Britwater	0.11	24.39	HAY	0	w N rep	2946	77.3
195	10	36.37	-94.41	47	Britwater	0.06	60.98	HAY	0	w N rep	3650	77.0
848	52	36.32	-94.68	5	Clarksville	0.10	24.39	OPAS	3.2308		346	76.2
713	44	36.3	-94.68	20	Doniphan	0.04	60.98	HAY	0	w N rep	1518	75.4
414	23	36.36	-94.55	3	Britwater	0.05	24.39	HAY	0	w N rep	192	75.2
876	53	36.35	-94.57	12	Britwater	0.07	24.39	HAY	0	w N rep	890	74.9
691	43	36.36	-94.65	68	Macedonia	0.03	60.98	HAY	0	w N rep	5053	74.8
668	42	36.3	-94.65	46	Doniphan	0.05	36.58	HAY	0	w N rep	3386	73.6
1049	69	36.35	-95.01	3	Britwater	0.06	24.39	HAY	0	w N rep	201	73.5
257	14	36.37	-94.66	70	Macedonia	0.03	91.46	HAY	0	w N rep	5105	73.3
5	1	36.44	-94.67	53	Razort	0.07	60.98	WPAS	0	w/o N rep	3891	73.2
773	48	36.4	-94.79	48	Razort	0.11	24.39	WPAS	0	w/o N rep	3464	72.4
654	42	36.3	-94.65	69	Razort	0.05	36.58	WPAS	0	w/o N rep	4997	72.4
219	13	36.41	-94.66	255	Razort	0.05	60.98	WPAS	0	w/o N rep	18493	72.4
407	23	36.36	-94.55	5	Healing	0.05	24.39	WPAS	0	w/o N rep	334	71.6
883	54	36.42	-94.62	25	Razort	0.02	91.46	WPAS	0	w/o N rep	1804	71.6
952	60	36.37	-94.81	2	Clarksville	0.10	18.29	OPAS	2.5846		138	71.6
364	20	36.36	-94.89	36	Clarksville	0.16	24.39	OPAS	2.5846		2593	71.5
43	2	36.43	-94.7	343	Clarksville	0.04	60.98	HAY	0	w N rep	24317	71.0
800	49	36.37	-94.73	270	Clarksville	0.07	36.58	HAY	0	w N rep	18956	70.2
102	5	36.41	-94.63	0	Razort	0.03	36.58	OPAS	0	w/o N rep	6	68.2
688	43	36.36	-94.65	44	Clarksville	0.03	60.98	HAY	0	w N rep	2931	66.6
248	14	36.37	-94.66	51	Jay	0.03	91.46	WPAS	0	w/o N rep	3367	66.0
18	1	36.44	-94.67	117	Clarksville	0.07	60.98	HAY	0	w N rep	7736	66.0
516	32	36.35	-94.77	7	Britwater	0.05	18.29	OPAS	2.5846		469	66.0
45	2	36.43	-94.7	373	Doniphan	0.04	60.98	HAY	0	w N rep	24589	65.8
159	8	36.37	-94.33	69	Tonti	0.03	91.46	HAY	0	w N rep	4488	65.3
587	36	36.34	-94.76	5	Britwater	0.05	60.98	OPAS	2.5846		316	64.8
57	3	36.42	-94.67	366	Jay	0.02	91.46	WPAS	0	w/o N rep	23529	64.4
139	7	36.4	-94.31	73	Tonti	0.03	91.46	HAY	0	w N rep	4701	64.1
480	29	36.34	-94.36	53	Tonti	0.06	60.98	HAY	0	w N rep	3366	64.0
754	46	36.29	-94.61	82	Taloka	0.03	60.98	HAY	0	w N rep	5196	63.7
866	53	36.35	-94.57	18	Waben	0.07	24.39	WPAS	0	w/o N rep	1152	63.6
700	44	36.3	-94.68	62	Captina	0.04	60.98	WPAS	0	w/o N rep	3952	63.6
405	23	36.36	-94.55	13	Captina	0.05	24.39	WPAS	0	w/o N rep	806	62.8
600	37	36.36	-94.59	52	Captina	0.06	24.39	WPAS	0	w/o N rep	3243	62.8
7	1	36.44	-94.67	49	Captina	0.07	60.98	WPAS	0	w/o N rep	3096	62.8
31	2	36.43	-94.7	158	Captina	0.04	60.98	WPAS	0	w/o N rep	9913	62.8
307	17	36.41	-94.48	59	Captina	0.06	60.98	WPAS	0	w/o N rep	3712	62.8
742	46	36.29	-94.61	277	Captina	0.03	60.98	WPAS	0	w/o N rep	17414	62.8
620	38	36.32	-94.53	454	Captina	0.05	60.98	WPAS	0	w/o N rep	28482	62.8
369	21	36.41	-94.51	222	Captina	0.04	60.98	WPAS	0	w/o N rep	13948	62.8
1023	68	36.33	-94.61	198	Captina	0.05	36.58	WPAS	0	w/o N rep	12421	62.8
422	24	36.34	-94.49	126	Captina	0.05	60.98	WPAS	0	w/o N rep	7921	62.8
233	13	36.41	-94.66	148	Clarksville	0.05	60.98	HAY	0	w N rep	9240	62.6
398	22	36.37	-94.51	29	Tonti	0.06	36.58	HAY	0	w N rep	1823	62.4
1040	69	36.35	-95.01	8	Captina	0.06	24.39	WPAS	0	w/o N rep	472	62.0
310	17	36.41	-94.48	51	Noark	0.06	60.98	WPAS	0	w/o N rep	3160	62.0
387	22	36.37	-94.51	172	Captina	0.06	36.58	WPAS	0	w/o N rep	10638	62.0

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
424	24	36.34	-94.49	234	Peridge	0.05	60.98	WPAS	0	w/o N rep	14510	62.0
56	3	36.42	-94.67	186	Captina	0.02	91.46	WPAS	0	w/o N rep	11495	62.0
269	15	34.4	-94.44	132	Noark	0.05	60.98	WPAS	0	w/o N rep	8152	62.0
328	18	36.39	-94.47	83	Captina	0.05	60.98	WPAS	0	w/o N rep	5156	62.0
36	2	36.43	-94.7	91	Taloka	0.04	60.98	OPAS	0	w/o N rep	5558	61.2
168	9	36.4	-94.37	231	Noark	0.05	60.98	WPAS	0	w/o N rep	14144	61.2
289	16	36.35	-94.44	271	Peridge	0.07	60.98	WPAS	0	w/o N rep	16545	61.2
60	3	36.42	-94.67	176	Peridge	0.02	91.46	WPAS	0	w/o N rep	10766	61.2
701	44	36.3	-94.68	48	Britwater	0.04	60.98	WPAS	0	w/o N rep	2949	61.2
867	53	36.35	-94.57	48	Peridge	0.07	24.39	WPAS	0	w/o N rep	2940	61.2
601	37	36.36	-94.59	34	Peridge	0.06	24.39	WPAS	0	w/o N rep	2078	61.2
1042	69	36.35	-95.01	25	Peridge	0.06	24.39	WPAS	0	w/o N rep	1545	61.2
408	23	36.36	-94.55	7	Peridge	0.05	24.39	WPAS	0	w/o N rep	408	61.2
631	38	36.32	-94.53	90	Tonti	0.05	60.98	HAY	0	w N rep	5510	60.9
782	48	36.4	-94.79	176	Clarksville	0.11	24.39	HAY	0	w N rep	10659	60.7
795	49	36.37	-94.73	45	Taloka	0.07	36.58	OPAS	0	w/o N rep	2737	60.6
378	21	36.41	-94.51	45	Tonti	0.04	60.98	HAY	0	w N rep	2730	60.6
223	13	36.41	-94.66	71	Razort	0.05	60.98	OPAS	0	w/o N rep	4302	60.5
568	35	36.32	-94.71	19	Macedonia	0.07	18.29	OPAS	2.5846		1161	60.4
278	15	34.4	-94.44	138	Tonti	0.05	60.98	HAY	0	w N rep	8362	60.4
919	56	36.38	-94.44	0	Britwater	0.08	60.98	WPAS	0	w/o N rep	24	60.4
657	42	36.3	-94.65	53	Britwater	0.05	36.58	WPAS	0	w/o N rep	3179	60.4
126	7	36.4	-94.31	299	Captina	0.03	91.46	WPAS	0	w/o N rep	18050	60.4
339	18	36.39	-94.47	65	Tonti	0.05	60.98	HAY	0	w N rep	3901	60.3
321	17	36.41	-94.48	70	Tonti	0.06	60.98	HAY	0	w N rep	4190	60.2
197	10	36.37	-94.41	48	Tonti	0.06	60.98	HAY	0	w N rep	2900	60.1
22	1	36.44	-94.67	54	Doniphan	0.07	60.98	HAY	0	w N rep	3239	60.1
514	32	36.35	-94.77	9	Clarksville	0.05	18.29	OPAS	2.5846		532	60.0
892	54	36.42	-94.62	15	Clarksville	0.02	91.46	HAY	0	w N rep	911	60.0
101	5	36.41	-94.63	0	Britwater	0.03	36.58	WPAS	0	w/o N rep	11	59.6
643	41	36.33	-94.65	97	Britwater	0.07	24.39	WPAS	0	w/o N rep	5804	59.6
655	42	36.3	-94.65	96	Clarksville	0.05	36.58	WPAS	0	w/o N rep	5695	59.6
790	49	36.37	-94.73	418	Clarksville	0.07	36.58	WPAS	0	w/o N rep	24899	59.6
30	2	36.43	-94.7	290	Clarksville	0.04	60.98	WPAS	0	w/o N rep	17251	59.6
146	8	36.37	-94.33	184	Captina	0.03	91.46	WPAS	0	w/o N rep	10965	59.6
500	31	36.36	-94.78	7	Clarksville	0.05	24.39	OPAS	2.5846		405	59.1
177	9	36.4	-94.37	201	Tonti	0.05	60.98	HAY	0	w N rep	11814	58.8
641	41	36.33	-94.65	22	Clarksville	0.07	24.39	WPAS	0	w/o N rep	1269	58.8
222	13	36.41	-94.66	152	Newtonia	0.05	60.98	WPAS	0	w/o N rep	8944	58.8
681	43	36.36	-94.65	207	Newtonia	0.03	60.98	WPAS	0	w/o N rep	12175	58.8
246	14	36.37	-94.66	40	Clarksville	0.03	91.46	WPAS	0	w/o N rep	2379	58.8
220	13	36.41	-94.66	325	Clarksville	0.05	60.98	WPAS	0	w/o N rep	19067	58.8
743	46	36.29	-94.61	469	Taloka	0.03	60.98	WPAS	0	w/o N rep	27534	58.8
249	14	36.37	-94.66	74	Newtonia	0.03	91.46	WPAS	0	w/o N rep	4365	58.8
774	48	36.4	-94.79	247	Clarksville	0.11	24.39	WPAS	0	w/o N rep	14503	58.8
723	45	36.28	-94.67	92	Newtonia	0.03	91.46	WPAS	0	w/o N rep	5412	58.8
6	1	36.44	-94.67	123	Clarksville	0.07	60.98	WPAS	0	w/o N rep	7244	58.8
129	7	36.4	-94.31	103	Noark	0.03	91.46	WPAS	0	w/o N rep	6070	58.8
690	43	36.36	-94.65	41	Doniphan	0.03	60.98	HAY	0	w N rep	2391	58.1
1041	69	36.35	-95.01	16	Britwater	0.06	24.39	WPAS	0	w/o N rep	931	57.9
678	43	36.36	-94.65	87	Clarksville	0.03	60.98	WPAS	0	w/o N rep	5026	57.9
741	46	36.29	-94.61	269	Clarksville	0.03	60.98	WPAS	0	w/o N rep	15615	57.9
58	3	36.42	-94.67	256	Newtonia	0.02	91.46	WPAS	0	w/o N rep	14859	57.9
33	2	36.43	-94.7	184	Taloka	0.04	60.98	WPAS	0	w/o N rep	10684	57.9
113	6	36.38	-94.61	345	Newtonia	0.01	121.95	WPAS	0	w/o N rep	20013	57.9

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
885	54	36.42	-94.62	23	Britwater	0.02	91.46	WPAS	0	w/o N rep	1331	57.9
865	53	36.35	-94.57	45	Britwater	0.07	24.39	WPAS	0	w/o N rep	2631	57.9
642	41	36.33	-94.65	16	Clarksville	0.07	24.39	WPAS	0	w/o N rep	930	57.9
588	36	36.34	-94.76	2	Elsah	0.05	60.98	OPAS	2.5846		118	57.8
235	13	36.41	-94.66	112	Doniphan	0.05	60.98	HAY	0	w N rep	6446	57.7
656	42	36.3	-94.65	47	Clarksville	0.05	36.58	WPAS	0	w/o N rep	2681	57.1
679	43	36.36	-94.65	77	Clarksville	0.03	60.98	WPAS	0	w/o N rep	4412	57.1
886	54	36.42	-94.62	93	Newtonia	0.02	91.46	WPAS	0	w/o N rep	5303	57.1
884	54	36.42	-94.62	31	Clarksville	0.02	91.46	WPAS	0	w/o N rep	1795	57.1
831	51	36.35	-94.75	1	Elsah	0.06	15.24	OPAS	2.5846		51	56.6
702	44	36.3	-94.68	63	Macedonia	0.04	60.98	WPAS	0	w/o N rep	3530	56.3
791	49	36.37	-94.73	151	Clarksville	0.07	36.58	WPAS	0	w/o N rep	8525	56.3
83	4	36.4	-94.57	377	Newtonia	0.02	121.95	WPAS	0	w/o N rep	21248	56.3
221	13	36.41	-94.66	164	Clarksville	0.05	60.98	WPAS	0	w/o N rep	9263	56.3
1021	68	36.33	-94.61	278	Clarksville	0.05	36.58	WPAS	0	w/o N rep	15685	56.3
680	43	36.36	-94.65	107	Macedonia	0.03	60.98	WPAS	0	w/o N rep	6013	56.3
775	48	36.4	-94.79	51	Clarksville	0.11	24.39	WPAS	0	w/o N rep	2872	56.3
659	42	36.3	-94.65	56	Macedonia	0.05	36.58	WPAS	0	w/o N rep	3177	56.3
247	14	36.37	-94.66	95	Macedonia	0.03	91.46	WPAS	0	w/o N rep	5254	55.5
792	49	36.37	-94.73	230	Macedonia	0.07	36.58	WPAS	0	w/o N rep	12748	55.5
112	6	36.38	-94.61	227	Taloka	0.01	121.95	WPAS	0	w/o N rep	12598	55.5
82	4	36.4	-94.57	292	Taloka	0.02	121.95	WPAS	0	w/o N rep	16230	55.5
776	48	36.4	-94.79	23	Razort	0.11	24.39	OPAS	0	w/o N rep	1277	55.5
704	44	36.3	-94.68	18	Taloka	0.04	60.98	OPAS	0	w/o N rep	981	55.4
608	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	0	w N rep	362	55.2
1039	69	36.35	-95.01	13	Clarksville	0.06	24.39	WPAS	0	w/o N rep	686	54.7
306	17	36.41	-94.48	50	Clarksville	0.06	60.98	WPAS	0	w/o N rep	2726	54.7
287	16	36.35	-94.44	195	Clarksville	0.07	60.98	WPAS	0	w/o N rep	10692	54.7
619	38	36.32	-94.53	233	Clarksville	0.05	60.98	WPAS	0	w/o N rep	12730	54.7
184	10	36.37	-94.41	63	Clarksville	0.06	60.98	WPAS	0	w/o N rep	3450	54.7
658	42	36.3	-94.65	50	Doniphan	0.05	36.58	WPAS	0	w/o N rep	2671	53.9
486	30	36.33	-94.39	110	Clarksville	0.08	36.58	WPAS	0	w/o N rep	5943	53.9
421	24	36.34	-94.49	171	Clarksville	0.05	60.98	WPAS	0	w/o N rep	9231	53.9
406	23	36.36	-94.55	7	Nixa	0.05	24.39	WPAS	0	w/o N rep	353	53.9
327	18	36.39	-94.47	65	Clarksville	0.05	60.98	WPAS	0	w/o N rep	3484	53.9
386	22	36.37	-94.51	202	Clarksville	0.06	36.58	WPAS	0	w/o N rep	10867	53.9
370	21	36.41	-94.51	152	Nixa	0.04	60.98	WPAS	0	w/o N rep	8194	53.9
1022	68	36.33	-94.61	216	Clarksville	0.05	36.58	WPAS	0	w/o N rep	11664	53.9
722	45	36.28	-94.67	100	Macedonia	0.03	91.46	WPAS	0	w/o N rep	5410	53.9
599	37	36.36	-94.59	36	Clarksville	0.06	24.39	WPAS	0	w/o N rep	1964	53.9
864	53	36.35	-94.57	25	Clarksville	0.07	24.39	WPAS	0	w/o N rep	1345	53.9
329	18	36.39	-94.47	89	Nixa	0.05	60.98	WPAS	0	w/o N rep	4752	53.1
471	29	36.34	-94.36	111	Clarksville	0.06	60.98	WPAS	0	w/o N rep	5877	53.1
267	15	34.4	-94.44	110	Nixa	0.05	60.98	WPAS	0	w/o N rep	5836	53.1
388	22	36.37	-94.51	201	Nixa	0.06	36.58	WPAS	0	w/o N rep	10673	53.1
8	1	36.44	-94.67	44	Doniphan	0.07	60.98	WPAS	0	w/o N rep	2326	53.1
487	30	36.33	-94.39	274	Nixa	0.08	36.58	WPAS	0	w/o N rep	14567	53.1
308	17	36.41	-94.48	109	Nixa	0.06	60.98	WPAS	0	w/o N rep	5808	53.1
288	16	36.35	-94.44	317	Nixa	0.07	60.98	WPAS	0	w/o N rep	16823	53.1
167	9	36.4	-94.37	226	Tonti	0.05	60.98	WPAS	0	w/o N rep	12013	53.1
621	38	36.32	-94.53	314	Nixa	0.05	60.98	WPAS	0	w/o N rep	16666	53.1
166	9	36.4	-94.37	728	Nixa	0.05	60.98	WPAS	0	w/o N rep	38672	53.1
185	10	36.37	-94.41	123	Nixa	0.06	60.98	WPAS	0	w/o N rep	6544	53.1
268	15	34.4	-94.44	183	Tonti	0.05	60.98	WPAS	0	w/o N rep	9698	53.1
423	24	36.34	-94.49	480	Nixa	0.05	60.98	WPAS	0	w/o N rep	25481	53.1

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
32	2	36.43	-94.7	186	Doniphan	0.04	60.98	WPAS	0	w/o N rep	9871	53.1
537	33	36.35	-94.82	2	Taloka	0.11	24.39	OPAS	2.5846		130	52.8
1032	68	36.33	-94.61	102	Clarksville	0.05	36.58	HAY	0	w N rep	5389	52.8
94	4	36.4	-94.57	84	Tonti	0.02	121.95	HAY	0	w N rep	4436	52.7
330	18	36.39	-94.47	53	Tonti	0.05	60.98	WPAS	0	w/o N rep	2760	52.3
186	10	36.37	-94.41	77	Secesh	0.06	60.98	WPAS	0	w/o N rep	4024	52.3
371	21	36.41	-94.51	105	Tonti	0.04	60.98	WPAS	0	w/o N rep	5498	52.3
622	38	36.32	-94.53	342	Tonti	0.05	60.98	WPAS	0	w/o N rep	17877	52.3
309	17	36.41	-94.48	105	Tonti	0.06	60.98	WPAS	0	w/o N rep	5487	52.3
187	10	36.37	-94.41	57	Tonti	0.06	60.98	WPAS	0	w/o N rep	2994	52.3
692	43	36.36	-94.65	40	Taloka	0.03	60.98	HAY	0	w N rep	2095	52.2
1035	68	36.33	-94.61	73	Tonti	0.05	36.58	HAY	0	w N rep	3807	51.8
931	57	36.39	-94.94	27	Britwater	0.09	18.29	OPAS	0.5385	w/o N rep	1385	51.6
721	45	36.28	-94.67	177	Doniphan	0.03	91.46	WPAS	0	w/o N rep	9127	51.5
84	4	36.4	-94.57	174	Nixa	0.02	121.95	WPAS	0	w/o N rep	8983	51.5
59	3	36.42	-94.67	324	Nixa	0.02	91.46	WPAS	0	w/o N rep	16689	51.5
147	8	36.37	-94.33	131	Nixa	0.03	91.46	WPAS	0	w/o N rep	6640	50.7
127	7	36.4	-94.31	155	Nixa	0.03	91.46	WPAS	0	w/o N rep	7882	50.7
472	29	36.34	-94.36	384	Nixa	0.06	60.98	WPAS	0	w/o N rep	19458	50.7
473	29	36.34	-94.36	166	Tonti	0.06	60.98	WPAS	0	w/o N rep	8310	49.9
148	8	36.37	-94.33	230	Tonti	0.03	91.46	WPAS	0	w/o N rep	11493	49.9
128	7	36.4	-94.31	199	Tonti	0.03	91.46	WPAS	0	w/o N rep	9949	49.9
1024	68	36.33	-94.61	198	Doniphan	0.05	36.58	WPAS	0	w/o N rep	9868	49.9
565	35	36.32	-94.71	14	Clarksville	0.07	18.29	OPAS	2.5846		695	48.8
918	56	36.38	-94.44	1	Clarksville	0.08	60.98	WPAS	0	w/o N rep	29	48.3
207	11	36.4	-94.99	20	Clarksville	0.10	24.39	OPAS	0.5385	w/o N rep	967	48.2
930	57	36.39	-94.94	4	Clarksville	0.09	18.29	OPAS	1.0769	w/o N rep	179	47.1
86	4	36.4	-94.57	30	Jay	0.02	121.95	OPAS	0	w/o N rep	1409	46.6
567	35	36.32	-94.71	19	Doniphan	0.07	18.29	OPAS	2.5846		863	46.5
35	2	36.43	-94.7	136	Captina	0.04	60.98	OPAS	0	w/o N rep	6161	45.2
652	41	36.33	-94.65	14	Clarksville	0.07	24.39	HAY	0	w N rep	622	44.0
901	55	36.27	-94.74	133	Clarksville	0.06	60.98	OPAS	1.0769	w/o N rep	5770	43.4
972	62	36.33	-94.8	35	Clarksville	0.05	36.58	OPAS	2.5846		1485	42.9
902	55	36.27	-94.74	499	Doniphan	0.06	60.98	OPAS	1.8308	w/o N rep	21257	42.6
501	31	36.36	-94.78	2	Clarksville	0.05	24.39	OPAS	1.8308	w/o N rep	102	41.7
252	14	36.37	-94.66	71	Newtonia	0.03	91.46	OPAS	0	w/o N rep	2941	41.6
711	44	36.3	-94.68	16	Clarksville	0.04	60.98	HAY	0	w N rep	656	41.2
953	60	36.37	-94.81	0	Clarksville	0.10	18.29	OPAS	1.8308	w/o N rep	17	41.0
761	47	36.39	-94.84	18	Clarksville	0.09	24.39	OPAS	1.8308	w/o N rep	733	40.4
762	47	36.39	-94.84	6	Doniphan	0.09	24.39	OPAS	1.8308	w/o N rep	259	40.4
973	62	36.33	-94.8	45	Doniphan	0.05	36.58	OPAS	1.8308	w/o N rep	1819	40.3
1043	69	36.35	-95.01	7	Captina	0.06	24.39	OPAS	0	w/o N rep	263	39.7
515	32	36.35	-94.77	3	Clarksville	0.05	18.29	OPAS	1.8308	w/o N rep	129	39.4
812	50	36.27	-94.81	100	Clarksville	0.09	24.39	OPAS	1.8308	w/o N rep	3896	39.1
813	50	36.27	-94.81	86	Doniphan	0.09	24.39	OPAS	1.8308	w/o N rep	3358	39.1
227	13	36.41	-94.66	96	Newtonia	0.05	60.98	OPAS	0	w/o N rep	3714	38.8
1045	69	36.35	-95.01	3	Peridge	0.06	24.39	OPAS	0	w/o N rep	132	38.6
119	6	36.38	-94.61	59	Taloka	0.01	121.95	HAY	0	w N rep	2271	38.4
667	42	36.3	-94.65	27	Clarksville	0.05	36.58	HAY	0	w N rep	1041	38.4
745	46	36.29	-94.61	75	Captina	0.03	60.98	OPAS	0	w/o N rep	2825	37.9
85	4	36.4	-94.57	46	Captina	0.02	121.95	OPAS	0	w/o N rep	1734	37.4
777	48	36.4	-94.79	82	Clarksville	0.11	24.39	OPAS	0	w/o N rep	3047	37.4
389	22	36.37	-94.51	51	Captina	0.06	36.58	OPAS	0	w/o N rep	1905	37.3
725	45	36.28	-94.67	59	Macedonia	0.03	91.46	OPAS	0	w/o N rep	2201	37.1
130	7	36.4	-94.31	55	Captina	0.03	91.46	OPAS	0	w/o N rep	2017	36.7

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
602	37	36.36	-94.59	4	Clarksville	0.06	24.39	OPAS	0	w/o N rep	132	36.5
1044	69	36.35	-95.01	4	Nixa	0.06	24.39	OPAS	0	w/o N rep	161	36.5
605	37	36.36	-94.59	3	Nixa	0.06	24.39	OPAS	0	w/o N rep	125	36.5
868	53	36.35	-94.57	8	Clarksville	0.07	24.39	OPAS	0	w/o N rep	294	36.5
409	23	36.36	-94.55	5	Captina	0.05	24.39	OPAS	0	w/o N rep	196	36.5
604	37	36.36	-94.59	4	Taloka	0.06	24.39	OPAS	0	w/o N rep	140	36.5
606	37	36.36	-94.59	6	Peridge	0.06	24.39	OPAS	0	w/o N rep	210	36.5
410	23	36.36	-94.55	10	Peridge	0.05	24.39	OPAS	0	w/o N rep	354	36.5
191	10	36.37	-94.41	17	Peridge	0.06	60.98	OPAS	0	w/o N rep	626	36.5
314	17	36.41	-94.48	18	Noark	0.06	60.98	OPAS	0	w/o N rep	657	36.5
705	44	36.3	-94.68	20	Macedonia	0.04	60.98	OPAS	0	w/o N rep	712	36.5
660	42	36.3	-94.65	10	Clarksville	0.05	36.58	OPAS	0	w/o N rep	372	36.5
332	18	36.39	-94.47	23	Nixa	0.05	60.98	OPAS	0	w/o N rep	830	36.5
490	30	36.33	-94.39	9	Nixa	0.08	36.58	OPAS	0	w/o N rep	343	36.5
662	42	36.3	-94.65	23	Macedonia	0.05	36.58	OPAS	0	w/o N rep	858	36.5
392	22	36.37	-94.51	14	Peridge	0.06	36.58	OPAS	0	w/o N rep	514	36.5
13	1	36.44	-94.67	28	Macedonia	0.07	60.98	OPAS	0	w/o N rep	1032	36.5
427	24	36.34	-94.49	28	Secesh	0.05	60.98	OPAS	0	w/o N rep	1032	36.5
250	14	36.37	-94.66	33	Doniphan	0.03	91.46	OPAS	0	w/o N rep	1207	36.5
703	44	36.3	-94.68	17	Captina	0.04	60.98	OPAS	0	w/o N rep	603	36.5
132	7	36.4	-94.31	21	Tonti	0.03	91.46	OPAS	0	w/o N rep	779	36.5
271	15	34.4	-94.44	22	Nixa	0.05	60.98	OPAS	0	w/o N rep	805	36.5
64	3	36.42	-94.67	44	Peridge	0.02	91.46	OPAS	0	w/o N rep	1612	36.5
150	8	36.37	-94.33	24	Nixa	0.03	91.46	OPAS	0	w/o N rep	860	36.5
224	13	36.41	-94.66	50	Clarksville	0.05	60.98	OPAS	0	w/o N rep	1813	36.5
661	42	36.3	-94.65	28	Doniphan	0.05	36.58	OPAS	0	w/o N rep	1006	36.5
169	9	36.4	-94.37	61	Captina	0.05	60.98	OPAS	0	w/o N rep	2215	36.5
684	43	36.36	-94.65	61	Newtonia	0.03	60.98	OPAS	0	w/o N rep	2218	36.5
225	13	36.41	-94.66	62	Clarksville	0.05	60.98	OPAS	0	w/o N rep	2276	36.5
10	1	36.44	-94.67	38	Clarksville	0.07	60.98	OPAS	0	w/o N rep	1386	36.5
333	18	36.39	-94.47	38	Tonti	0.05	60.98	OPAS	0	w/o N rep	1386	36.5
793	49	36.37	-94.73	82	Clarksville	0.07	36.58	OPAS	0	w/o N rep	2997	36.5
373	21	36.41	-94.51	48	Nixa	0.04	60.98	OPAS	0	w/o N rep	1757	36.5
290	16	36.35	-94.44	53	Nixa	0.07	60.98	OPAS	0	w/o N rep	1935	36.5
226	13	36.41	-94.66	59	Doniphan	0.05	60.98	OPAS	0	w/o N rep	2164	36.5
625	38	36.32	-94.53	60	Tonti	0.05	60.98	OPAS	0	w/o N rep	2193	36.5
149	8	36.37	-94.33	65	Captina	0.03	91.46	OPAS	0	w/o N rep	2366	36.5
797	49	36.37	-94.73	80	Macedonia	0.07	36.58	OPAS	0	w/o N rep	2916	36.5
63	3	36.42	-94.67	88	Nixa	0.02	91.46	OPAS	0	w/o N rep	3207	36.5
34	2	36.43	-94.7	159	Clarksville	0.04	60.98	OPAS	0	w/o N rep	5792	36.5
37	2	36.43	-94.7	154	Doniphan	0.04	60.98	OPAS	0	w/o N rep	5632	36.5
170	9	36.4	-94.37	149	Nixa	0.05	60.98	OPAS	0	w/o N rep	5427	36.5
682	43	36.36	-94.65	85	Clarksville	0.03	60.98	OPAS	0	w/o N rep	3098	36.5
87	4	36.4	-94.57	56	Newtonia	0.02	121.95	OPAS	0	w/o N rep	2056	36.5
61	3	36.42	-94.67	48	Captina	0.02	91.46	OPAS	0	w/o N rep	1766	36.5
251	14	36.37	-94.66	42	Macedonia	0.03	91.46	OPAS	0	w/o N rep	1537	36.5
744	46	36.29	-94.61	36	Clarksville	0.03	60.98	OPAS	0	w/o N rep	1303	36.5
1026	68	36.33	-94.61	33	Captina	0.05	36.58	OPAS	0	w/o N rep	1189	36.5
151	8	36.37	-94.33	32	Tonti	0.03	91.46	OPAS	0	w/o N rep	1158	36.5
1028	68	36.33	-94.61	23	Tonti	0.05	36.58	OPAS	0	w/o N rep	837	36.5
131	7	36.4	-94.31	18	Nixa	0.03	91.46	OPAS	0	w/o N rep	663	36.5
623	38	36.32	-94.53	128	Captina	0.05	60.98	OPAS	0	w/o N rep	4667	36.5
115	6	36.38	-94.61	125	Newtonia	0.01	121.95	OPAS	0	w/o N rep	4582	36.5
38	2	36.43	-94.7	112	Macedonia	0.04	60.98	OPAS	0	w/o N rep	4075	36.5
683	43	36.36	-94.65	94	Macedonia	0.03	60.98	OPAS	0	w/o N rep	3415	36.5

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
796	49	36.37	-94.73	41	Doniphan	0.07	36.58	OPAS	0	w/o N rep	1505	36.5
746	46	36.29	-94.61	30	Tonti	0.03	60.98	OPAS	0	w/o N rep	1102	36.5
390	22	36.37	-94.51	18	Nixa	0.06	36.58	OPAS	0	w/o N rep	666	36.5
311	17	36.41	-94.48	12	Captina	0.06	60.98	OPAS	0	w/o N rep	431	36.5
426	24	36.34	-94.49	78	Nixa	0.05	60.98	OPAS	0	w/o N rep	2843	36.5
272	15	34.4	-94.44	73	Tonti	0.05	60.98	OPAS	0	w/o N rep	2669	36.5
9	1	36.44	-94.67	56	Clarksville	0.07	60.98	OPAS	0	w/o N rep	2061	36.5
778	48	36.4	-94.79	56	Clarksville	0.11	24.39	OPAS	0	w/o N rep	2032	36.5
331	18	36.39	-94.47	51	Captina	0.05	60.98	OPAS	0	w/o N rep	1860	36.5
270	15	34.4	-94.44	48	Captina	0.05	60.98	OPAS	0	w/o N rep	1771	36.5
425	24	36.34	-94.49	46	Captina	0.05	60.98	OPAS	0	w/o N rep	1687	36.5
887	54	36.42	-94.62	45	Newtonia	0.02	91.46	OPAS	0	w/o N rep	1628	36.5
624	38	36.32	-94.53	45	Nixa	0.05	60.98	OPAS	0	w/o N rep	1626	36.5
171	9	36.4	-94.37	82	Tonti	0.05	60.98	OPAS	0	w/o N rep	2991	36.5
291	16	36.35	-94.44	80	Peridge	0.07	60.98	OPAS	0	w/o N rep	2936	36.5
724	45	36.28	-94.67	75	Doniphan	0.03	91.46	OPAS	0	w/o N rep	2734	36.5
11	1	36.44	-94.67	37	Captina	0.07	60.98	OPAS	0	w/o N rep	1340	36.5
313	17	36.41	-94.48	37	Tonti	0.06	60.98	OPAS	0	w/o N rep	1336	36.5
475	29	36.34	-94.36	68	Nixa	0.06	60.98	OPAS	0	w/o N rep	2501	36.5
189	10	36.37	-94.41	33	Nixa	0.06	60.98	OPAS	0	w/o N rep	1193	36.5
62	3	36.42	-94.67	61	Newtonia	0.02	91.46	OPAS	0	w/o N rep	2210	36.5
372	21	36.41	-94.51	59	Captina	0.04	60.98	OPAS	0	w/o N rep	2152	36.5
1027	68	36.33	-94.61	29	Doniphan	0.05	36.58	OPAS	0	w/o N rep	1046	36.5
794	49	36.37	-94.73	51	Clarksville	0.07	36.58	OPAS	0	w/o N rep	1865	36.5
312	17	36.41	-94.48	22	Nixa	0.06	60.98	OPAS	0	w/o N rep	786	36.5
488	30	36.33	-94.39	4	Clarksville	0.08	36.58	OPAS	0	w/o N rep	146	36.5
1025	68	36.33	-94.61	39	Clarksville	0.05	36.58	OPAS	0	w/o N rep	1429	36.5
391	22	36.37	-94.51	18	Tonti	0.06	36.58	OPAS	0	w/o N rep	674	36.5
747	46	36.29	-94.61	37	Taloka	0.03	60.98	OPAS	0	w/o N rep	1345	36.5
869	53	36.35	-94.57	4	Britwater	0.07	24.39	OPAS	0	w/o N rep	132	36.5
88	4	36.4	-94.57	34	Nixa	0.02	121.95	OPAS	0	w/o N rep	1230	36.5
114	6	36.38	-94.61	30	Taloka	0.01	121.95	OPAS	0	w/o N rep	1081	36.5
428	24	36.34	-94.49	28	Peridge	0.05	60.98	OPAS	0	w/o N rep	1024	36.5
474	29	36.34	-94.36	12	Clarksville	0.06	60.98	OPAS	0	w/o N rep	438	36.5
12	1	36.44	-94.67	23	Doniphan	0.07	60.98	OPAS	0	w/o N rep	852	36.5
188	10	36.37	-94.41	11	Britwater	0.06	60.98	OPAS	0	w/o N rep	411	36.5
644	41	36.33	-94.65	7	Clarksville	0.07	24.39	OPAS	0	w/o N rep	265	36.5
646	41	36.33	-94.65	3	Captina	0.07	24.39	OPAS	0	w/o N rep	104	36.5
603	37	36.36	-94.59	11	Captina	0.06	24.39	OPAS	0	w/o N rep	385	36.5
489	30	36.33	-94.39	4	Captina	0.08	36.58	OPAS	0	w/o N rep	150	36.5
870	53	36.35	-94.57	6	Waben	0.07	24.39	OPAS	0	w/o N rep	224	36.5
190	10	36.37	-94.41	9	Tonti	0.06	60.98	OPAS	0	w/o N rep	344	36.5
871	53	36.35	-94.57	7	Peridge	0.07	24.39	OPAS	0	w/o N rep	240	36.5
645	41	36.33	-94.65	5	Clarksville	0.07	24.39	OPAS	0	w/o N rep	199	36.5
689	43	36.36	-94.65	61	Clarksville	0.03	60.98	HAY	0	w N rep	1882	30.8
279	15	34.4	-94.44	35	Noark	0.05	60.98	HAY	0	w N rep	1053	30.4
234	13	36.41	-94.66	109	Clarksville	0.05	60.98	HAY	0	w N rep	3054	27.9
801	49	36.37	-94.73	117	Clarksville	0.07	36.58	HAY	0	w N rep	3227	27.5
19	1	36.44	-94.67	47	Clarksville	0.07	60.98	HAY	0	w N rep	1256	26.9
783	48	36.4	-94.79	54	Clarksville	0.11	24.39	HAY	0	w N rep	1263	23.2
877	53	36.35	-94.57	6	Waben	0.07	24.39	HAY	0	w/o N rep	144	22.2
395	22	36.37	-94.51	21	Clarksville	0.06	36.58	HAY	0	w N rep	392	18.5
609	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	0	w N rep	137	18.4
875	53	36.35	-94.57	18	Clarksville	0.07	24.39	HAY	0	w N rep	335	18.3
494	30	36.33	-94.39	9	Clarksville	0.08	36.58	HAY	0	w N rep	147	16.8

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price	Per hectare shadow price ($/ha.)
295	16	36.35	-94.44	41	Clarksville	0.07	60.98	HAY	0	w N rep	671	16.5
1033	68	36.33	-94.61	136	Clarksville	0.05	36.58	HAY	0	w N rep	2175	16.0
431	24	36.34	-94.49	52	Clarksville	0.05	60.98	HAY	0	w N rep	837	16.0
628	38	36.32	-94.53	61	Clarksville	0.05	60.98	HAY	0	w N rep	906	14.8
338	18	36.39	-94.47	53	Nixa	0.05	60.98	HAY	0	w N rep	768	14.6
377	21	36.41	-94.51	104	Nixa	0.04	60.98	HAY	0	w N rep	1491	14.3
320	17	36.41	-94.48	49	Nixa	0.06	60.98	HAY	0	w N rep	668	13.8
277	15	34.4	-94.44	85	Nixa	0.05	60.98	HAY	0	w N rep	1165	13.8
478	29	36.34	-94.36	37	Clarksville	0.06	60.98	HAY	0	w N rep	503	13.7
923	56	36.38	-94.44	0	Clarksville	0.08	60.98	HAY	0	w/o N rep	4	13.2
397	22	36.37	-94.51	35	Nixa	0.06	36.58	HAY	0	w N rep	456	12.9
415	23	36.36	-94.55	4	Nixa	0.05	24.39	HAY	0	w N rep	46	12.9
611	37	36.36	-94.59	7	Nixa	0.06	24.39	HAY	0	w N rep	94	12.8
495	30	36.33	-94.39	42	Nixa	0.08	36.58	HAY	0	w N rep	530	12.5
433	24	36.34	-94.49	190	Nixa	0.05	60.98	HAY	0	w N rep	2373	12.5
297	16	36.35	-94.44	102	Nixa	0.07	60.98	HAY	0	w N rep	1174	11.5
630	38	36.32	-94.53	123	Nixa	0.05	60.98	HAY	0	w N rep	1409	11.4
924	56	36.38	-94.44	1	Britwater	0.08	60.98	HAY	0	w/o N rep	8	11.2
196	10	36.37	-94.41	98	Nixa	0.06	60.98	HAY	0	w N rep	1019	10.5
1050	69	36.35	-95.01	3	Nixa	0.06	24.39	HAY	0	w N rep	26	10.4
176	9	36.4	-94.37	407	Nixa	0.05	60.98	HAY	0	w N rep	2276	5.6
138	7	36.4	-94.31	32	Nixa	0.03	91.46	HAY	0	w/o N rep	38	1.2
158	8	36.37	-94.33	41	Nixa	0.03	91.46	HAY	0	w/o N rep	41	1.0
479	29	36.34	-94.36	144	Nixa	0.06	60.98	HAY	0	w/o N rep	129	0.9
69	3	36.42	-94.67	226	Nixa	0.02	91.46	HAY	0	w N rep	202	0.9
93	4	36.4	-94.57	151	Nixa	0.02	121.95	HAY	0	w/o N rep	41	0.3
954	60	36.37	-94.81	0	Water	0.10	18.29	OPAS	0	w/o N rep	-13	-32.6
538	33	36.35	-94.82	5	Water	0.11	24.39	OPAS	0	w/o N rep	-157	-32.6
446	25	36.37	-94.87	2	Water	0.11	24.39	HAY	1	w/o N rep	-58	-36.5
543	33	36.35	-94.82	6	Water	0.11	24.39	HAY	1	w/o N rep	-225	-36.6
1003	64	36.37	-94.91	2	Water	0.11	36.58	HAY	0	w/o N rep	-86	-37.7
925	56	36.38	-94.44	0	Water	0.08	60.98	HAY	0	w/o N rep	-7	-37.7
205	11	36.4	-94.99	24	Water	0.10	24.39	WPAS	0	w/o N rep	-938	-38.5
534	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0	w/o N rep	-188	-38.5
455	27	36.36	-94.8	2	Water	0.13	36.58	WPAS	0	w/o N rep	-76	-38.5
443	25	36.37	-94.87	4	Water	0.11	24.39	WPAS	0	w/o N rep	-168	-38.5

Table A 9. Spatial Detail for the Optimal Solution for Policy 3.

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
733	45	36.28	-94.67	10	Captina	0.02	91.46	HAST	6		1570	1	163.2
577	35	36.32	-94.71	6	Razort	0.04	18.29	HAST	4	w N rep	990	1	160.2
854	52	36.32	-94.68	1	Razort	0.10	24.39	HAST	4.8		184	0	159.1
572	35	36.32	-94.71	41	Razort	0.07	18.29	HAST	4	w N rep	6460	0	158.7
911	55	36.27	-94.74	31	Captina	0.04	60.98	HAST	4.8		4773	1	155.2
507	31	36.36	-94.78	5	Healing	0.05	24.39	HAST	4	w N rep	744	0	153.2
735	45	36.28	-94.67	31	Macedonia	0.02	91.46	HAST	6	w alum;	4782	1	153.1
730	45	36.28	-94.67	40	Clarksville	0.03	91.46	HAST	6	w alum;	6145	0	152.0
522	32	36.35	-94.77	22	Healing	0.05	18.29	HAST	4	w N rep	3327	0	151.9
734	45	36.28	-94.67	16	Doniphan	0.02	91.46	HAST	6		2362	1	151.7
821	50	36.27	-94.81	15	Razort	0.09	24.39	HAST	4	w N rep	2286	1	151.6
593	36	36.34	-94.76	2	Razort	0.02	60.98	HAST	4	w N rep	372	1	151.5
817	50	36.27	-94.81	118	Razort	0.09	24.39	HAST	4	w N rep	17839	0	151.1
835	51	36.35	-94.75	1	Razort	0.01	15.24	HAST	4	w N rep	217	1	150.9
592	36	36.34	-94.76	3	Razort	0.05	60.98	HAST	4	w N rep	398	0	150.8
731	45	36.28	-94.67	158	Doniphan	0.03	91.46	HAST	6		23853	0	150.8
732	45	36.28	-94.67	83	Macedonia	0.03	91.46	HAST	6	w alum;	12579	0	150.8
912	55	36.27	-94.74	40	Britwater	0.04	60.98	HAST	6	w alum;	5941	1	150.0
834	51	36.35	-94.75	1	Razort	0.06	15.24	HAST	4	w N rep	161	0	149.9
766	47	36.39	-94.84	26	Razort	0.09	24.39	HAST	4	w N rep	3824	0	149.4
504	31	36.36	-94.78	3	Razort	0.05	24.39	HAST	4	w N rep	391	0	149.0
523	32	36.35	-94.77	6	Razort	0.03	18.29	HAST	4	w N rep	939	1	148.8
990	63	36.32	-94.89	4	Razort	0.08	18.29	HAST	4	w N rep	544	0	148.5
712	44	36.3	-94.68	21	Captina	0.04	60.98	HAST	4.8	w alum;	3139	0	148.2
520	32	36.35	-94.77	5	Razort	0.05	18.29	HAST	4	w N rep	796	0	148.1
755	46	36.29	-94.61	41	Captina	0.02	60.98	HAST	4.8		6052	1	147.8
367	20	36.36	-94.89	14	Razort	0.16	24.39	HAST	4	w N rep	2012	0	146.0
695	43	36.36	-94.65	150	Newtonia	0.01	60.98	HAST	4.8		21930	1	145.7
907	55	36.27	-94.74	348	Clarksville	0.06	60.98	HAST	4.8	w alum;	50705	0	145.5
580	35	36.32	-94.71	7	Britwater	0.04	18.29	HAST	6	w alum;	1079	1	145.5
913	55	36.27	-94.74	79	Doniphan	0.04	60.98	HAST	6		11560	1	145.5
753	46	36.29	-94.61	184	Captina	0.03	60.98	HAST	4.8	w alum;	26592	0	144.5
232	13	36.41	-94.66	114	Razort	0.05	60.98	HAST	4	w N rep	16473	0	144.3
909	55	36.27	-94.74	808	Doniphan	0.06	60.98	HAST	4.8		116400	0	144.1
653	41	36.33	-94.65	18	Britwater	0.07	24.39	HAST	6	w alum;	2509	0	143.4
693	43	36.36	-94.65	60	Newtonia	0.03	60.98	HAST	4.8		8619	0	143.4
856	52	36.32	-94.68	2	Britwater	0.10	24.39	HAST	6	w alum;	247	0	142.6
354	19	36.35	-94.92	7	Razort	0.06	24.39	HAST	3.4	w/o N rep	1062	0	141.6
714	44	36.3	-94.68	33	Macedonia	0.04	60.98	HAST	4.8	w alum;	4681	0	141.5
713	44	36.3	-94.68	20	Doniphan	0.04	60.98	HAST	4.8		2841	0	141.1
1000	64	36.37	-94.91	6	Razort	0.11	36.58	HAST	4	w N rep	781	0	140.6
710	44	36.3	-94.68	13	Clarksville	0.04	60.98	HAST	6	w alum;	1895	0	140.6
715	44	36.3	-94.68	5	Clarksville	0.08	60.98	HAST	4.8	w alum;	664	1	139.8
857	52	36.32	-94.68	2	Doniphan	0.10	24.39	HAST	4.8		254	0	139.5
262	14	36.37	-94.66	19	Newtonia	0.02	91.46	HAST	4.8		2675	1	139.4
717	44	36.3	-94.68	3	Macedonia	0.08	60.98	HAST	4.8	w alum;	353	1	139.3
575	35	36.32	-94.71	38	Doniphan	0.07	18.29	HAST	4.8		5304	0	139.1
756	46	36.29	-94.61	31	Taloka	0.02	60.98	HAST	4.8	w alum;	4343	1	138.9
259	14	36.37	-94.66	115	Newtonia	0.03	91.46	HAST	4.8		15900	0	138.8
240	13	36.41	-94.66	62	Newtonia	0.03	60.98	HAST	4.8		8582	1	138.6
578	35	36.32	-94.71	15	Clarksville	0.04	18.29	HAST	4.8		2110	1	138.4
576	35	36.32	-94.71	56	Macedonia	0.07	18.29	HAST	4.8	w alum;	7726	0	138.4
858	52	36.32	-94.68	1	Clarksville	0.09	24.39	HAST	4.8		111	1	138.0
594	36	36.34	-94.76	7	Britwater	0.02	60.98	HAST	4.8	w alum;	903	1	137.8
836	51	36.35	-94.75	1	Britwater	0.01	15.24	HAST	4.8	w alum;	87	1	137.5
573	35	36.32	-94.71	87	Clarksville	0.07	18.29	HAST	4.8	w alum;	11909	0	137.4
651	41	36.33	-94.65	24	Clarksville	0.07	24.39	HAST	4.8	w alum;	3335	0	137.3
672	42	36.3	-94.65	5	Doniphan	0.05	36.58	HAST	4.8		688	1	137.0
668	42	36.3	-94.65	46	Doniphan	0.05	36.58	HAST	4.8		6305	0	137.0
984	62	36.33	-94.8	17	Jay	0.03	36.58	HAST	4	w alum;	2277	1	136.9
805	49	36.37	-94.73	12	Taloka	0.06	36.58	HAST	4	w alum;	1669	1	136.8
160	8	36.37	-94.33	39	Captina	0.02	91.46	HAST	6	w alum;	5271	1	136.8
666	42	36.3	-94.65	35	Clarksville	0.05	36.58	HAST	4.8	w alum;	4823	0	136.3
670	42	36.3	-94.65	4	Clarksville	0.05	36.58	HAST	4.8	w alum;	602	1	136.3

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
669	42	36.3	-94.65	40	Macedonia	0.05	36.58	HAST	4.8	w alum;	5387	0	136.2
17	1	36.44	-94.67	52	Razort	0.07	60.98	HAST	4	w N rep	7076	0	135.7
673	42	36.3	-94.65	13	Macedonia	0.05	36.58	HAST	4.8	w alum;	1701	1	135.4
157	8	36.37	-94.33	58	Captina	0.03	91.46	HAST	6	w alum;	7860	0	134.6
781	48	36.4	-94.79	45	Razort	0.11	24.39	HAST	4	w alum;	5995	0	134.5
910	55	36.27	-94.74	24	Clarksville	0.04	60.98	HAST	4.8	w alum;	3197	1	134.5
525	32	36.35	-94.77	4	Britwater	0.03	18.29	HAST	4.8		565	1	134.3
908	55	36.27	-94.74	228	Clarksville	0.06	60.98	HAST	4.8	w alum;	30600	0	134.3
754	46	36.29	-94.61	82	Taloka	0.03	60.98	HAST	4.8	w alum;	10957	0	134.2
236	13	36.41	-94.66	119	Newtonia	0.05	60.98	HAST	4.8	w alum;	16024	0	134.2
752	46	36.29	-94.61	101	Clarksville	0.03	60.98	HAST	4.8	w alum;	13546	0	134.1
47	2	36.43	-94.7	58	Captina	0.03	60.98	HAST	4.8	w alum;	7811	1	134.1
140	7	36.4	-94.31	21	Captina	0.02	91.46	HAST	6	w alum;	2796	1	133.0
24	1	36.44	-94.67	12	Captina	0.05	60.98	HAST	4	w N rep	1650	1	132.9
694	43	36.36	-94.65	99	Taloka	0.01	60.98	HAST	4.8	w alum;	13113	1	132.9
981	62	36.33	-94.8	5	Clarksville	0.03	36.58	HAST	4.8		637	1	132.8
983	62	36.33	-94.8	13	Doniphan	0.03	36.58	HAST	4.8		1707	1	132.0
978	62	36.33	-94.8	50	Clarksville	0.05	36.58	HAST	4.8		6572	0	132.0
25	1	36.44	-94.67	5	Taloka	0.05	60.98	HAST	4	w alum;	676	1	131.9
459	27	36.36	-94.8	1	Britwater	0.13	36.58	HAST	4.8	w alum;	142	0	131.9
980	62	36.33	-94.8	99	Doniphan	0.05	36.58	HAST	4.8		13075	0	131.5
691	43	36.36	-94.65	68	Macedonia	0.03	60.98	HAST	4.8	w alum;	8875	0	131.4
820	50	36.27	-94.81	107	Doniphan	0.09	24.39	HAST	4.8		14005	0	131.1
992	63	36.32	-94.89	5	Britwater	0.08	18.29	HAST	4.8	w alum;	599	0	130.8
44	2	36.43	-94.7	314	Captina	0.04	60.98	HAST	4.8	w alum;	41008	0	130.8
822	50	36.27	-94.81	64	Clarksville	0.09	24.39	HAST	4.8		8414	1	130.7
690	43	36.36	-94.65	41	Doniphan	0.03	60.98	HAST	4.8	w alum;	5378	0	130.7
137	7	36.4	-94.31	143	Captina	0.03	91.46	HAST	6	w alum;	18647	0	130.5
818	50	36.27	-94.81	300	Clarksville	0.09	24.39	HAST	4.8	w alum;	39075	0	130.4
258	14	36.37	-94.66	67	Jay	0.03	91.46	HAST	4	w alum;	8657	0	130.1
468	28	36.36	-94.79	8	Clarksville	0.07	24.39	HAST	4.8	w alum;	1062	0	130.1
300	16	36.35	-94.44	14	Newtonia	0.05	60.98	HAST	4.8		1809	1	129.5
711	44	36.3	-94.68	16	Clarksville	0.04	60.98	HAST	4.8	w alum;	2058	0	129.4
716	44	36.3	-94.68	8	Clarksville	0.08	60.98	HAST	4.8	w alum;	1079	1	129.3
178	9	36.4	-94.37	26	Captina	0.04	60.98	HAST	4.8	w alum;	3319	1	129.1
180	9	36.4	-94.37	12	Tonti	0.04	60.98	HAST	6	w alum;	1545	1	128.8
692	43	36.36	-94.65	40	Taloka	0.03	60.98	HAST	4.8	w alum;	5167	0	128.8
688	43	36.36	-94.65	44	Clarksville	0.03	60.98	HAST	4.8	w alum;	5657	0	128.6
458	27	36.36	-94.8	2	Clarksville	0.13	36.58	HAST	4.8	w alum;	275	0	128.5
956	60	36.37	-94.81	6	Clarksville	0.10	18.29	HAST	4.8	w alum;	821	0	128.3
581	35	36.32	-94.71	5	Elsah	0.04	18.29	HAST	6		661	1	128.2
302	16	36.35	-94.44	42	Peridge	0.05	60.98	HAST	4.8	w alum;	5377	1	128.0
299	16	36.35	-94.44	12	Captina	0.05	60.98	HAST	4	w alum;	1480	1	128.0
579	35	36.32	-94.71	7	Clarksville	0.04	18.29	HAST	4.8	w alum;	936	1	127.9
542	33	36.35	-94.82	5	Britwater	0.11	24.39	HAST	4.8	w alum;	665	0	127.8
574	35	36.32	-94.71	46	Clarksville	0.07	18.29	HAST	4.8	w alum;	5818	0	127.8
652	41	36.33	-94.65	14	Clarksville	0.07	24.39	HAST	4.8	w alum;	1806	0	127.6
855	52	36.32	-94.68	5	Clarksville	0.10	24.39	HAST	4.8	w alum;	661	0	127.2
209	11	36.4	-94.99	11	Razort	0.10	24.39	HAST	3.4	w/o N rep	1429	0	127.0
967	61	36.35	-94.79	2	Doniphan	0.06	24.39	HAST	4.8		206	0	126.6
239	13	36.41	-94.66	26	Doniphan	0.03	60.98	HAST	4.8	w alum;	3332	1	126.4
261	14	36.37	-94.66	48	Macedonia	0.02	91.46	HAST	4.8	w alum;	6123	1	126.4
177	9	36.4	-94.37	201	Tonti	0.05	60.98	HAST	6	w alum;	25398	0	126.4
257	14	36.37	-94.66	70	Macedonia	0.03	91.46	HAST	4.8	w alum;	8789	0	126.3
340	18	36.39	-94.47	10	Captina	0.03	60.98	HAST	4	w alum;	1222	1	126.3
162	8	36.37	-94.33	21	Tonti	0.02	91.46	HAST	6	w alum;	2608	1	126.2
480	29	36.34	-94.36	53	Tonti	0.06	60.98	HAST	6	w alum;	6637	0	126.1
991	63	36.32	-94.89	5	Clarksville	0.08	18.29	HAST	4.8		646	0	126.1
241	13	36.41	-94.66	25	Clarksville	0.03	60.98	HAST	4.8	w alum;	3154	1	126.0
671	42	36.3	-94.65	8	Clarksville	0.05	36.58	HAST	4.8	w alum;	1038	1	125.9
667	42	36.3	-94.65	27	Clarksville	0.05	36.58	HAST	4.8	w alum;	3415	0	125.9
235	13	36.41	-94.66	112	Doniphan	0.05	60.98	HAST	4.8	w alum;	14053	0	125.8
200	10	36.37	-94.41	5	Tonti	0.06	60.98	HAST	6	w alum;	607	1	125.7
280	15	34.4	-94.44	14	Captina	0.04	60.98	HAST	4	w alum;	1770	1	125.5
283	15	34.4	-94.44	13	Peridge	0.04	60.98	HAST	4	w alum;	1676	1	125.3

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
159	8	36.37	-94.33	69	Tonti	0.03	91.46	HAST	6	w alum;	8608	0	125.3
524	32	36.35	-94.77	2	Clarksville	0.03	18.29	HAST	4.8		241	1	125.3
399	22	36.37	-94.51	25	Captina	0.05	36.58	HAST	4	w alum;	3109	1	125.3
505	31	36.36	-94.78	7	Clarksville	0.05	24.39	HAST	4.8	w alum;	827	0	125.1
806	49	36.37	-94.73	11	Doniphan	0.06	36.58	HAST	4.8		1430	1	124.9
521	32	36.35	-94.77	9	Clarksville	0.05	18.29	HAST	4.8	w alum;	1082	0	124.9
807	49	36.37	-94.73	17	Macedonia	0.06	36.58	HAST	4.8	w alum;	2081	1	124.8
20	1	36.44	-94.67	51	Captina	0.07	60.98	HAST	4	w alum;	6381	0	124.8
161	8	36.37	-94.33	9	Taloka	0.02	91.46	HAST	4.8	w alum;	1091	1	124.6
966	61	36.35	-94.79	2	Clarksville	0.06	24.39	HAST	4.8	w alum;	286	0	124.5
175	9	36.4	-94.37	128	Captina	0.05	60.98	HAST	4	w alum;	15915	0	124.2
197	10	36.37	-94.41	48	Tonti	0.06	60.98	HAST	6	w alum;	5982	0	124.0
635	38	36.32	-94.53	46	Peridge	0.03	60.98	HAST	4	w alum;	5704	1	123.9
237	13	36.41	-94.66	27	Clarksville	0.03	60.98	HAST	4.8	w alum;	3354	1	123.8
260	14	36.37	-94.66	14	Clarksville	0.02	91.46	HAST	4.8	w alum;	1751	1	123.7
322	17	36.41	-94.48	4	Captina	0.04	60.98	HAST	4	w alum;	500	1	123.7
142	7	36.4	-94.31	13	Tonti	0.02	91.46	HAST	6		1580	1	123.6
416	23	36.36	-94.55	5	Peridge	0.05	24.39	HAST	4	w alum;	632	0	123.6
276	15	34.4	-94.44	57	Captina	0.05	60.98	HAST	4	w alum;	7054	0	123.5
632	38	36.32	-94.53	80	Captina	0.03	60.98	HAST	4	w alum;	9944	1	123.5
413	23	36.36	-94.55	2	Captina	0.05	24.39	HAST	4	w alum;	252	0	123.5
615	37	36.36	-94.59	2	Peridge	0.05	24.39	HAST	4	w N rep	271	1	123.1
437	24	36.34	-94.49	31	Peridge	0.04	60.98	HAST	4	w alum;	3820	1	123.0
233	13	36.41	-94.66	148	Clarksville	0.05	60.98	HAST	4.8	w alum;	18119	0	122.8
613	37	36.36	-94.59	6	Captina	0.05	24.39	HAST	4	w N rep	776	1	122.8
139	7	36.4	-94.31	73	Tonti	0.03	91.46	HAST	6	w alum;	8991	0	122.6
382	21	36.41	-94.51	4	Peridge	0.03	60.98	HAST	4	w alum;	432	1	122.5
401	22	36.37	-94.51	9	Tonti	0.05	36.58	HAST	6	w alum;	1059	1	122.5
803	49	36.37	-94.73	28	Clarksville	0.06	36.58	HAST	4.8	w alum;	3404	1	122.5
337	18	36.39	-94.47	89	Captina	0.05	60.98	HAST	4	w alum;	10869	0	122.5
379	21	36.41	-94.51	7	Captina	0.03	60.98	HAST	4	w alum;	874	1	122.5
1051	69	36.35	-95.01	2	Healing	0.06	24.39	HAST	3.4	w/o N rep	295	0	122.3
342	18	36.39	-94.47	10	Tonti	0.03	60.98	HAST	6	w alum;	1171	1	122.3
936	57	36.39	-94.94	23	Healing	0.09	18.29	HAST	3.4	w/o N rep	2857	0	122.2
435	24	36.34	-94.49	52	Captina	0.04	60.98	HAST	4	w alum;	6349	1	122.2
49	2	36.43	-94.7	39	Taloka	0.03	60.98	HAST	4.8	w alum;	4728	1	122.0
767	47	36.39	-94.84	129	Clarksville	0.09	24.39	HAST	4.8	w alum;	15652	0	121.8
982	62	36.33	-94.8	10	Clarksville	0.03	36.58	HAST	4.8		1224	1	121.5
819	50	36.27	-94.81	146	Clarksville	0.09	24.39	HAST	4.8		17685	0	121.5
298	16	36.35	-94.44	31	Peridge	0.07	60.98	HAST	4.8	w alum;	3798	0	121.4
550	34	36.33	-94.86	4	Clarksville	0.10	24.39	HAST	4	w N rep	521	0	121.4
823	50	36.27	-94.81	33	Clarksville	0.09	24.39	HAST	4.8		4005	1	121.4
540	33	36.35	-94.82	19	Clarksville	0.11	24.39	HAST	4.8	w alum;	2325	0	121.3
48	2	36.43	-94.7	75	Doniphan	0.03	60.98	HAST	4.8		9116	1	121.3
979	62	36.33	-94.8	113	Clarksville	0.05	36.58	HAST	4.8		13714	0	121.3
800	49	36.37	-94.73	270	Clarksville	0.07	36.58	HAST	4.8	w alum;	32717	0	121.2
434	24	36.34	-94.49	59	Peridge	0.05	60.98	HAST	4	w alum;	7089	0	121.2
45	2	36.43	-94.7	373	Doniphan	0.04	60.98	HAST	4.8	w alum;	45154	0	120.9
282	15	34.4	-94.44	13	Tonti	0.04	60.98	HAST	6	w alum;	1590	1	120.8
198	10	36.37	-94.41	5	Britwater	0.06	60.98	HAST	4.8	w alum;	553	1	120.7
21	1	36.44	-94.67	45	Taloka	0.07	60.98	HAST	3.4	w alum; w/o N rep	5372	0	120.7
319	17	36.41	-94.48	51	Captina	0.06	60.98	HAST	4	w alum;	6146	0	120.6
802	49	36.37	-94.73	217	Macedonia	0.07	36.58	HAST	4.8	w alum;	26198	0	120.6
1037	68	36.33	-94.61	24	Captina	0.04	36.58	HAST	4	w N rep	2851	1	120.5
339	18	36.39	-94.47	65	Tonti	0.05	60.98	HAST	6	w alum;	7799	0	120.5
878	53	36.35	-94.57	10	Peridge	0.07	24.39	HAST	4	w alum;	1224	0	120.5
894	54	36.42	-94.62	6	Newtonia	0.02	91.46	HAST	4	w N rep	729	1	120.4
432	24	36.34	-94.49	62	Captina	0.05	60.98	HAST	4	w alum;	7449	0	120.3
376	21	36.41	-94.51	139	Captina	0.04	60.98	HAST	4	w alum;	16675	0	120.1
96	4	36.4	-94.57	15	Newtonia	0.02	121.95	HAST	4	w N rep	1780	1	120.1
296	16	36.35	-94.44	37	Captina	0.07	60.98	HAST	4	w alum;	4412	0	120.0
445	25	36.37	-94.87	2	Clarksville	0.11	24.39	HAST	4.8	w alum;	273	0	119.8
396	22	36.37	-94.51	62	Captina	0.06	36.58	HAST	4	w alum;	7445	0	119.7
610	37	36.36	-94.59	17	Captina	0.06	24.39	HAST	4	w alum;	2000	0	119.7
278	15	34.4	-94.44	138	Tonti	0.05	60.98	HAST	6	w alum;	16570	0	119.7

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
92	4	36.4	-94.57	130	Newtonia	0.02	121.95	HAST	4	w N rep	15524	0	119.5
629	38	36.32	-94.53	110	Captina	0.05	60.98	HAST	4	w alum;	13198	0	119.5
73	3	36.42	-94.67	28	Newtonia	0.02	91.46	HAST	4	w N rep	3330	1	119.3
494	30	36.33	-94.39	9	Clarksville	0.08	36.58	HAST	4.8	w alum;	1043	0	119.3
355	19	36.35	-94.92	11	Clarksville	0.06	24.39	HAST	4	w N rep	1327	0	119.1
368	20	36.36	-94.89	92	Clarksville	0.16	24.39	HAST	4	w alum;	11006	0	119.1
398	22	36.37	-94.51	29	Tonti	0.06	36.58	HAST	6	w alum;	3468	0	118.8
893	54	36.42	-94.62	88	Newtonia	0.02	91.46	HAST	4	w N rep	10448	0	118.7
71	3	36.42	-94.67	28	Captina	0.02	91.46	HAST	4	w alum;	3309	1	118.6
1002	64	36.37	-94.91	5	Britwater	0.11	36.58	HAST	4	w alum;	615	0	118.5
46	2	36.43	-94.7	38	Clarksville	0.03	60.98	HAST	4.8	w alum;	4543	1	118.5
689	43	36.36	-94.65	61	Clarksville	0.03	60.98	HAST	4.8	w alum;	7241	0	118.4
122	6	36.38	-94.61	63	Newtonia	0.01	121.95	HAST	4	w N rep	7438	1	118.2
957	60	36.37	-94.81	2	Clarksville	0.10	18.29	HAST	4.8	w alum;	201	0	118.2
95	4	36.4	-94.57	13	Captina	0.02	121.95	HAST	4	w alum;	1527	1	117.9
357	19	36.35	-94.92	9	Doniphan	0.06	24.39	HAST	4	w N rep	1026	0	117.9
43	2	36.43	-94.7	343	Clarksville	0.04	60.98	HAST	4.8	w alum;	40359	0	117.8
634	38	36.32	-94.53	45	Tonti	0.03	60.98	HAST	6	w alum;	5354	1	117.8
98	4	36.4	-94.57	22	Peridge	0.02	121.95	HAST	4	w alum;	2579	1	117.8
120	6	36.38	-94.61	142	Newtonia	0.01	121.95	HAST	4	w N rep	16680	0	117.7
381	21	36.41	-94.51	2	Tonti	0.03	60.98	HAST	6		272	1	117.7
324	17	36.41	-94.48	8	Tonti	0.04	60.98	HAST	6	w alum;	926	1	117.6
195	10	36.37	-94.41	47	Britwater	0.06	60.98	HAST	4.8	w alum;	5576	0	117.6
1034	68	36.33	-94.61	76	Captina	0.05	36.58	HAST	4	w alum;	8879	0	117.3
91	4	36.4	-94.57	144	Captina	0.02	121.95	HAST	4	w alum;	16831	0	117.2
70	3	36.42	-94.67	88	Peridge	0.02	91.46	HAST	4	w alum;	10362	0	117.1
67	3	36.42	-94.67	166	Captina	0.02	91.46	HAST	4	w alum;	19419	0	116.9
460	27	36.36	-94.8	1	Elsah	0.13	36.58	HAST	4.8		136	0	116.9
414	23	36.36	-94.55	3	Britwater	0.05	24.39	HAST	4	w alum;	299	0	116.8
551	34	36.33	-94.86	13	Tonti	0.10	24.39	HAST	4	w alum;	1520	0	116.7
378	21	36.41	-94.51	45	Tonti	0.04	60.98	HAST	6	w alum;	5250	0	116.5
22	1	36.44	-94.67	54	Doniphan	0.07	60.98	HAST	4.8	w alum;	6276	0	116.5
321	17	36.41	-94.48	70	Tonti	0.06	60.98	HAST	6	w alum;	8076	0	116.1
631	38	36.32	-94.53	90	Tonti	0.05	60.98	HAST	6	w alum;	10482	0	115.9
784	48	36.4	-94.79	38	Britwater	0.11	24.39	HAST	4	w alum;	4397	0	115.3
1001	64	36.37	-94.91	9	Clarksville	0.11	36.58	HAST	4	w N rep	1026	0	115.1
595	36	36.34	-94.76	6	Elsah	0.02	60.98	HAST	4.8		700	1	114.8
72	3	36.42	-94.67	23	Jay	0.02	91.46	HAST	3.4	w alum; w/o N rep	2611	1	114.0
768	47	36.39	-94.84	57	Clarksville	0.09	24.39	HAST	4.8	w alum;	6460	0	113.9
238	13	36.41	-94.66	22	Clarksville	0.03	60.98	HAST	4.8	w alum;	2519	1	113.8
358	19	36.35	-94.92	21	Tonti	0.06	24.39	HAST	4	w alum;	2377	0	113.8
837	51	36.35	-94.75	1	Elsah	0.01	15.24	HAST	4.8		164	1	113.7
876	53	36.35	-94.57	12	Britwater	0.07	24.39	HAST	4	w alum;	1350	0	113.6
234	13	36.41	-94.66	109	Clarksville	0.05	60.98	HAST	4.8	w alum;	12426	0	113.5
481	29	36.34	-94.36	4	Clarksville	0.06	60.98	HAST	6	w alum;	454	1	113.3
478	29	36.34	-94.36	37	Clarksville	0.06	60.98	HAST	6	w alum;	4147	0	113.2
18	1	36.44	-94.67	117	Clarksville	0.07	60.98	HAST	4.8	w alum;	13247	0	113.0
804	49	36.37	-94.73	12	Clarksville	0.06	36.58	HAST	4.8	w alum;	1378	1	113.0
1038	68	36.33	-94.61	33	Tonti	0.04	36.59	HAST	6		3679	1	112.6
801	49	36.37	-94.73	117	Clarksville	0.07	36.58	HAST	4.8	w alum;	13186	0	112.6
541	33	36.35	-94.82	7	Clarksville	0.11	24.39	HAST	4.8	w alum;	844	0	112.5
785	48	36.4	-94.79	18	Clarksville	0.07	24.39	HAST	4	w alum;	2021	1	112.2
68	3	36.42	-94.67	116	Jay	0.02	91.46	HAST	3.4	w alum; w/o N rep	12966	0	112.1
506	31	36.36	-94.78	5	Elsah	0.05	24.39	HAST	4.8		585	0	111.4
782	48	36.4	-94.79	176	Clarksville	0.11	24.39	HAST	4	w alum;	19368	0	110.2
1035	68	36.33	-94.61	73	Tonti	0.05	36.58	HAST	6	w alum;	8093	0	110.1
608	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAST	4	w alum;	721	0	109.8
94	4	36.4	-94.57	84	Tonti	0.02	121.95	HAST	6	w alum;	9191	0	109.2
210	11	36.4	-94.99	25	Clarksville	0.10	24.39	HAST	3.4	w alum; w/o N rep	2711	0	109.0
1052	69	36.35	-95.01	4	Peridge	0.06	24.39	HAST	3.4	w alum; w/o N rep	478	0	108.9
1048	69	36.35	-95.01	7	Captina	0.06	24.39	HAST	3.4	w alum; w/o N rep	812	0	108.9
356	19	36.35	-94.92	10	Clarksville	0.06	24.39	HAST	4	w N rep	1131	0	108.8
74	3	36.42	-94.67	15	Tonti	0.02	91.46	HAST	4.8	w alum;	1583	1	108.3
1032	68	36.33	-94.61	102	Clarksville	0.05	36.58	HAST	4	w alum;	11055	0	108.3
295	16	36.35	-94.44	41	Clarksville	0.07	60.98	HAST	4.8	w alum;	4402	0	107.9

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
121	6	36.38	-94.61	69	Taloka	0.01	121.95	HAST	4	w alum;	7444	1	107.3
119	6	36.38	-94.61	59	Taloka	0.01	121.95	HAST	4	w alum;	6303	0	106.6
395	22	36.37	-94.51	21	Clarksville	0.06	36.58	HAST	4	w alum;	2252	0	106.1
431	24	36.34	-94.49	52	Clarksville	0.05	60.98	HAST	4	w alum;	5512	0	105.4
935	57	36.39	-94.94	74	Britwater	0.09	18.29	HAST	3.4	w alum; w/o N rep	7831	0	105.2
1013	66	36.36	-95.02	8	Clarksville	0.07	18.29	HAST	3.4	w/o N rep	787	0	104.5
934	57	36.39	-94.94	28	Clarksville	0.09	18.29	HAST	3.4	w alum; w/o N rep	2964	0	104.2
23	1	36.44	-94.67	3	Clarksville	0.05	60.98	HAST	4	w alum;	283	1	103.9
892	54	36.42	-94.62	15	Clarksville	0.02	91.46	HAST	4	w alum;	1576	0	103.7
19	1	36.44	-94.67	47	Clarksville	0.07	60.98	HAST	4	w alum;	4836	0	103.4
628	38	36.32	-94.53	61	Clarksville	0.05	60.98	HAST	4	w alum;	6319	0	103.0
1049	69	36.35	-95.01	3	Britwater	0.06	24.39	HAST	3.4	w alum; w/o N rep	281	0	102.7
786	48	36.4	-94.79	11	Clarksville	0.07	24.39	HAST	4	w alum;	1156	1	102.7
875	53	36.35	-94.57	18	Clarksville	0.07	24.39	HAST	4	w alum;	1872	0	102.6
877	53	36.35	-94.57	6	Waben	0.07	24.39	HAST	4.8		663	0	102.4
783	48	36.4	-94.79	54	Clarksville	0.11	24.39	HAST	4	w alum;	5573	0	102.3
879	53	36.35	-94.57	7	Clarksville	0.12	24.39	HAST	4	w alum;	718	1	102.1
612	37	36.36	-94.59	4	Clarksville	0.05	24.39	HAST	4	w alum;	398	1	101.8
609	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAST	4	w alum;	753	0	101.3
1036	68	36.33	-94.61	13	Clarksville	0.04	36.58	HAST	4	w alum;	1301	1	100.8
1033	68	36.33	-94.61	136	Clarksville	0.05	36.58	HAST	4	w alum;	13632	0	100.4
279	15	34.4	-94.44	35	Noark	0.05	60.98	HAST	4	w alum;	3431	0	99.2
1014	66	36.36	-95.02	11	Clarksville	0.07	18.29	HAST	3.4	w/o N rep	1014	0	95.1
495	30	36.33	-94.39	42	Nixa	0.08	36.58	HAST	4.8	w alum;	4021	0	94.9
301	16	36.35	-94.44	15	Nixa	0.05	60.98	HAST	4	w alum;	1295	1	88.6
179	9	36.4	-94.37	60	Nixa	0.04	60.98	HAST	4	w alum;	5308	1	88.2
199	10	36.37	-94.41	10	Nixa	0.06	60.98	HAST	4	w alum;	834	1	87.4
176	9	36.4	-94.37	407	Nixa	0.05	60.98	HAST	4	w alum;	35490	0	87.1
297	16	36.35	-94.44	102	Nixa	0.07	60.98	HAST	4	w alum;	8908	0	87.0
400	22	36.37	-94.51	7	Nixa	0.05	36.58	HAST	4	w alum;	577	1	86.9
482	29	36.34	-94.36	28	Nixa	0.06	60.98	HAST	6	w alum;	2390	1	86.6
479	29	36.34	-94.36	144	Nixa	0.06	60.98	HAST	6	w alum;	12496	0	86.5
196	10	36.37	-94.41	98	Nixa	0.06	60.98	HAST	4	w alum;	8436	0	86.5
397	22	36.37	-94.51	35	Nixa	0.06	36.58	HAST	4	w alum;	3024	0	85.6
158	8	36.37	-94.33	41	Nixa	0.03	91.46	HAST	4.8	w alum;	3508	0	84.6
341	18	36.39	-94.47	6	Nixa	0.03	60.98	HAST	4	w alum;	539	1	83.9
415	23	36.36	-94.55	4	Nixa	0.05	24.39	HAST	4	w alum;	301	0	83.9
436	24	36.34	-94.49	33	Nixa	0.04	60.98	HAST	4	w alum;	2730	1	83.7
281	15	34.4	-94.44	11	Nixa	0.04	60.98	HAST	4	w alum;	934	1	83.7
338	18	36.39	-94.47	53	Nixa	0.05	60.98	HAST	4	w alum;	4370	0	83.0
277	15	34.4	-94.44	85	Nixa	0.05	60.98	HAST	4	w alum;	7029	0	83.0
433	24	36.34	-94.49	190	Nixa	0.05	60.98	HAST	4	w alum;	15745	0	83.0
380	21	36.41	-94.51	6	Nixa	0.03	60.98	HAST	4	w alum;	457	1	82.6
633	38	36.32	-94.53	31	Nixa	0.03	60.98	HAST	4	w alum;	2567	1	82.4
614	37	36.36	-94.59	3	Nixa	0.05	24.39	HAST	4	w alum;	205	1	82.0
141	7	36.4	-94.31	7	Nixa	0.02	91.46	HAST	4.8	w alum;	597	1	81.9
377	21	36.41	-94.51	104	Nixa	0.04	60.98	HAST	4	w alum;	8514	0	81.9
323	17	36.41	-94.48	12	Nixa	0.04	60.98	HAST	4	w alum;	981	1	81.6
630	38	36.32	-94.53	123	Nixa	0.05	60.98	HAST	4	w alum;	10038	0	81.4
138	7	36.4	-94.31	32	Nixa	0.03	91.46	HAST	4.8	w alum;	2618	0	81.2
611	37	36.36	-94.59	7	Nixa	0.06	24.39	HAST	4	w alum;	592	0	81.1
320	17	36.41	-94.48	49	Nixa	0.06	60.98	HAST	4	w alum;	3922	0	80.8
880	53	36.35	-94.57	8	Nixa	0.12	24.39	HAST	4	w alum;	641	1	80.4
97	4	36.4	-94.57	13	Nixa	0.02	121.95	HAST	4	w alum;	945	1	73.0
1015	66	36.36	-95.02	7	Nixa	0.07	18.29	HAST	3.4	w alum; w/o N rep	511	0	72.6
93	4	36.4	-94.57	151	Nixa	0.02	121.95	HAST	4	w alum;	10924	0	72.4
517	32	36.35	-94.77	4	Healing	0.05	18.29	WPAS	0	w/o N rep	293	1	72.1
513	32	36.35	-94.77	25	Healing	0.05	18.29	WPAS	0	w/o N rep	1823	0	72.0
69	3	36.42	-94.67	226	Nixa	0.02	91.46	HAST	3.4	w alum; w/o N rep	16219	0	71.8
499	31	36.36	-94.78	11	Healing	0.05	24.39	WPAS	0	w/o N rep	799	0	71.7
963	61	36.35	-94.79	3	Healing	0.06	24.39	WPAS	0	w/o N rep	186	0	71.7
5	1	36.44	-94.67	53	Razort	0.07	60.98	WPAS	0	w/o N rep	3811	0	71.7
845	52	36.32	-94.68	2	Razort	0.10	24.39	WPAS	0	w/o N rep	133	0	71.7
563	35	36.32	-94.71	23	Razort	0.07	18.29	WPAS	0	w/o N rep	1647	1	71.7
985	63	36.32	-94.89	5	Razort	0.08	18.29	WPAS	0	w/o N rep	341	0	71.7

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
557	35	36.32	-94.71	69	Razort	0.07	18.29	WPAS	0	w/o N rep	4978	0	71.6
948	60	36.37	-94.81	2	Razort	0.10	18.29	WPAS	0	w/o N rep	142	0	71.6
830	51	36.35	-94.75	0	Razort	0.06	15.24	WPAS	0	w/o N rep	26	1	71.6
511	32	36.35	-94.77	13	Razort	0.05	18.29	WPAS	0	w/o N rep	922	0	71.5
828	51	36.35	-94.75	1	Razort	0.06	15.24	WPAS	0	w/o N rep	90	0	71.5
938	58	36.35	-94.85	0	Razort	0.15	18.29	WPAS	0	w/o N rep	21	0	71.5
585	36	36.34	-94.76	0	Razort	0.05	60.98	WPAS	0	w/o N rep	13	0	71.5
757	47	36.39	-94.84	45	Razort	0.09	24.39	WPAS	0	w/o N rep	3236	0	71.5
496	31	36.36	-94.78	5	Razort	0.05	24.39	WPAS	0	w/o N rep	365	0	71.4
808	50	36.27	-94.81	159	Razort	0.09	24.39	WPAS	0	w/o N rep	11371	0	71.4
995	64	36.37	-94.91	7	Razort	0.11	36.58	WPAS	0	w/o N rep	498	0	71.4
654	42	36.3	-94.65	69	Razort	0.05	36.58	WPAS	0	w/o N rep	4923	0	71.3
943	59	36.36	-94.86	2	Razort	0.17	18.29	WPAS	0	w/o N rep	149	0	71.3
102	5	36.41	-94.63	0	Razort	0.03	36.58	WPAS	0	w/o N rep	6	1	71.3
363	20	36.36	-94.89	6	Razort	0.16	24.39	WPAS	0	w/o N rep	455	1	71.2
361	20	36.36	-94.89	26	Razort	0.16	24.39	WPAS	0	w/o N rep	1823	0	71.1
223	13	36.41	-94.66	71	Razort	0.05	60.98	WPAS	0	w/o N rep	5044	1	71.0
219	13	36.41	-94.66	255	Razort	0.05	60.98	WPAS	0	w/o N rep	18109	0	70.9
929	57	36.39	-94.94	4	Razort	0.09	18.29	WPAS	0	w/o N rep	268	1	70.7
776	48	36.4	-94.79	23	Razort	0.11	24.39	WPAS	0	w/o N rep	1626	1	70.7
773	48	36.4	-94.79	48	Razort	0.11	24.39	WPAS	0	w/o N rep	3379	0	70.6
407	23	36.36	-94.55	5	Healing	0.05	24.39	WPAS	0	w/o N rep	328	0	70.4
883	54	36.42	-94.62	25	Razort	0.02	91.46	WPAS	0	w/o N rep	1774	0	70.4
1016	67	36.37	-94.98	4	Razort	0.13	15.24	WPAS	0	w/o N rep	293	0	69.9
206	11	36.4	-94.99	3	Razort	0.10	24.39	WPAS	0	w/o N rep	201	1	69.7
203	11	36.4	-94.99	19	Razort	0.10	24.39	WPAS	0	w/o N rep	1324	0	69.6
1050	69	36.35	-95.01	3	Nixa	0.06	24.39	HAST	3.4	w alum; w/o N rep	175	0	69.4
333	18	36.39	-94.47	38	Tonti	0.05	60.98	WPAS	1	w/o N rep	2550	1	67.2
330	18	36.39	-94.47	53	Tonti	0.05	60.98	WPAS	1	w/o N rep	3543	0	67.2
171	9	36.4	-94.37	82	Tonti	0.05	60.98	WPAS	1	w/o N rep	5476	1	66.9
190	10	36.37	-94.41	9	Tonti	0.06	60.98	WPAS	1	w/o N rep	630	1	66.8
167	9	36.4	-94.37	226	Tonti	0.05	60.98	WPAS	1	w/o N rep	15091	0	66.7
704	44	36.3	-94.68	18	Taloka	0.04	60.98	WPAS	0	w/o N rep	1178	1	66.6
187	10	36.37	-94.41	57	Tonti	0.06	60.98	WPAS	1	w/o N rep	3810	0	66.6
272	15	34.4	-94.44	73	Tonti	0.05	60.98	WPAS	1	w/o N rep	4849	1	66.4
268	15	34.4	-94.44	183	Tonti	0.05	60.98	WPAS	1	w/o N rep	12098	0	66.3
313	17	36.41	-94.48	37	Tonti	0.06	60.98	WPAS	1	w/o N rep	2406	1	65.8
371	21	36.41	-94.51	105	Tonti	0.04	60.98	WPAS	1	w/o N rep	6909	0	65.8
309	17	36.41	-94.48	105	Tonti	0.06	60.98	WPAS	1	w/o N rep	6885	0	65.7
625	38	36.32	-94.53	60	Tonti	0.05	60.98	WPAS	1	w/o N rep	3933	1	65.5
622	38	36.32	-94.53	342	Tonti	0.05	60.98	WPAS	1	w/o N rep	22320	0	65.3
1028	68	36.33	-94.61	23	Tonti	0.05	36.58	WPAS	1	w/o N rep	1492	1	65.1
391	22	36.37	-94.51	18	Tonti	0.06	36.58	WPAS	1	w/o N rep	1198	1	64.9
36	2	36.43	-94.7	91	Taloka	0.04	60.98	WPAS	0	w/o N rep	5892	1	64.9
151	8	36.37	-94.33	32	Tonti	0.03	91.46	WPAS	1	w/o N rep	2035	1	64.2
148	8	36.37	-94.33	230	Tonti	0.03	91.46	WPAS	1	w/o N rep	14765	0	64.1
132	7	36.4	-94.31	21	Tonti	0.03	91.46	WPAS	1	w/o N rep	1348	1	63.2
974	62	36.33	-94.8	18	Jay	0.05	36.58	WPAS	0	w/o N rep	1156	1	63.2
473	29	36.34	-94.36	166	Tonti	0.06	60.98	WPAS	1	w/o N rep	10511	0	63.1
128	7	36.4	-94.31	199	Tonti	0.03	91.46	WPAS	1	w/o N rep	12583	0	63.1
870	53	36.35	-94.57	6	Waben	0.07	24.39	WPAS	0	w/o N rep	386	1	62.9
866	53	36.35	-94.57	18	Waben	0.07	24.39	WPAS	0	w/o N rep	1139	0	62.8
795	49	36.37	-94.73	45	Taloka	0.07	36.58	WPAS	0	w/o N rep	2835	1	62.8
248	14	36.37	-94.66	51	Jay	0.03	91.46	WPAS	0	w/o N rep	3190	0	62.5
646	41	36.33	-94.65	3	Captina	0.07	24.39	WPAS	0	w/o N rep	175	1	61.5
703	44	36.3	-94.68	17	Captina	0.04	60.98	WPAS	0	w/o N rep	1012	1	61.3
700	44	36.3	-94.68	62	Captina	0.04	60.98	WPAS	0	w/o N rep	3797	0	61.1
409	23	36.36	-94.55	5	Captina	0.05	24.39	WPAS	0	w/o N rep	326	1	60.9
464	28	36.36	-94.79	1	Elsah	0.07	24.39	WPAS	1	w/o N rep	77	0	60.8
405	23	36.36	-94.55	13	Captina	0.05	24.39	WPAS	0	w/o N rep	780	0	60.8
745	46	36.29	-94.61	75	Captina	0.03	60.98	WPAS	0	w/o N rep	4522	1	60.7
600	37	36.36	-94.59	52	Captina	0.06	24.39	WPAS	0	w/o N rep	3130	0	60.6
86	4	36.4	-94.57	30	Jay	0.02	121.95	WPAS	0	w/o N rep	1829	1	60.6
742	46	36.29	-94.61	277	Captina	0.03	60.98	WPAS	0	w/o N rep	16795	0	60.5
1026	68	36.33	-94.61	33	Captina	0.05	36.58	WPAS	0	w/o N rep	1970	1	60.5

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
314	17	36.41	-94.48	18	Noark	0.06	60.98	WPAS	0	w/o N rep	1087	1	60.4
269	15	34.4	-94.44	132	Noark	0.05	60.98	WPAS	0	w/o N rep	7945	0	60.4
310	17	36.41	-94.48	51	Noark	0.06	60.98	WPAS	0	w/o N rep	3079	0	60.4
35	2	36.43	-94.7	136	Captina	0.04	60.98	WPAS	0	w/o N rep	8211	1	60.3
31	2	36.43	-94.7	158	Captina	0.04	60.98	WPAS	0	w/o N rep	9522	0	60.3
372	21	36.41	-94.51	59	Captina	0.04	60.98	WPAS	0	w/o N rep	3551	1	60.3
1023	68	36.33	-94.61	198	Captina	0.05	36.58	WPAS	0	w/o N rep	11911	0	60.2
270	15	34.4	-94.44	48	Captina	0.05	60.98	WPAS	0	w/o N rep	2917	1	60.2
311	17	36.41	-94.48	12	Captina	0.06	60.98	WPAS	0	w/o N rep	710	1	60.1
369	21	36.41	-94.51	222	Captina	0.04	60.98	WPAS	0	w/o N rep	13358	0	60.1
586	36	36.34	-94.76	1	Elsah	0.05	60.98	WPAS	1	w/o N rep	49	0	60.1
588	36	36.34	-94.76	2	Elsah	0.05	60.98	WPAS	1	w/o N rep	123	1	60.0
1045	69	36.35	-95.01	3	Peridge	0.06	24.39	WPAS	0	w/o N rep	206	1	60.0
603	37	36.36	-94.59	11	Captina	0.06	24.39	WPAS	0	w/o N rep	632	1	60.0
307	17	36.41	-94.48	59	Captina	0.06	60.98	WPAS	0	w/o N rep	3540	0	59.9
85	4	36.4	-94.57	46	Captina	0.02	121.95	WPAS	0	w/o N rep	2775	1	59.8
57	3	36.42	-94.67	366	Jay	0.02	91.46	WPAS	0	w/o N rep	21861	0	59.8
1043	69	36.35	-95.01	7	Captina	0.06	24.39	WPAS	0	w/o N rep	395	1	59.7
1040	69	36.35	-95.01	8	Captina	0.06	24.39	WPAS	0	w/o N rep	455	0	59.7
425	24	36.34	-94.49	46	Captina	0.05	60.98	WPAS	0	w/o N rep	2753	1	59.6
623	38	36.32	-94.53	128	Captina	0.05	60.98	WPAS	0	w/o N rep	7605	1	59.5
349	19	36.35	-94.92	27	Tonti	0.06	24.39	WPAS	0	w/o N rep	1610	0	59.5
61	3	36.42	-94.67	48	Captina	0.02	91.46	WPAS	0	w/o N rep	2876	1	59.5
168	9	36.4	-94.37	231	Noark	0.05	60.98	WPAS	0	w/o N rep	13755	0	59.5
422	24	36.34	-94.49	126	Captina	0.05	60.98	WPAS	0	w/o N rep	7499	0	59.4
606	37	36.36	-94.59	6	Peridge	0.06	24.39	WPAS	0	w/o N rep	342	1	59.4
11	1	36.44	-94.67	37	Captina	0.07	60.98	WPAS	0	w/o N rep	2179	1	59.4
408	23	36.36	-94.55	7	Peridge	0.05	24.39	WPAS	0	w/o N rep	396	0	59.4
410	23	36.36	-94.55	10	Peridge	0.05	24.39	WPAS	0	w/o N rep	575	1	59.4
7	1	36.44	-94.67	49	Captina	0.07	60.98	WPAS	0	w/o N rep	2927	0	59.3
56	3	36.42	-94.67	186	Captina	0.02	91.46	WPAS	0	w/o N rep	11007	0	59.3
952	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	0	w/o N rep	114	1	59.3
620	38	36.32	-94.53	454	Captina	0.05	60.98	WPAS	0	w/o N rep	26903	0	59.3
169	9	36.4	-94.37	61	Captina	0.05	60.98	WPAS	0	w/o N rep	3592	1	59.2
331	18	36.39	-94.47	51	Captina	0.05	60.98	WPAS	0	w/o N rep	3015	1	59.2
601	37	36.36	-94.59	34	Peridge	0.06	24.39	WPAS	0	w/o N rep	2011	0	59.2
328	18	36.39	-94.47	83	Captina	0.05	60.98	WPAS	0	w/o N rep	4920	0	59.1
831	51	36.35	-94.75	1	Elsah	0.06	15.24	WPAS	1	w/o N rep	53	1	59.1
1042	69	36.35	-95.01	25	Peridge	0.06	24.39	WPAS	0	w/o N rep	1490	0	59.0
871	53	36.35	-94.57	7	Peridge	0.07	24.39	WPAS	0	w/o N rep	386	1	58.9
489	30	36.33	-94.39	4	Captina	0.08	36.58	WPAS	0	w/o N rep	241	1	58.9
744	46	36.29	-94.61	36	Clarksville	0.03	60.98	WPAS	1	w/o N rep	2101	1	58.9
64	3	36.42	-94.67	44	Peridge	0.02	91.46	WPAS	0	w/o N rep	2599	1	58.9
566	35	36.32	-94.71	20	Britwater	0.07	18.29	WPAS	0	w/o N rep	1166	1	58.9
901	55	36.27	-94.74	133	Clarksville	0.06	60.98	WPAS	1	w/o N rep	7825	1	58.9
424	24	36.34	-94.49	234	Peridge	0.05	60.98	WPAS	0	w/o N rep	13787	0	58.9
498	31	36.36	-94.78	4	Elsah	0.05	24.39	WPAS	1	w/o N rep	264	0	58.9
701	44	36.3	-94.68	48	Britwater	0.04	60.98	WPAS	0	w/o N rep	2836	0	58.8
560	35	36.32	-94.71	44	Britwater	0.07	18.29	WPAS	0	w/o N rep	2564	0	58.8
564	35	36.32	-94.71	30	Clarksville	0.07	18.29	WPAS	1	w/o N rep	1736	1	58.8
741	46	36.29	-94.61	269	Clarksville	0.03	60.98	WPAS	1	w/o N rep	15840	0	58.8
962	61	36.35	-94.79	1	Elsah	0.06	24.39	WPAS	1	w/o N rep	62	0	58.8
60	3	36.42	-94.67	176	Peridge	0.02	91.46	WPAS	0	w/o N rep	10341	0	58.8
898	55	36.27	-94.74	520	Clarksville	0.06	60.98	WPAS	1	w/o N rep	30551	0	58.7
191	10	36.37	-94.41	17	Peridge	0.06	60.98	WPAS	0	w/o N rep	1007	1	58.7
558	35	36.32	-94.71	95	Clarksville	0.07	18.29	WPAS	1	w/o N rep	5604	0	58.7
350	19	36.35	-94.92	22	Tonti	0.06	24.39	WPAS	0	w/o N rep	1282	1	58.7
971	62	36.33	-94.8	19	Clarksville	0.05	36.58	WPAS	0	w/o N rep	1103	1	58.7
951	60	36.37	-94.81	2	Britwater	0.10	18.29	WPAS	0	w/o N rep	127	0	58.7
829	51	36.35	-94.75	0	Clarksville	0.06	15.24	WPAS	0	w/o N rep	16	0	58.6
149	8	36.37	-94.33	65	Captina	0.03	91.46	WPAS	1	w/o N rep	3798	1	58.6
514	32	36.35	-94.77	9	Clarksville	0.05	18.29	WPAS	0	w/o N rep	520	1	58.6
968	62	36.33	-94.8	80	Clarksville	0.05	36.58	WPAS	0	w/o N rep	4680	0	58.6
986	63	36.32	-94.89	6	Clarksville	0.08	18.29	WPAS	0	w/o N rep	349	0	58.6
512	32	36.35	-94.77	27	Clarksville	0.05	18.29	WPAS	0	w/o N rep	1572	0	58.6

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
867	53	36.35	-94.57	48	Peridge	0.07	24.39	WPAS	0	w/o N rep	2816	0	58.6
463	28	36.36	-94.79	3	Clarksville	0.07	24.39	WPAS	0	w/o N rep	197	0	58.5
848	52	36.32	-94.68	5	Clarksville	0.10	24.39	WPAS	0	w/o N rep	266	1	58.5
346	19	36.35	-94.92	34	Clarksville	0.06	24.39	WPAS	0	w/o N rep	1976	0	58.5
389	22	36.37	-94.51	51	Captina	0.06	36.58	WPAS	0	w/o N rep	2989	1	58.5
500	31	36.36	-94.78	7	Clarksville	0.05	24.39	WPAS	0	w/o N rep	401	1	58.4
949	60	36.37	-94.81	7	Clarksville	0.10	18.29	WPAS	0	w/o N rep	407	0	58.4
497	31	36.36	-94.78	9	Clarksville	0.05	24.39	WPAS	0	w/o N rep	554	0	58.4
428	24	36.34	-94.49	28	Peridge	0.05	60.98	WPAS	0	w/o N rep	1639	1	58.4
1010	66	36.36	-95.02	10	Parsons	0.07	18.29	WPAS	0	w/o N rep	579	0	58.4
146	8	36.37	-94.33	184	Captina	0.03	91.46	WPAS	1	w/o N rep	10756	0	58.4
961	61	36.35	-94.79	5	Clarksville	0.06	24.39	WPAS	0	w/o N rep	298	0	58.4
811	50	36.27	-94.81	192	Clarksville	0.09	24.39	WPAS	0	w/o N rep	11183	1	58.4
392	22	36.37	-94.51	14	Peridge	0.06	36.58	WPAS	0	w/o N rep	821	1	58.4
516	32	36.35	-94.77	7	Britwater	0.05	18.29	WPAS	0	w/o N rep	415	1	58.3
809	50	36.27	-94.81	489	Clarksville	0.09	24.39	WPAS	0	w/o N rep	28500	0	58.3
387	22	36.37	-94.51	172	Captina	0.06	36.58	WPAS	0	w/o N rep	10005	0	58.3
547	34	36.33	-94.86	22	Clarksville	0.10	24.39	WPAS	0	w/o N rep	1282	0	58.3
548	34	36.33	-94.86	25	Tonti	0.10	24.39	WPAS	0	w/o N rep	1460	0	58.3
760	47	36.39	-94.84	30	Clarksville	0.09	24.39	WPAS	0	w/o N rep	1751	1	58.2
987	63	36.32	-94.89	3	Britwater	0.08	18.29	WPAS	0	w/o N rep	165	0	58.2
919	56	36.38	-94.44	0	Britwater	0.08	60.98	WPAS	0	w/o N rep	23	0	58.2
758	47	36.39	-94.84	159	Clarksville	0.09	24.39	WPAS	0	w/o N rep	9245	0	58.2
644	41	36.33	-94.65	7	Clarksville	0.07	24.39	WPAS	1	w/o N rep	422	1	58.1
655	42	36.3	-94.65	96	Clarksville	0.05	36.58	WPAS	1	w/o N rep	5557	0	58.1
34	2	36.43	-94.7	159	Clarksville	0.04	60.98	WPAS	0	w/o N rep	9213	1	58.1
846	52	36.32	-94.68	2	Clarksville	0.10	24.39	WPAS	1	w/o N rep	143	0	58.1
453	27	36.36	-94.8	2	Clarksville	0.13	36.58	WPAS	0	w/o N rep	104	0	58.1
130	7	36.4	-94.31	55	Captina	0.03	91.46	WPAS	1	w/o N rep	3193	1	58.1
30	2	36.43	-94.7	290	Clarksville	0.04	60.98	WPAS	0	w/o N rep	16820	0	58.1
587	36	36.34	-94.76	5	Britwater	0.05	60.98	WPAS	0	w/o N rep	283	1	58.0
641	41	36.33	-94.65	22	Clarksville	0.07	24.39	WPAS	1	w/o N rep	1253	0	58.0
793	49	36.37	-94.73	82	Clarksville	0.07	36.58	WPAS	0	w/o N rep	4750	1	57.9
931	57	36.39	-94.94	27	Britwater	0.09	18.29	WPAS	0	w/o N rep	1550	1	57.8
790	49	36.37	-94.73	418	Clarksville	0.07	36.58	WPAS	0	w/o N rep	24146	0	57.8
454	27	36.36	-94.8	1	Britwater	0.13	36.58	WPAS	0	w/o N rep	58	0	57.7
657	42	36.3	-94.65	53	Britwater	0.05	36.58	WPAS	0	w/o N rep	3040	0	57.7
101	5	36.41	-94.63	0	Britwater	0.03	36.58	WPAS	0	w/o N rep	10	0	57.7
847	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	0	w/o N rep	322	0	57.7
849	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	0	w/o N rep	320	1	57.7
126	7	36.4	-94.31	299	Captina	0.03	91.46	WPAS	1	w/o N rep	17238	0	57.6
746	46	36.29	-94.61	30	Tonti	0.03	60.98	WPAS	1	w/o N rep	1738	1	57.6
1021	68	36.33	-94.61	278	Clarksville	0.05	36.58	WPAS	1	w/o N rep	16025	0	57.6
928	57	36.39	-94.94	114	Britwater	0.09	18.29	WPAS	0	w/o N rep	6539	0	57.5
535	33	36.35	-94.82	9	Clarksville	0.11	24.39	WPAS	0	w/o N rep	517	1	57.5
252	14	36.37	-94.66	71	Newtonia	0.03	91.46	WPAS	0	w/o N rep	4062	1	57.5
249	14	36.37	-94.66	74	Newtonia	0.03	91.46	WPAS	0	w/o N rep	4270	0	57.5
939	58	36.35	-94.85	1	Clarksville	0.15	18.29	WPAS	0	w/o N rep	44	0	57.5
246	14	36.37	-94.66	40	Clarksville	0.03	91.46	WPAS	0	w/o N rep	2326	0	57.5
532	33	36.35	-94.82	23	Clarksville	0.11	24.39	WPAS	0	w/o N rep	1314	0	57.4
186	10	36.37	-94.41	77	Secesh	0.06	60.98	WPAS	1	w/o N rep	4418	0	57.4
442	25	36.37	-94.87	2	Britwater	0.11	24.39	WPAS	0	w/o N rep	125	0	57.4
441	25	36.37	-94.87	13	Clarksville	0.11	24.39	WPAS	0	w/o N rep	724	0	57.4
427	24	36.34	-94.49	28	Secesh	0.05	60.98	WPAS	1	w/o N rep	1622	1	57.4
129	7	36.4	-94.31	103	Noark	0.03	91.46	WPAS	0	w/o N rep	5923	0	57.3
940	58	36.35	-94.85	0	Britwater	0.15	18.29	WPAS	0	w/o N rep	28	0	57.3
723	45	36.28	-94.67	92	Newtonia	0.03	91.46	WPAS	1	w/o N rep	5277	0	57.3
944	59	36.36	-94.86	4	Clarksville	0.17	18.29	WPAS	0	w/o N rep	243	0	57.2
565	35	36.32	-94.71	14	Clarksville	0.07	18.29	WPAS	0	w/o N rep	813	1	57.2
972	62	36.33	-94.8	35	Clarksville	0.05	36.58	WPAS	0	w/o N rep	1977	1	57.2
969	62	36.33	-94.8	99	Clarksville	0.05	36.58	WPAS	0	w/o N rep	5683	0	57.2
559	35	36.32	-94.71	73	Clarksville	0.07	18.29	WPAS	0	w/o N rep	4187	0	57.1
515	32	36.35	-94.77	3	Clarksville	0.05	18.29	WPAS	0	w/o N rep	187	1	57.1
953	60	36.37	-94.81	0	Clarksville	0.10	18.29	WPAS	0	w/o N rep	23	1	57.1
950	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	0	w/o N rep	107	0	57.1

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
643	41	36.33	-94.65	97	Britwater	0.07	24.39	WPAS	0	w/o N rep	5561	0	57.1
9	1	36.44	-94.67	56	Clarksville	0.07	60.98	WPAS	0	w/o N rep	3219	1	57.0
812	50	36.27	-94.81	100	Clarksville	0.09	24.39	WPAS	0	w/o N rep	5683	1	57.0
810	50	36.27	-94.81	167	Clarksville	0.09	24.39	WPAS	0	w/o N rep	9505	0	57.0
347	19	36.35	-94.92	19	Clarksville	0.06	24.39	WPAS	0	w/o N rep	1079	0	57.0
6	1	36.44	-94.67	123	Clarksville	0.07	60.98	WPAS	0	w/o N rep	7025	0	57.0
224	13	36.41	-94.66	50	Clarksville	0.05	60.98	WPAS	0	w/o N rep	2826	1	56.9
684	43	36.36	-94.65	61	Newtonia	0.03	60.98	WPAS	0	w/o N rep	3457	1	56.9
645	41	36.33	-94.65	5	Clarksville	0.07	24.39	WPAS	0	w/o N rep	310	1	56.9
291	16	36.35	-94.44	80	Peridge	0.07	60.98	WPAS	0	w/o N rep	4573	1	56.9
642	41	36.33	-94.65	16	Clarksville	0.07	24.39	WPAS	0	w/o N rep	913	0	56.9
220	13	36.41	-94.66	325	Clarksville	0.05	60.98	WPAS	0	w/o N rep	18430	0	56.8
681	43	36.36	-94.65	207	Newtonia	0.03	60.98	WPAS	0	w/o N rep	11768	0	56.8
115	6	36.38	-94.61	125	Newtonia	0.01	121.95	WPAS	0	w/o N rep	7123	1	56.8
113	6	36.38	-94.61	345	Newtonia	0.01	121.95	WPAS	0	w/o N rep	19592	0	56.7
777	48	36.4	-94.79	82	Clarksville	0.11	24.39	WPAS	0	w/o N rep	4622	1	56.7
536	33	36.35	-94.82	3	Britwater	0.11	24.39	WPAS	0	w/o N rep	193	1	56.6
678	43	36.36	-94.65	87	Clarksville	0.03	60.98	WPAS	1	w/o N rep	4911	0	56.6
997	64	36.37	-94.91	17	Britwater	0.11	36.58	WPAS	0	w/o N rep	939	0	56.6
533	33	36.35	-94.82	4	Britwater	0.11	24.39	WPAS	0	w/o N rep	248	0	56.6
774	48	36.4	-94.79	247	Clarksville	0.11	24.39	WPAS	0	w/o N rep	13968	0	56.6
289	16	36.35	-94.44	271	Peridge	0.07	60.98	WPAS	0	w/o N rep	15296	0	56.5
996	64	36.37	-94.91	16	Clarksville	0.11	36.58	WPAS	0	w/o N rep	880	0	56.5
488	30	36.33	-94.39	4	Clarksville	0.08	36.58	WPAS	1	w/o N rep	225	1	56.4
188	10	36.37	-94.41	11	Britwater	0.06	60.98	WPAS	1	w alum; w/o N rep	633	1	56.3
486	30	36.33	-94.39	110	Clarksville	0.08	36.58	WPAS	1	w/o N rep	6191	0	56.2
501	31	36.36	-94.78	2	Clarksville	0.05	24.39	WPAS	0	w/o N rep	138	1	56.2
759	47	36.39	-94.84	51	Clarksville	0.09	24.39	WPAS	0	w/o N rep	2861	0	56.1
761	47	36.39	-94.84	18	Clarksville	0.09	24.39	WPAS	0	w/o N rep	1019	1	56.1
364	20	36.36	-94.89	36	Clarksville	0.16	24.39	WPAS	0	w/o N rep	2033	1	56.1
62	3	36.42	-94.67	61	Newtonia	0.02	91.46	WPAS	0	w/o N rep	3388	1	56.0
362	20	36.36	-94.89	122	Clarksville	0.16	24.39	WPAS	0	w/o N rep	6825	0	55.9
885	54	36.42	-94.62	23	Britwater	0.02	91.46	WPAS	0	w/o N rep	1285	0	55.9
660	42	36.3	-94.65	10	Clarksville	0.05	36.58	WPAS	0	w/o N rep	569	1	55.9
87	4	36.4	-94.57	56	Newtonia	0.02	121.95	WPAS	1	w/o N rep	3146	1	55.9
656	42	36.3	-94.65	47	Clarksville	0.05	36.58	WPAS	0	w/o N rep	2621	0	55.9
227	13	36.41	-94.66	96	Newtonia	0.05	60.98	WPAS	0	w/o N rep	5351	1	55.9
58	3	36.42	-94.67	256	Newtonia	0.02	91.46	WPAS	0	w/o N rep	14307	0	55.8
679	43	36.36	-94.65	77	Clarksville	0.03	60.98	WPAS	0	w/o N rep	4307	0	55.8
222	13	36.41	-94.66	152	Newtonia	0.05	60.98	WPAS	0	w/o N rep	8487	0	55.7
83	4	36.4	-94.57	377	Newtonia	0.02	121.95	WPAS	1	w/o N rep	21002	0	55.7
887	54	36.42	-94.62	45	Newtonia	0.02	91.46	WPAS	0	w/o N rep	2482	1	55.7
886	54	36.42	-94.62	93	Newtonia	0.02	91.46	WPAS	0	w/o N rep	5162	0	55.6
884	54	36.42	-94.62	31	Clarksville	0.02	91.46	WPAS	0	w/o N rep	1746	0	55.6
1041	69	36.35	-95.01	16	Britwater	0.06	24.39	WPAS	0	w/o N rep	892	0	55.5
869	53	36.35	-94.57	4	Britwater	0.07	24.39	WPAS	1	w/o N rep	199	1	55.3
930	57	36.39	-94.94	4	Clarksville	0.09	18.29	WPAS	1	w/o N rep	210	1	55.3
568	35	36.32	-94.71	19	Macedonia	0.07	18.29	WPAS	0	w/o N rep	1061	1	55.2
794	49	36.37	-94.73	51	Clarksville	0.07	36.58	WPAS	0	w/o N rep	2811	1	55.0
10	1	36.44	-94.67	38	Clarksville	0.07	60.98	WPAS	0	w/o N rep	2087	1	55.0
791	49	36.37	-94.73	151	Clarksville	0.07	36.58	WPAS	0	w/o N rep	8323	0	55.0
682	43	36.36	-94.65	85	Clarksville	0.03	60.98	WPAS	0	w/o N rep	4663	1	55.0
562	35	36.32	-94.71	73	Macedonia	0.07	18.29	WPAS	0	w/o N rep	4017	0	55.0
775	48	36.4	-94.79	51	Clarksville	0.11	24.39	WPAS	0	w/o N rep	2799	0	54.9
778	48	36.4	-94.79	56	Clarksville	0.11	24.39	WPAS	0	w/o N rep	3055	1	54.9
225	13	36.41	-94.66	62	Clarksville	0.05	60.98	WPAS	0	w/o N rep	3420	1	54.9
865	53	36.35	-94.57	45	Britwater	0.07	24.39	WPAS	0	w/o N rep	2491	0	54.9
221	13	36.41	-94.66	164	Clarksville	0.05	60.98	WPAS	0	w/o N rep	9016	0	54.8
1007	66	36.36	-95.02	19	Clarksville	0.07	18.29	WPAS	1	w/o N rep	1020	0	54.8
1017	67	36.37	-94.98	28	Clarksville	0.13	15.24	WPAS	1	w/o N rep	1510	0	54.8
474	29	36.34	-94.36	12	Clarksville	0.06	60.98	WPAS	1	w/o N rep	655	1	54.6
471	29	36.34	-94.36	111	Clarksville	0.06	60.98	WPAS	1	w/o N rep	6030	0	54.5
899	55	36.27	-94.74	347	Clarksville	0.06	60.98	WPAS	0	w/o N rep	18921	0	54.5
927	57	36.39	-94.94	48	Clarksville	0.09	18.29	WPAS	1	w/o N rep	2580	0	54.2
724	45	36.28	-94.67	75	Doniphan	0.03	91.46	WPAS	1	w/o N rep	4058	1	54.2

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
721	45	36.28	-94.67	177	Doniphan	0.03	91.46	WPAS	1	w/o N rep	9597	0	54.2
207	11	36.4	-94.99	20	Clarksville	0.10	24.39	WPAS	1	w/o N rep	1084	1	54.1
184	10	36.37	-94.41	63	Clarksville	0.06	60.98	WPAS	1	w/o N rep	3410	0	54.1
287	16	36.35	-94.44	195	Clarksville	0.07	60.98	WPAS	1	w/o N rep	10561	0	54.1
348	19	36.35	-94.92	12	Doniphan	0.06	24.39	WPAS	0	w/o N rep	660	0	54.0
204	11	36.4	-94.99	35	Clarksville	0.10	24.39	WPAS	1	w/o N rep	1887	0	54.0
306	17	36.41	-94.48	50	Clarksville	0.06	60.98	WPAS	1	w/o N rep	2686	0	53.9
813	50	36.27	-94.81	86	Doniphan	0.09	24.39	WPAS	0	w/o N rep	4631	1	53.9
421	24	36.34	-94.49	171	Clarksville	0.05	60.98	WPAS	1	w/o N rep	9226	0	53.9
567	35	36.32	-94.71	19	Doniphan	0.07	18.29	WPAS	1	w/o N rep	1000	1	53.9
561	35	36.32	-94.71	50	Doniphan	0.07	18.29	WPAS	1	w/o N rep	2678	0	53.8
725	45	36.28	-94.67	59	Macedonia	0.03	91.46	WPAS	1	w/o N rep	3184	1	53.7
661	42	36.3	-94.65	28	Doniphan	0.05	36.58	WPAS	0	w/o N rep	1478	1	53.7
722	45	36.28	-94.67	100	Macedonia	0.03	91.46	WPAS	1	w/o N rep	5375	0	53.6
868	53	36.35	-94.57	8	Clarksville	0.07	24.39	WPAS	1	w/o N rep	430	1	53.5
658	42	36.3	-94.65	50	Doniphan	0.05	36.58	WPAS	1	w/o N rep	2651	0	53.5
327	18	36.39	-94.47	65	Clarksville	0.05	60.98	WPAS	1	w/o N rep	3457	0	53.5
864	53	36.35	-94.57	25	Clarksville	0.07	24.39	WPAS	1	w/o N rep	1334	0	53.5
619	38	36.32	-94.53	233	Clarksville	0.05	60.98	WPAS	1	w/o N rep	12426	0	53.4
537	33	36.35	-94.82	2	Taloka	0.11	24.39	WPAS	0	w/o N rep	131	1	53.4
1039	69	36.35	-95.01	13	Clarksville	0.06	24.39	WPAS	0	w/o N rep	669	0	53.4
902	55	36.27	-94.74	499	Doniphan	0.06	60.98	WPAS	1	w/o N rep	26630	1	53.4
900	55	36.27	-94.74	586	Doniphan	0.06	60.98	WPAS	1	w/o N rep	31266	0	53.3
602	37	36.36	-94.59	4	Clarksville	0.06	24.39	WPAS	1	w/o N rep	193	1	53.3
970	62	36.33	-94.8	47	Doniphan	0.05	36.58	WPAS	0	w/o N rep	2488	0	53.3
973	62	36.33	-94.8	45	Doniphan	0.05	36.58	WPAS	0	w/o N rep	2409	1	53.3
599	37	36.36	-94.59	36	Clarksville	0.06	24.39	WPAS	1	w/o N rep	1939	0	53.3
251	14	36.37	-94.66	42	Macedonia	0.03	91.46	WPAS	0	w/o N rep	2242	1	53.3
762	47	36.39	-94.84	6	Doniphan	0.09	24.39	WPAS	0	w/o N rep	341	1	53.2
247	14	36.37	-94.66	95	Macedonia	0.03	91.46	WPAS	0	w/o N rep	5028	0	53.2
705	44	36.3	-94.68	20	Macedonia	0.04	60.98	WPAS	0	w/o N rep	1036	1	53.1
1027	68	36.33	-94.61	29	Doniphan	0.05	36.58	WPAS	1	w/o N rep	1519	1	53.0
1024	68	36.33	-94.61	198	Doniphan	0.05	36.58	WPAS	1	w/o N rep	10466	0	52.9
680	43	36.36	-94.65	107	Macedonia	0.03	60.98	WPAS	0	w/o N rep	5642	0	52.9
683	43	36.36	-94.65	94	Macedonia	0.03	60.98	WPAS	0	w/o N rep	4942	1	52.9
702	44	36.3	-94.68	63	Macedonia	0.04	60.98	WPAS	0	w/o N rep	3309	0	52.8
386	22	36.37	-94.51	202	Clarksville	0.06	36.58	WPAS	1	w/o N rep	10628	0	52.7
1025	68	36.33	-94.61	39	Clarksville	0.05	36.58	WPAS	0	w/o N rep	2063	1	52.7
1022	68	36.33	-94.61	216	Clarksville	0.05	36.58	WPAS	0	w/o N rep	11395	0	52.7
105	5	36.41	-94.63	1	Razort	0.04	36.58	HAST	0	w/o N rep	66	1	52.7
747	46	36.29	-94.61	37	Taloka	0.03	60.98	WPAS	1	w alum; w/o N rep	1938	1	52.6
38	2	36.43	-94.7	112	Macedonia	0.04	60.98	WPAS	0	w/o N rep	5868	1	52.6
662	42	36.3	-94.65	23	Macedonia	0.05	36.58	WPAS	0	w/o N rep	1233	1	52.5
32	2	36.43	-94.7	186	Doniphan	0.04	60.98	WPAS	1	w/o N rep	9738	0	52.4
37	2	36.43	-94.7	154	Doniphan	0.04	60.98	WPAS	1	w/o N rep	8083	1	52.4
659	42	36.3	-94.65	56	Macedonia	0.05	36.58	WPAS	0	w/o N rep	2942	0	52.2
12	1	36.44	-94.67	23	Doniphan	0.07	60.98	WPAS	0	w/o N rep	1212	1	52.0
796	49	36.37	-94.73	41	Doniphan	0.07	36.58	WPAS	0	w/o N rep	2140	1	51.9
8	1	36.44	-94.67	44	Doniphan	0.07	60.98	WPAS	0	w/o N rep	2273	0	51.9
605	37	36.36	-94.59	3	Nixa	0.06	24.39	WPAS	0	w/o N rep	177	1	51.9
743	46	36.29	-94.61	469	Taloka	0.03	60.98	WPAS	1	w alum; w/o N rep	24279	0	51.8
406	23	36.36	-94.55	7	Nixa	0.05	24.39	WPAS	0	w/o N rep	339	0	51.8
226	13	36.41	-94.66	59	Doniphan	0.05	60.98	WPAS	1	w/o N rep	3068	1	51.8
13	1	36.44	-94.67	28	Macedonia	0.07	60.98	WPAS	0	w/o N rep	1462	1	51.7
33	2	36.43	-94.7	184	Taloka	0.04	60.98	WPAS	0	w/o N rep	9528	0	51.7
1044	69	36.35	-95.01	4	Nixa	0.06	24.39	WPAS	0	w/o N rep	228	1	51.6
114	6	36.38	-94.61	30	Taloka	0.01	121.95	WPAS	0	w/o N rep	1528	1	51.6
373	21	36.41	-94.51	48	Nixa	0.04	60.98	WPAS	0	w/o N rep	2483	1	51.6
370	21	36.41	-94.51	152	Nixa	0.04	60.98	WPAS	0	w/o N rep	7827	0	51.5
797	49	36.37	-94.73	80	Macedonia	0.07	36.58	WPAS	0	w/o N rep	4111	1	51.5
250	14	36.37	-94.66	33	Doniphan	0.03	91.46	WPAS	0	w/o N rep	1699	1	51.4
112	6	36.38	-94.61	227	Taloka	0.01	121.95	WPAS	0	w/o N rep	11624	0	51.2
792	49	36.37	-94.73	230	Macedonia	0.07	36.58	WPAS	0	w/o N rep	11741	0	51.1
604	37	36.36	-94.59	4	Taloka	0.06	24.39	WPAS	0	w/o N rep	196	1	51.1
271	15	34.4	-94.44	22	Nixa	0.05	60.98	WPAS	0	w/o N rep	1119	1	50.7

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)	Land Converted =1, Original land use =0	Per hectare shadow price ($/ha.)
332	18	36.39	-94.47	23	Nixa	0.05	60.98	WPAS	0	w/o N rep	1152	1	50.7
312	17	36.41	-94.48	22	Nixa	0.06	60.98	WPAS	0	w/o N rep	1090	1	50.6
267	15	34.4	-94.44	110	Nixa	0.05	60.98	WPAS	0	w/o N rep	5562	0	50.6
329	18	36.39	-94.47	89	Nixa	0.05	60.98	WPAS	0	w/o N rep	4527	0	50.6
624	38	36.32	-94.53	45	Nixa	0.05	60.98	WPAS	0	w/o N rep	2251	1	50.6
170	9	36.4	-94.37	149	Nixa	0.05	60.98	WPAS	0	w/o N rep	7510	1	50.5
308	17	36.41	-94.48	109	Nixa	0.06	60.98	WPAS	0	w/o N rep	5524	0	50.5
390	22	36.37	-94.51	18	Nixa	0.06	36.58	WPAS	0	w/o N rep	920	1	50.5
426	24	36.34	-94.49	78	Nixa	0.05	60.98	WPAS	0	w/o N rep	3930	1	50.5
166	9	36.4	-94.37	728	Nixa	0.05	60.98	WPAS	0	w/o N rep	36720	0	50.4
621	38	36.32	-94.53	314	Nixa	0.05	60.98	WPAS	0	w/o N rep	15821	0	50.4
189	10	36.37	-94.41	33	Nixa	0.06	60.98	WPAS	0	w/o N rep	1646	1	50.4
423	24	36.34	-94.49	480	Nixa	0.05	60.98	WPAS	0	w/o N rep	24150	0	50.3
388	22	36.37	-94.51	201	Nixa	0.06	36.58	WPAS	0	w/o N rep	10113	0	50.3
185	10	36.37	-94.41	123	Nixa	0.06	60.98	WPAS	0	w/o N rep	6192	0	50.3
290	16	36.35	-94.44	53	Nixa	0.07	60.98	WPAS	0	w/o N rep	2659	1	50.2
487	30	36.33	-94.39	274	Nixa	0.08	36.58	WPAS	0	w/o N rep	13739	0	50.1
288	16	36.35	-94.44	317	Nixa	0.07	60.98	WPAS	0	w/o N rep	15837	0	50.0
490	30	36.33	-94.39	9	Nixa	0.08	36.58	WPAS	0	w/o N rep	465	1	49.6
1008	66	36.36	-95.02	26	Clarksville	0.07	18.29	WPAS	1	w/o N rep	1286	0	49.5
82	4	36.4	-94.57	292	Taloka	0.02	121.95	WPAS	0	w/o N rep	14445	0	49.4
84	4	36.4	-94.57	174	Nixa	0.02	121.95	WPAS	0	w/o N rep	8494	0	48.7
63	3	36.42	-94.67	88	Nixa	0.02	91.46	WPAS	0	w/o N rep	4268	1	48.6
59	3	36.42	-94.67	324	Nixa	0.02	91.46	WPAS	0	w/o N rep	15728	0	48.6
131	7	36.4	-94.31	18	Nixa	0.03	91.46	WPAS	0	w/o N rep	882	1	48.5
150	8	36.37	-94.33	24	Nixa	0.03	91.46	WPAS	0	w/o N rep	1140	1	48.4
127	7	36.4	-94.31	155	Nixa	0.03	91.46	WPAS	0	w/o N rep	7524	0	48.4
147	8	36.37	-94.33	131	Nixa	0.03	91.46	WPAS	0	w/o N rep	6329	0	48.3
88	4	36.4	-94.57	34	Nixa	0.02	121.95	WPAS	0	w/o N rep	1617	1	48.0
475	29	36.34	-94.36	68	Nixa	0.06	60.98	WPAS	0	w/o N rep	3279	1	47.9
472	29	36.34	-94.36	384	Nixa	0.06	60.98	WPAS	0	w/o N rep	18309	0	47.7
918	56	36.38	-94.44	1	Clarksville	0.08	60.98	WPAS	0	w/o N rep	28	0	46.7
1009	66	36.36	-95.02	35	Nixa	0.07	18.29	WPAS	1	w/o N rep	1486	0	42.8
923	56	36.38	-94.44	0	Clarksville	0.08	60.98	HAST	0	w/o N rep	3	0	10.5
926	56	36.38	-94.44	0	Elsah	0.09	60.98	HAST	0	w/o N rep	3	1	7.8
924	56	36.38	-94.44	1	Britwater	0.08	60.98	HAST	0	w/o N rep	1	0	1.7
543	33	36.35	-94.82	6	Water	0.11	24.39	HAST	0	w/o N rep	-231	0	-37.7
446	25	36.37	-94.87	2	Water	0.11	24.39	HAST	0	w/o N rep	-60	0	-37.7
1003	64	36.37	-94.91	2	Water	0.11	36.58	HAST	0	w/o N rep	-86	0	-37.7
925	56	36.38	-94.44	0	Water	0.08	60.98	HAST	0	w/o N rep	-7	0	-37.7
954	60	36.37	-94.81	0	Water	0.10	18.29	WPAS	0	w/o N rep	-15	1	-38.5
538	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0	w/o N rep	-186	1	-38.5
443	25	36.37	-94.87	4	Water	0.11	24.39	WPAS	0	w/o N rep	-168	0	-38.5
205	11	36.4	-94.99	24	Water	0.10	24.39	WPAS	0	w/o N rep	-938	0	-38.5
534	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0	w/o N rep	-188	0	-38.5
455	27	36.36	-94.8	2	Water	0.13	36.58	WPAS	0	w/o N rep	-76	0	-38.5

Table A 10. Spatial Detail for the Optimal Solution for Policy 4.

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
401	22	36.37	-94.51	9	Tonti	0.05	36.58	WWHT	0	1.95	w alum;	3364	389.1
74	3	36.42	-94.67	15	Tonti	0.02	91.46	WWHT	0	1.95	w alum;	5609	383.9
1038	68	36.33	-94.61	33	Tonti	0.04	36.59	WWHT	0	1.95	w alum;	12497	382.5
381	21	36.41	-94.51	2	Tonti	0.03	60.98	WWHT	0	1.95	w alum;	866	374.2
342	18	36.39	-94.47	10	Tonti	0.03	60.98	WWHT	0	1.95	w alum;	3556	371.6
180	9	36.4	-94.37	12	Tonti	0.04	60.98	WWHT	0	1.95	w alum;	4427	369.0
634	38	36.32	-94.53	45	Tonti	0.03	60.98	WWHT	0	1.95	w alum;	16664	366.6
282	15	34.4	-94.44	13	Tonti	0.04	60.98	WWHT	0	1.95	w alum;	4651	353.3
324	17	36.41	-94.48	8	Tonti	0.04	60.98	WWHT	0	1.95	w alum;	2772	352.2
162	8	36.37	-94.33	21	Tonti	0.02	91.46	WWHT	0	1.95	w alum;	7032	340.2
142	7	36.4	-94.31	13	Tonti	0.02	91.46	WWHT	0	1.95	w alum;	4282	335.0
200	10	36.37	-94.41	5	Tonti	0.06	60.98	WWHT	0	1.95	w alum;	1600	331.2
835	51	36.35	-94.75	1	Razort	0.01	15.24	WWHT	0	1.11	w/o N rep	396	274.9
577	35	36.32	-94.71	6	Razort	0.04	18.29	WWHT	0	1.11	w/o N rep	1675	271.1
523	32	36.35	-94.77	6	Razort	0.03	18.29	WWHT	0	1.11	w/o N rep	1701	269.6
593	36	36.34	-94.76	2	Razort	0.02	60.98	WWHT	0	0.98	w/o N rep	618	251.7
837	51	36.35	-94.75	1	Elsah	0.01	15.24	WWHT	0	1.95		351	244.1
756	46	36.29	-94.61	31	Taloka	0.02	60.98	WWHT	0	1.95	w alum;	7525	240.6
595	36	36.34	-94.76	6	Elsah	0.02	60.98	WWHT	0	1.95		1465	240.2
105	5	36.41	-94.63	1	Razort	0.04	36.58	WWHT	0	1.11	w alum; w/o N rep	297	236.5
615	37	36.36	-94.59	2	Peridge	0.05	24.39	WWHT	0	1.95	w alum;	504	228.5
121	6	36.38	-94.61	69	Taloka	0.01	121.95	WWHT	0	0.00	w N rep	15643	225.5
581	35	36.32	-94.71	5	Elsah	0.04	18.29	WWHT	0	1.95		1150	223.3
179	9	36.4	-94.37	60	Nixa	0.04	60.98	WWHT	0	1.95		12981	215.7
141	7	36.4	-94.31	7	Nixa	0.02	91.46	WWHT	0	1.95		1530	210.0
161	8	36.37	-94.33	9	Taloka	0.02	91.46	WWHT	0	0.00	w N rep	1785	203.9
380	21	36.41	-94.51	6	Nixa	0.03	60.98	WWHT	0	1.95		1124	203.5
400	22	36.37	-94.51	7	Nixa	0.05	36.58	WWHT	0	1.95		1347	202.8
614	37	36.36	-94.59	3	Nixa	0.05	24.39	WWHT	0	1.95		506	201.8
341	18	36.39	-94.47	6	Nixa	0.03	60.98	WWHT	0	1.95		1287	200.5
97	4	36.4	-94.57	13	Nixa	0.02	121.95	WWHT	0	1.95		2560	197.6
821	50	36.27	-94.81	15	Razort	0.09	24.39	WWHT	0	0.00	w N rep	2956	196.0
281	15	34.4	-94.44	11	Nixa	0.04	60.98	WWHT	0	1.95		2184	195.7
323	17	36.41	-94.48	12	Nixa	0.04	60.98	WWHT	0	1.95		2308	191.9
301	16	36.35	-94.44	15	Nixa	0.05	60.98	WWHT	0	1.95		2771	189.5
633	38	36.32	-94.53	31	Nixa	0.03	60.98	WWHT	0	1.95		5895	189.2
578	35	36.32	-94.71	15	Clarksville	0.04	18.29	WWHT	0	0.65	w/o N rep	2879	188.9
836	51	36.35	-94.75	1	Britwater	0.01	15.24	WWHT	0	1.95	w alum;	119	188.1
73	3	36.42	-94.67	28	Newtonia	0.02	91.46	WWHT	0	0.00	w N rep	5162	185.0
926	56	36.38	-94.44	0	Elsah	0.09	60.98	WWHT	0	1.95		66	182.3
524	32	36.35	-94.77	2	Clarksville	0.03	18.29	WWHT	0	0.65	w/o N rep	349	181.5
98	4	36.4	-94.57	22	Peridge	0.02	121.95	WWHT	0	0.00	w N rep	3972	181.4
894	54	36.42	-94.62	6	Newtonia	0.02	91.46	WWHT	0	0.00	w N rep	1096	180.9
199	10	36.37	-94.41	10	Nixa	0.06	60.98	WWHT	0	1.95		1686	176.7
755	46	36.29	-94.61	41	Captina	0.02	60.98	WWHT	0	0.00	w N rep	7205	176.0
382	21	36.41	-94.51	4	Peridge	0.03	60.98	WWHT	0	0.00	w N rep	618	175.5
525	32	36.35	-94.77	4	Britwater	0.03	18.29	WWHT	0	1.95	w alum;	735	174.7
140	7	36.4	-94.31	21	Captina	0.02	91.46	WWHT	0	0.00	w N rep	3668	174.6
635	38	36.32	-94.53	46	Peridge	0.03	60.98	WWHT	0	1.95	w alum;	8013	174.0
858	52	36.32	-94.68	1	Clarksville	0.09	24.39	WWHT	0	0.98	w/o N rep	140	173.7
580	35	36.32	-94.71	7	Britwater	0.04	18.29	WWHT	0	1.95	w alum;	1276	172.1
981	62	36.33	-94.8	5	Clarksville	0.03	36.58	WWHT	0	0.65	w/o N rep	807	168.0
160	8	36.37	-94.33	39	Captina	0.02	91.46	WWHT	0	0.00	w N rep	6459	167.6
612	37	36.36	-94.59	4	Clarksville	0.05	24.39	WWHT	0	1.95		655	167.2
733	45	36.28	-94.67	10	Captina	0.02	91.46	WWHT	1	1.95		1598	166.1
399	22	36.37	-94.51	25	Captina	0.05	36.58	WWHT	0	0.00	w N rep	4108	165.5
613	37	36.36	-94.59	6	Captina	0.05	24.39	WWHT	0	0.00	w N rep	1040	164.5
854	52	36.32	-94.68	1	Razort	0.10	24.39	HAY	0	4.80		188	162.0
122	6	36.38	-94.61	63	Newtonia	0.01	121.95	WWHT	0	0.00	w N rep	10119	160.9

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
572	35	36.32	-94.71	41	Razort	0.07	18.29	HAY	0	4.80		6546	160.8
71	3	36.42	-94.67	28	Captina	0.02	91.46	WWHT	0	0.00	w N rep	4485	160.7
1036	68	36.33	-94.61	13	Clarksville	0.04	36.58	WWHT	0	1.30	w N rep	2052	158.9
300	16	36.35	-94.44	14	Newtonia	0.05	60.98	WWHT	0	0.00	w N rep	2209	158.1
911	55	36.27	-94.74	31	Captina	0.04	60.98	WWHT	1	1.56		4839	157.3
302	16	36.35	-94.44	42	Peridge	0.05	60.98	WWHT	0	0.00	w N rep	6583	156.7
178	9	36.4	-94.37	26	Captina	0.04	60.98	WWHT	0	0.00	w N rep	4028	156.7
507	31	36.36	-94.78	5	Healing	0.05	24.39	HAY	0	4.00	w N rep	759	156.1
735	45	36.28	-94.67	31	Macedonia	0.02	91.46	WWHT	1	1.95	w alum;	4876	156.1
730	45	36.28	-94.67	40	Clarksville	0.03	91.46	HAY	0	6.00	w alum;	6266	155.0
579	35	36.32	-94.71	7	Clarksville	0.04	18.29	WWHT	0	0.33	w/o N rep	1134	154.9
734	45	36.28	-94.67	16	Doniphan	0.02	91.46	WWHT	1	1.95		2408	154.7
436	24	36.34	-94.49	33	Nixa	0.04	60.98	WWHT	0	1.95		5038	154.6
983	62	36.33	-94.8	13	Doniphan	0.03	36.58	WWHT	0	0.33	w/o N rep	1993	154.1
522	32	36.35	-94.77	22	Healing	0.05	18.29	HAY	0	4.00	w N rep	3367	153.8
731	45	36.28	-94.67	158	Doniphan	0.03	91.46	HAY	0	6.00		24311	153.7
732	45	36.28	-94.67	83	Macedonia	0.03	91.46	HAY	0	6.00	w alum;	12816	153.6
817	50	36.27	-94.81	118	Razort	0.09	24.39	HAY	0	4.00	w N rep	18064	153.0
912	55	36.27	-94.74	40	Britwater	0.04	60.98	WWHT	1	1.95	w alum;	6058	152.9
592	36	36.34	-94.76	3	Razort	0.05	60.98	HAY	0	4.00	w N rep	403	152.7
766	47	36.39	-94.84	26	Razort	0.09	24.39	HAY	0	4.00	w N rep	3903	152.4
72	3	36.42	-94.67	23	Jay	0.02	91.46	WWHT	0	0.00	w N rep	3489	152.4
834	51	36.35	-94.75	1	Razort	0.06	15.24	HAY	0	4.00	w N rep	164	152.2
504	31	36.36	-94.78	3	Razort	0.05	24.39	HAY	0	4.00	w N rep	399	152.0
982	62	36.33	-94.8	10	Clarksville	0.03	36.58	WWHT	0	0.98	w/o N rep	1526	151.5
990	63	36.32	-94.89	4	Razort	0.08	18.29	HAY	0	4.00	w N rep	551	150.5
712	44	36.3	-94.68	21	Captina	0.04	60.98	HAY	0	6.00	w alum;	3187	150.4
694	43	36.36	-94.65	99	Taloka	0.01	60.98	WWHT	0	0.00	w N rep	14844	150.4
695	43	36.36	-94.65	150	Newtonia	0.01	60.98	WWHT	1	1.95		22598	150.2
481	29	36.34	-94.36	4	Clarksville	0.06	60.98	WWHT	0	1.95	w alum;	601	150.0
520	32	36.35	-94.77	5	Razort	0.05	18.29	HAY	0	4.00	w N rep	806	150.0
379	21	36.41	-94.51	7	Captina	0.03	60.98	WWHT	0	0.00	w N rep	1066	149.4
367	20	36.36	-94.89	14	Razort	0.16	24.39	HAY	0	4.00	w N rep	2052	148.9
907	55	36.27	-94.74	348	Clarksville	0.06	60.98	HAY	0	6.00	w alum;	51720	148.4
913	55	36.27	-94.74	79	Doniphan	0.04	60.98	WWHT	1	1.95		11793	148.4
283	15	34.4	-94.44	13	Peridge	0.04	60.98	WWHT	0	0.00	w N rep	1980	148.0
232	13	36.41	-94.66	114	Razort	0.05	60.98	HAY	0	4.80	w alum;	16848	147.6
693	43	36.36	-94.65	60	Newtonia	0.03	60.98	HAY	0	4.80		8862	147.4
909	55	36.27	-94.74	808	Doniphan	0.06	60.98	HAY	0	6.00	w alum;	118800	147.0
910	55	36.27	-94.74	24	Clarksville	0.04	60.98	WWHT	0	0.65	w/o N rep	3490	146.8
856	52	36.32	-94.68	2	Britwater	0.10	24.39	HAY	0	6.00	w alum;	254	146.7
753	46	36.29	-94.61	184	Captina	0.03	60.98	HAY	0	4.80	w alum;	27000	146.7
653	41	36.33	-94.65	18	Britwater	0.07	24.39	HAY	0	6.00	w alum;	2557	146.1
354	19	36.35	-94.92	7	Razort	0.06	24.39	HAY	0	4.00	w N rep	1085	144.7
713	44	36.3	-94.68	20	Doniphan	0.04	60.98	HAY	0	6.00		2900	144.1
714	44	36.3	-94.68	33	Macedonia	0.04	60.98	HAY	0	4.80	w alum;	4755	143.7
1000	64	36.37	-94.91	6	Razort	0.11	36.58	HAY	0	4.00	w N rep	798	143.7
710	44	36.3	-94.68	13	Clarksville	0.04	60.98	HAY	0	6.00	w alum;	1936	143.6
25	1	36.44	-94.67	5	Taloka	0.05	60.98	WWHT	0	0.00	w N rep	733	143.2
857	52	36.32	-94.68	2	Doniphan	0.10	24.39	HAY	0	6.00	w alum;	261	143.1
262	14	36.37	-94.66	19	Newtonia	0.02	91.46	WWHT	1	1.56		2747	143.1
715	44	36.3	-94.68	5	Clarksville	0.08	60.98	WWHT	1	1.95	w alum;	678	142.7
259	14	36.37	-94.66	115	Newtonia	0.03	91.46	HAY	0	4.80		16324	142.5
240	13	36.41	-94.66	62	Newtonia	0.03	60.98	WWHT	1	1.56		8806	142.2
786	48	36.4	-94.79	11	Clarksville	0.07	24.39	WWHT	0	0.00	w/o N rep	1598	142.0
575	35	36.32	-94.71	38	Doniphan	0.07	18.29	HAY	0	4.80		5394	141.5
717	44	36.3	-94.68	3	Macedonia	0.08	60.98	WWHT	1	1.56	w alum;	358	141.3
576	35	36.32	-94.71	56	Macedonia	0.07	18.29	HAY	0	4.80	w alum;	7869	140.9
594	36	36.34	-94.76	7	Britwater	0.02	60.98	WWHT	1	1.56	w alum;	920	140.5
573	35	36.32	-94.71	87	Clarksville	0.07	18.29	HAY	0	6.00	w alum;	12148	140.2

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter applicatio n rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
1037	68	36.33	-94.61	24	Captina	0.04	36.58	WWHT	0	0.00	w N rep	3310	140.0
672	42	36.3	-94.65	5	Doniphan	0.05	36.58	WWHT	1	1.95	w alum;	703	139.9
668	42	36.3	-94.65	46	Doniphan	0.05	36.58	HAY	0	6.00	w alum;	6440	139.9
805	49	36.37	-94.73	12	Taloka	0.06	36.58	WWHT	1	1.30	w alum;	1705	139.8
651	41	36.33	-94.65	24	Clarksville	0.07	24.39	HAY	0	4.80	w alum;	3391	139.6
803	49	36.37	-94.73	28	Clarksville	0.06	36.58	WWHT	0	0.65	w alum; w/o N rep	3868	139.2
666	42	36.3	-94.65	35	Clarksville	0.05	36.58	HAY	0	6.00	w alum;	4921	139.1
670	42	36.3	-94.65	4	Clarksville	0.05	36.58	WWHT	1	1.95	w alum;	614	139.1
238	13	36.41	-94.66	22	Clarksville	0.03	60.98	WWHT	0	0.33	w/o N rep	3072	138.8
984	62	36.33	-94.8	17	Jay	0.03	36.58	WWHT	1	1.30	w alum;	2308	138.8
17	1	36.44	-94.67	52	Razort	0.07	60.98	HAY	0	4.00	w N rep	7227	138.6
669	42	36.3	-94.65	40	Macedonia	0.05	36.58	HAY	0	6.00	w alum;	5477	138.5
299	16	36.35	-94.44	12	Captina	0.05	60.98	WWHT	0	0.00	w N rep	1601	138.5
47	2	36.43	-94.7	58	Captina	0.03	60.98	WWHT	1	1.56	w alum;	8043	138.0
236	13	36.41	-94.66	119	Newtonia	0.05	60.98	HAY	0	4.80	w alum;	16472	138.0
781	48	36.4	-94.79	45	Razort	0.11	24.39	HAY	0	4.00	w alum;	6140	137.8
157	8	36.37	-94.33	58	Captina	0.03	91.46	HAY	0	6.00	w alum;	8041	137.6
673	42	36.3	-94.65	13	Macedonia	0.05	36.58	WWHT	1	1.95	w alum;	1727	137.5
96	4	36.4	-94.57	15	Newtonia	0.02	121.95	WWHT	0	0.00	w N rep	2036	137.4
95	4	36.4	-94.57	13	Captina	0.02	121.95	WWHT	0	0.00	w N rep	1779	137.4
908	55	36.27	-94.74	228	Clarksville	0.06	60.98	HAY	0	6.00	w alum;	31188	136.9
752	46	36.29	-94.61	101	Clarksville	0.03	60.98	HAY	0	6.00	w alum;	13805	136.6
322	17	36.41	-94.48	4	Captina	0.04	60.98	WWHT	0	0.00	w N rep	552	136.4
754	46	36.29	-94.61	82	Taloka	0.03	60.98	HAY	0	4.80	w alum;	11116	136.2
24	1	36.44	-94.67	12	Captina	0.05	60.98	WWHT	1	1.30	w N rep	1688	135.9
691	43	36.36	-94.65	68	Macedonia	0.03	60.98	HAY	0	4.80	w alum;	9166	135.7
690	43	36.36	-94.65	41	Doniphan	0.03	60.98	HAY	0	6.00	w alum;	5584	135.7
459	27	36.36	-94.8	1	Britwater	0.13	36.58	HAY	0	4.80	w alum;	146	135.5
44	2	36.43	-94.7	314	Captina	0.04	60.98	HAY	0	4.80	w alum;	42184	134.5
468	28	36.36	-94.79	8	Clarksville	0.07	24.39	HAY	0	4.80	w alum;	1095	134.2
978	62	36.33	-94.8	50	Clarksville	0.05	36.58	HAY	0	4.80		6683	134.2
980	62	36.33	-94.8	99	Doniphan	0.05	36.58	HAY	0	4.80		13311	133.9
137	7	36.4	-94.31	143	Captina	0.03	91.46	HAY	0	6.00	w alum;	19089	133.6
820	50	36.27	-94.81	107	Doniphan	0.09	24.39	HAY	0	4.80		14254	133.4
258	14	36.37	-94.66	67	Jay	0.03	91.46	HAY	0	4.00	w alum;	8864	133.2
992	63	36.32	-94.89	5	Britwater	0.08	18.29	HAY	0	4.80	w alum;	610	133.1
688	43	36.36	-94.65	44	Clarksville	0.03	60.98	HAY	0	4.80	w alum;	5852	133.0
822	50	36.27	-94.81	64	Clarksville	0.09	24.39	WWHT	1	1.56		8552	132.9
692	43	36.36	-94.65	40	Taloka	0.03	60.98	HAY	0	4.80	w alum;	5325	132.8
260	14	36.37	-94.66	14	Clarksville	0.02	91.46	WWHT	0	1.11	w alum; w/o N rep	1878	132.8
818	50	36.27	-94.81	300	Clarksville	0.09	24.39	HAY	0	4.80	w alum;	39754	132.6
458	27	36.36	-94.8	2	Clarksville	0.13	36.58	HAY	0	4.80	w alum;	284	132.5
23	1	36.44	-94.67	3	Clarksville	0.05	60.98	WWHT	0	0.33	w/o N rep	361	132.5
956	60	36.37	-94.81	6	Clarksville	0.10	18.29	HAY	0	4.80	w alum;	847	132.3
711	44	36.3	-94.68	16	Clarksville	0.04	60.98	HAY	0	6.00	w alum;	2099	131.9
716	44	36.3	-94.68	8	Clarksville	0.08	60.98	WWHT	1	1.95	w alum;	1100	131.8
177	9	36.4	-94.37	201	Tonti	0.05	60.98	HAY	0	6.00	w alum;	26408	131.4
280	15	34.4	-94.44	14	Captina	0.04	60.98	WWHT	0	0.00	w N rep	1853	131.4
671	42	36.3	-94.65	8	Clarksville	0.05	36.58	WWHT	0	0.00	w/o N rep	1078	130.8
855	52	36.32	-94.68	5	Clarksville	0.10	24.39	HAY	0	4.80	w alum;	679	130.7
237	13	36.41	-94.66	27	Clarksville	0.03	60.98	WWHT	0	0.33	w/o N rep	3538	130.6
239	13	36.41	-94.66	26	Doniphan	0.03	60.98	WWHT	1	1.56	w alum;	3439	130.5
574	35	36.32	-94.71	46	Clarksville	0.07	18.29	HAY	0	4.80	w alum;	5942	130.5
967	61	36.35	-94.79	2	Doniphan	0.06	24.39	HAY	0	4.80	w alum;	213	130.5
261	14	36.37	-94.66	48	Macedonia	0.02	91.46	WWHT	1	1.56	w alum;	6315	130.4
257	14	36.37	-94.66	70	Macedonia	0.03	91.46	HAY	0	4.80	w alum;	9064	130.2
241	13	36.41	-94.66	25	Clarksville	0.03	60.98	WWHT	1	1.56	w alum;	3252	129.9
542	33	36.35	-94.82	5	Britwater	0.11	24.39	HAY	0	4.80	w alum;	676	129.9
652	41	36.33	-94.65	14	Clarksville	0.07	24.39	HAY	0	4.80	w alum;	1839	129.9
235	13	36.41	-94.66	112	Doniphan	0.05	60.98	HAY	0	4.80	w alum;	14504	129.9

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
209	11	36.4	-94.99	11	Razort	0.10	24.39	HAY	0	3.40	w alum; w/o N rep	1458	129.6
340	18	36.39	-94.47	10	Captina	0.03	60.98	WWHT	1	1.30	w alum;	1254	129.6
480	29	36.34	-94.36	53	Tonti	0.06	60.98	HAY	0	6.00	w alum;	6808	129.4
505	31	36.36	-94.78	7	Clarksville	0.05	24.39	HAY	0	4.80	w alum;	854	129.1
785	48	36.4	-94.79	18	Clarksville	0.07	24.39	WWHT	0	0.00	w N rep	2324	129.0
806	49	36.37	-94.73	11	Doniphan	0.06	36.58	WWHT	1	1.56	w alum;	1475	128.9
807	49	36.37	-94.73	17	Macedonia	0.06	36.58	WWHT	1	1.56	w alum;	2146	128.8
159	8	36.37	-94.33	69	Tonti	0.03	91.46	HAY	0	6.00	w alum;	8836	128.6
966	61	36.35	-94.79	2	Clarksville	0.06	24.39	HAY	0	4.80	w alum;	295	128.6
991	63	36.32	-94.89	5	Clarksville	0.08	18.29	HAY	0	4.80		657	128.3
667	42	36.3	-94.65	27	Clarksville	0.05	36.58	HAY	0	4.80	w alum;	3477	128.2
175	9	36.4	-94.37	128	Captina	0.05	60.98	HAY	0	4.80	w alum;	16376	127.8
20	1	36.44	-94.67	51	Captina	0.07	60.98	HAY	0	4.00	w alum;	6528	127.7
521	32	36.35	-94.77	9	Clarksville	0.05	18.29	HAY	0	4.80	w alum;	1103	127.3
197	10	36.37	-94.41	48	Tonti	0.06	60.98	HAY	0	6.00	w alum;	6137	127.3
416	23	36.36	-94.55	5	Peridge	0.05	24.39	HAY	0	4.00	w alum;	649	126.9
276	15	34.4	-94.44	57	Captina	0.05	60.98	HAY	0	4.80	w alum;	7245	126.9
233	13	36.41	-94.66	148	Clarksville	0.05	60.98	HAY	0	4.80	w alum;	18705	126.8
413	23	36.36	-94.55	2	Captina	0.05	24.39	HAY	0	4.00	w alum;	259	126.7
139	7	36.4	-94.31	73	Tonti	0.03	91.46	HAY	0	6.00	w alum;	9235	125.9
767	47	36.39	-94.84	129	Clarksville	0.09	24.39	HAY	0	4.80	w alum;	16166	125.8
49	2	36.43	-94.7	39	Taloka	0.03	60.98	WWHT	1	1.56	w alum;	4872	125.7
339	18	36.39	-94.47	65	Tonti	0.05	60.98	HAY	0	6.00	w alum;	8128	125.6
337	18	36.39	-94.47	89	Captina	0.05	60.98	HAY	0	4.00	w alum;	11139	125.5
632	38	36.32	-94.53	80	Captina	0.03	60.98	WWHT	1	1.30	w alum;	10096	125.4
48	2	36.43	-94.7	75	Doniphan	0.03	60.98	WWHT	1	1.56	w alum;	9422	125.4
46	2	36.43	-94.7	38	Clarksville	0.03	60.98	WWHT	0	0.33	w/o N rep	4806	125.3
804	49	36.37	-94.73	12	Clarksville	0.06	36.58	WWHT	0	0.65	w/o N rep	1527	125.2
800	49	36.37	-94.73	270	Clarksville	0.07	36.58	HAY	0	4.80	w alum;	33789	125.2
437	24	36.34	-94.49	31	Peridge	0.04	60.98	WWHT	1	1.30	w alum;	3882	125.0
45	2	36.43	-94.7	373	Doniphan	0.04	60.98	HAY	0	4.80	w alum;	46674	125.0
1051	69	36.35	-95.01	2	Healing	0.06	24.39	HAY	0	3.40	w/o N rep	302	124.9
936	57	36.39	-94.94	23	Healing	0.09	18.29	HAY	0	3.40	w alum; w/o N rep	2919	124.9
278	15	34.4	-94.44	138	Tonti	0.05	60.98	HAY	0	6.00	w alum;	17272	124.7
802	49	36.37	-94.73	217	Macedonia	0.07	36.58	HAY	0	4.80	w alum;	26995	124.3
435	24	36.34	-94.49	52	Captina	0.04	60.98	WWHT	1	1.30	w alum;	6449	124.1
878	53	36.35	-94.57	10	Peridge	0.07	24.39	HAY	0	4.00	w alum;	1259	124.0
445	25	36.37	-94.87	2	Clarksville	0.11	24.39	HAY	0	4.80	w alum;	282	123.9
398	22	36.37	-94.51	29	Tonti	0.06	36.58	HAY	0	6.00	w alum;	3616	123.8
819	50	36.27	-94.81	146	Clarksville	0.09	24.39	HAY	0	4.80		18011	123.7
540	33	36.35	-94.82	19	Clarksville	0.11	24.39	HAY	0	4.80	w alum;	2370	123.7
823	50	36.27	-94.81	33	Clarksville	0.09	24.39	WWHT	1	1.56		4079	123.6
550	34	36.33	-94.86	4	Clarksville	0.10	24.39	HAY	0	4.80	w alum;	530	123.6
319	17	36.41	-94.48	51	Captina	0.06	60.98	HAY	0	4.00	w alum;	6301	123.6
298	16	36.35	-94.44	31	Peridge	0.07	60.98	HAY	0	4.80	w alum;	3865	123.6
979	62	36.33	-94.8	113	Clarksville	0.05	36.58	HAY	0	4.80		13971	123.6
376	21	36.41	-94.51	139	Captina	0.04	60.98	HAY	0	4.00	w alum;	17108	123.2
610	37	36.36	-94.59	17	Captina	0.06	24.39	HAY	0	4.00	w alum;	2060	123.2
198	10	36.37	-94.41	5	Britwater	0.06	60.98	WWHT	1	1.56	w alum;	564	123.1
21	1	36.44	-94.67	45	Taloka	0.07	60.98	HAY	0	4.00	w alum;	5480	123.1
434	24	36.34	-94.49	59	Peridge	0.05	60.98	HAY	0	4.00	w alum;	7199	123.0
689	43	36.36	-94.65	61	Clarksville	0.03	60.98	HAY	0	4.80	w alum;	7513	122.9
368	20	36.36	-94.89	92	Clarksville	0.16	24.39	HAY	0	4.80	w alum;	11352	122.8
396	22	36.37	-94.51	62	Captina	0.06	36.58	HAY	0	4.00	w alum;	7629	122.7
92	4	36.4	-94.57	130	Newtonia	0.02	121.95	HAY	0	4.80	w alum;	15922	122.6
957	60	36.37	-94.81	2	Clarksville	0.10	18.29	HAY	0	4.80	w alum;	208	122.3
432	24	36.34	-94.49	62	Captina	0.05	60.98	HAY	0	4.00	w alum;	7560	122.1
355	19	36.35	-94.92	11	Clarksville	0.06	24.39	HAY	0	4.00	w N rep	1360	122.1
43	2	36.43	-94.7	343	Clarksville	0.04	60.98	HAY	0	4.80	w alum;	41734	121.8
893	54	36.42	-94.62	88	Newtonia	0.02	91.46	HAY	0	4.00	w N rep	10714	121.7

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
378	21	36.41	-94.51	45	Tonti	0.04	60.98	HAY	0	6.00	w alum;	5480	121.6
296	16	36.35	-94.44	37	Captina	0.07	60.98	HAY	0	4.80	w alum;	4470	121.6
494	30	36.33	-94.39	9	Clarksville	0.08	36.58	HAY	0	6.00	w alum;	1063	121.5
1002	64	36.37	-94.91	5	Britwater	0.11	36.58	HAY	0	4.00	w alum;	631	121.5
357	19	36.35	-94.92	9	Doniphan	0.06	24.39	HAY	0	4.80		1058	121.5
321	17	36.41	-94.48	70	Tonti	0.06	60.98	HAY	0	6.00	w alum;	8428	121.1
629	38	36.32	-94.53	110	Captina	0.05	60.98	HAY	0	4.00	w alum;	13377	121.1
460	27	36.36	-94.8	1	Elsah	0.13	36.58	HAY	0	6.00		141	121.1
120	6	36.38	-94.61	142	Newtonia	0.01	121.95	HAY	0	4.00	w N rep	17121	120.8
22	1	36.44	-94.67	54	Doniphan	0.07	60.98	HAY	0	4.80	w alum;	6493	120.5
91	4	36.4	-94.57	144	Captina	0.02	121.95	HAY	0	4.00	w alum;	17294	120.5
70	3	36.42	-94.67	88	Peridge	0.02	91.46	HAY	0	4.00	w alum;	10647	120.3
414	23	36.36	-94.55	3	Britwater	0.05	24.39	HAY	0	4.80	w alum;	307	120.2
67	3	36.42	-94.67	166	Captina	0.02	91.46	HAY	0	4.00	w alum;	19946	120.1
195	10	36.37	-94.41	47	Britwater	0.06	60.98	HAY	0	4.80	w alum;	5682	119.8
1034	68	36.33	-94.61	76	Captina	0.05	36.58	HAY	0	4.00	w alum;	9028	119.2
631	38	36.32	-94.53	90	Tonti	0.05	60.98	HAY	0	6.00	w alum;	10751	118.8
482	29	36.34	-94.36	28	Nixa	0.06	60.98	WWHT	0	1.95		3275	118.7
784	48	36.4	-94.79	38	Britwater	0.11	24.39	HAY	0	4.80	w alum;	4522	118.6
551	34	36.33	-94.86	13	Tonti	0.10	24.39	HAY	0	4.00	w alum;	1544	118.5
1001	64	36.37	-94.91	9	Clarksville	0.11	36.58	HAY	0	4.00	w alum;	1054	118.2
768	47	36.39	-94.84	57	Clarksville	0.09	24.39	HAY	0	4.80	w alum;	6690	118.0
234	13	36.41	-94.66	109	Clarksville	0.05	60.98	HAY	0	4.80	w alum;	12867	117.5
358	19	36.35	-94.92	21	Tonti	0.06	24.39	HAY	0	4.00	w alum;	2446	117.1
876	53	36.35	-94.57	12	Britwater	0.07	24.39	HAY	0	4.00	w alum;	1391	117.1
18	1	36.44	-94.67	117	Clarksville	0.07	60.98	HAY	0	4.80	w alum;	13711	117.0
801	49	36.37	-94.73	117	Clarksville	0.07	36.58	HAY	0	4.80	w alum;	13660	116.6
478	29	36.34	-94.36	37	Clarksville	0.06	60.98	HAY	0	6.00	w alum;	4268	116.5
506	31	36.36	-94.78	5	Elsah	0.05	24.39	HAY	0	4.80		605	115.1
541	33	36.35	-94.82	7	Clarksville	0.11	24.39	HAY	0	4.80	w alum;	862	114.9
68	3	36.42	-94.67	116	Jay	0.02	91.46	HAY	0	3.40	w alum; w/o N rep	13260	114.7
94	4	36.4	-94.57	84	Tonti	0.02	121.95	HAY	0	6.00	w alum;	9619	114.3
782	48	36.4	-94.79	176	Clarksville	0.11	24.39	HAY	0	4.80	w alum;	20031	114.0
608	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	0	4.00	w alum;	745	113.6
1035	68	36.33	-94.61	73	Tonti	0.05	36.58	HAY	0	6.00	w alum;	8339	113.5
356	19	36.35	-94.92	10	Clarksville	0.06	24.39	HAY	0	4.00	w N rep	1162	111.8
210	11	36.4	-94.99	25	Clarksville	0.10	24.39	HAY	0	3.40	w alum; w/o N rep	2780	111.8
1052	69	36.35	-95.01	4	Peridge	0.06	24.39	HAY	0	4.00	w alum;	490	111.7
1048	69	36.35	-95.01	7	Captina	0.06	24.39	HAY	0	3.40	w alum; w/o N rep	832	111.6
879	53	36.35	-94.57	7	Clarksville	0.12	24.39	WWHT	0	0.00	w N rep	778	110.8
295	16	36.35	-94.44	41	Clarksville	0.07	60.98	HAY	0	4.80	w alum;	4508	110.5
1032	68	36.33	-94.61	102	Clarksville	0.05	36.58	HAY	0	4.00	w alum;	11277	110.4
119	6	36.38	-94.61	59	Taloka	0.01	121.95	HAY	0	4.00	w alum;	6487	109.7
395	22	36.37	-94.51	21	Clarksville	0.06	36.58	HAY	0	4.80	w alum;	2327	109.7
935	57	36.39	-94.94	74	Britwater	0.09	18.29	HAY	0	3.40	w alum; w/o N rep	8021	107.7
431	24	36.34	-94.49	52	Clarksville	0.05	60.98	HAY	0	4.00	w alum;	5625	107.6
19	1	36.44	-94.67	47	Clarksville	0.07	60.98	HAY	0	4.80	w alum;	5022	107.4
892	54	36.42	-94.62	15	Clarksville	0.02	91.46	HAY	0	4.00	w alum;	1627	107.1
934	57	36.39	-94.94	28	Clarksville	0.09	18.29	HAY	0	3.40	w alum; w/o N rep	3045	107.1
1013	66	36.36	-95.02	8	Clarksville	0.07	18.29	HAY	0	3.40	w/o N rep	806	107.0
877	53	36.35	-94.57	6	Waben	0.07	24.39	HAY	0	4.80	w alum;	692	106.8
875	53	36.35	-94.57	18	Clarksville	0.07	24.39	HAY	0	4.00	w alum;	1940	106.3
1049	69	36.35	-95.01	3	Britwater	0.06	24.39	HAY	0	4.00	w alum;	290	106.0
783	48	36.4	-94.79	54	Clarksville	0.11	24.39	HAY	0	4.80	w alum;	5775	106.0
609	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	0	4.00	w alum;	780	105.1
628	38	36.32	-94.53	61	Clarksville	0.05	60.98	HAY	0	4.00	w alum;	6440	105.0
1033	68	36.33	-94.61	136	Clarksville	0.05	36.58	HAY	0	4.00	w alum;	13932	102.6
279	15	34.4	-94.44	35	Noark	0.05	60.98	HAY	0	4.00	w alum;	3548	102.5
1014	66	36.36	-95.02	11	Clarksville	0.07	18.29	HAY	0	3.40	w/o N rep	1041	97.6
495	30	36.33	-94.39	42	Nixa	0.08	36.58	HAY	0	6.00	w alum;	4104	96.8

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
176	9	36.4	-94.37	407	Nixa	0.05	60.98	HAY	0	4.80	w alum;	36909	90.6
479	29	36.34	-94.36	144	Nixa	0.06	60.98	HAY	0	6.00	w alum;	12945	89.6
297	16	36.35	-94.44	102	Nixa	0.07	60.98	HAY	0	4.00	w alum;	9116	89.0
397	22	36.37	-94.51	35	Nixa	0.06	36.58	HAY	0	4.00	w alum;	3139	88.9
196	10	36.37	-94.41	98	Nixa	0.06	60.98	HAY	0	4.00	w alum;	8635	88.6
158	8	36.37	-94.33	41	Nixa	0.03	91.46	HAY	0	6.00	w alum;	3630	87.6
415	23	36.36	-94.55	4	Nixa	0.05	24.39	HAY	0	4.00	w alum;	312	87.2
338	18	36.39	-94.47	53	Nixa	0.05	60.98	HAY	0	4.00	w alum;	4542	86.3
277	15	34.4	-94.44	85	Nixa	0.05	60.98	HAY	0	4.00	w alum;	7306	86.3
377	21	36.41	-94.51	104	Nixa	0.04	60.98	HAY	0	4.00	w alum;	8855	85.2
433	24	36.34	-94.49	190	Nixa	0.05	60.98	HAY	0	4.00	w alum;	16136	85.0
611	37	36.36	-94.59	7	Nixa	0.06	24.39	HAY	0	4.00	w alum;	619	84.7
320	17	36.41	-94.48	49	Nixa	0.06	60.98	HAY	0	4.00	w alum;	4080	84.1
880	53	36.35	-94.57	8	Nixa	0.12	24.39	WWHT	1	1.30	w alum;	669	84.0
138	7	36.4	-94.31	32	Nixa	0.03	91.46	HAY	0	4.80	w alum;	2699	83.7
630	38	36.32	-94.53	123	Nixa	0.05	60.98	HAY	0	4.00	w alum;	10268	83.2
93	4	36.4	-94.57	151	Nixa	0.02	121.95	HAY	0	4.00	w alum;	11411	75.6
1015	66	36.36	-95.02	7	Nixa	0.07	18.29	HAY	0	3.40	w alum; w/o N rep	531	75.4
69	3	36.42	-94.67	226	Nixa	0.02	91.46	HAY	0	4.00	w alum;	16908	74.9
1050	69	36.35	-95.01	3	Nixa	0.06	24.39	HAY	0	3.40	w alum; w/o N rep	182	72.2
517	32	36.35	-94.77	4	Healing	0.05	18.29	OPAS	1	0.00	w/o N rep	292	72.1
513	32	36.35	-94.77	25	Healing	0.05	18.29	WPAS	0	0.00	w/o N rep	1820	72.0
654	42	36.3	-94.65	69	Razort	0.05	36.58	WPAS	0	1.00	w/o N rep	4952	71.8
499	31	36.36	-94.78	11	Healing	0.05	24.39	WPAS	0	0.00	w/o N rep	798	71.6
845	52	36.32	-94.68	2	Razort	0.10	24.39	WPAS	0	0.00	w/o N rep	133	71.6
963	61	36.35	-94.79	3	Healing	0.06	24.39	WPAS	0	0.00	w/o N rep	186	71.6
5	1	36.44	-94.67	53	Razort	0.07	60.98	WPAS	0	0.00	w/o N rep	3805	71.6
563	35	36.32	-94.71	23	Razort	0.07	18.29	OPAS	1	0.00	w/o N rep	1646	71.6
985	63	36.32	-94.89	5	Razort	0.08	18.29	WPAS	0	0.00	w/o N rep	341	71.6
557	35	36.32	-94.71	69	Razort	0.07	18.29	WPAS	0	0.00	w/o N rep	4974	71.6
948	60	36.37	-94.81	2	Razort	0.10	18.29	WPAS	0	0.00	w/o N rep	142	71.5
830	51	36.35	-94.75	0	Razort	0.06	15.24	OPAS	1	0.00	w/o N rep	26	71.5
511	32	36.35	-94.77	13	Razort	0.05	18.29	WPAS	0	0.00	w/o N rep	921	71.5
828	51	36.35	-94.75	1	Razort	0.06	15.24	WPAS	0	0.00	w/o N rep	90	71.5
938	58	36.35	-94.85	0	Razort	0.15	18.29	WPAS	0	0.00	w/o N rep	21	71.5
585	36	36.34	-94.76	0	Razort	0.05	60.98	WPAS	0	0.00	w/o N rep	13	71.5
757	47	36.39	-94.84	45	Razort	0.09	24.39	WPAS	0	0.00	w/o N rep	3233	71.4
496	31	36.36	-94.78	5	Razort	0.05	24.39	WPAS	0	0.00	w/o N rep	365	71.3
808	50	36.27	-94.81	159	Razort	0.09	24.39	WPAS	0	0.00	w/o N rep	11359	71.3
995	64	36.37	-94.91	7	Razort	0.11	36.58	WPAS	0	0.00	w/o N rep	497	71.3
943	59	36.36	-94.86	2	Razort	0.17	18.29	WPAS	0	0.00	w/o N rep	148	71.2
102	5	36.41	-94.63	0	Razort	0.03	36.58	OPAS	1	0.00	w/o N rep	6	71.2
363	20	36.36	-94.89	6	Razort	0.16	24.39	OPAS	1	0.00	w/o N rep	454	71.1
361	20	36.36	-94.89	26	Razort	0.16	24.39	WPAS	0	0.00	w/o N rep	1821	71.0
223	13	36.41	-94.66	71	Razort	0.05	60.98	OPAS	1	0.00	w/o N rep	5037	70.9
219	13	36.41	-94.66	255	Razort	0.05	60.98	WPAS	0	0.00	w/o N rep	18081	70.8
929	57	36.39	-94.94	4	Razort	0.09	18.29	OPAS	1	0.00	w/o N rep	268	70.6
776	48	36.4	-94.79	23	Razort	0.11	24.39	OPAS	1	0.00	w/o N rep	1623	70.6
773	48	36.4	-94.79	48	Razort	0.11	24.39	WPAS	0	0.00	w/o N rep	3373	70.5
407	23	36.36	-94.55	5	Healing	0.05	24.39	WPAS	0	0.00	w/o N rep	328	70.3
883	54	36.42	-94.62	25	Razort	0.02	91.46	WPAS	0	0.00	w/o N rep	1771	70.3
1016	67	36.37	-94.98	4	Razort	0.13	15.24	WPAS	0	0.00	w/o N rep	292	69.8
206	11	36.4	-94.99	3	Razort	0.10	24.39	OPAS	1	0.00	w/o N rep	200	69.7
203	11	36.4	-94.99	19	Razort	0.10	24.39	WPAS	0	0.00	w/o N rep	1322	69.5
333	18	36.39	-94.47	38	Tonti	0.05	60.98	OPAS	1	0.54	w/o N rep	2577	67.9
330	18	36.39	-94.47	53	Tonti	0.05	60.98	WPAS	0	1.00	w/o N rep	3581	67.9
171	9	36.4	-94.37	82	Tonti	0.05	60.98	OPAS	1	0.54	w/o N rep	5534	67.6
167	9	36.4	-94.37	226	Tonti	0.05	60.98	WPAS	0	1.00	w/o N rep	15246	67.4
190	10	36.37	-94.41	9	Tonti	0.06	60.98	OPAS	1	0.54	w/o N rep	634	67.2
272	15	34.4	-94.44	73	Tonti	0.05	60.98	OPAS	1	0.54	w/o N rep	4902	67.1

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
268	15	34.4	-94.44	183	Tonti	0.05	60.98	WPAS	0	1.00	w/o N rep	12229	67.0
187	10	36.37	-94.41	57	Tonti	0.06	60.98	WPAS	0	1.00	w/o N rep	3831	67.0
313	17	36.41	-94.48	37	Tonti	0.06	60.98	OPAS	1	0.54	w/o N rep	2432	66.5
371	21	36.41	-94.51	105	Tonti	0.04	60.98	WPAS	0	1.00	w/o N rep	6986	66.5
309	17	36.41	-94.48	105	Tonti	0.06	60.98	WPAS	0	1.00	w/o N rep	6959	66.4
704	44	36.3	-94.68	18	Taloka	0.04	60.98	OPAS	1	0.00	w/o N rep	1172	66.2
625	38	36.32	-94.53	60	Tonti	0.05	60.98	OPAS	1	0.54	w/o N rep	3957	65.9
622	38	36.32	-94.53	342	Tonti	0.05	60.98	WPAS	0	1.00	w/o N rep	22455	65.7
391	22	36.37	-94.51	18	Tonti	0.06	36.58	OPAS	1	0.54	w/o N rep	1211	65.6
1028	68	36.33	-94.61	23	Tonti	0.05	36.58	OPAS	1	0.54	w/o N rep	1502	65.6
151	8	36.37	-94.33	32	Tonti	0.03	91.46	OPAS	1	0.54	w/o N rep	2049	64.6
148	8	36.37	-94.33	230	Tonti	0.03	91.46	WPAS	0	1.00	w/o N rep	14866	64.6
36	2	36.43	-94.7	91	Taloka	0.04	60.98	OPAS	1	0.00	w/o N rep	5853	64.5
132	7	36.4	-94.31	21	Tonti	0.03	91.46	OPAS	1	0.54	w/o N rep	1358	63.7
870	53	36.35	-94.57	6	Waben	0.07	24.39	OPAS	1	0.54	w/o N rep	391	63.7
866	53	36.35	-94.57	18	Waben	0.07	24.39	WPAS	0	1.00	w/o N rep	1154	63.7
128	7	36.4	-94.31	199	Tonti	0.03	91.46	WPAS	0	1.00	w/o N rep	12673	63.6
473	29	36.34	-94.36	166	Tonti	0.06	60.98	WPAS	0	1.00	w/o N rep	10577	63.5
974	62	36.33	-94.8	18	Jay	0.05	36.58	OPAS	1	0.00	w/o N rep	1153	63.0
248	14	36.37	-94.66	51	Jay	0.03	91.46	WPAS	0	0.00	w/o N rep	3177	62.3
795	49	36.37	-94.73	45	Taloka	0.07	36.58	OPAS	1	0.00	w/o N rep	2809	62.2
464	28	36.36	-94.79	1	Elsah	0.07	24.39	WPAS	0	1.00	w/o N rep	78	61.6
646	41	36.33	-94.65	3	Captina	0.07	24.39	OPAS	1	0.00	w/o N rep	174	61.4
703	44	36.3	-94.68	17	Captina	0.04	60.98	OPAS	1	0.00	w/o N rep	1010	61.1
700	44	36.3	-94.68	62	Captina	0.04	60.98	WPAS	0	0.00	w/o N rep	3785	60.9
409	23	36.36	-94.55	5	Captina	0.05	24.39	OPAS	1	0.00	w/o N rep	326	60.7
405	23	36.36	-94.55	13	Captina	0.05	24.39	WPAS	0	0.00	w/o N rep	778	60.6
586	36	36.34	-94.76	1	Elsah	0.05	60.98	WPAS	0	1.00	w/o N rep	49	60.5
588	36	36.34	-94.76	2	Elsah	0.05	60.98	OPAS	1	0.54	w/o N rep	124	60.5
745	46	36.29	-94.61	75	Captina	0.03	60.98	OPAS	1	0.00	w/o N rep	4511	60.5
600	37	36.36	-94.59	52	Captina	0.06	24.39	WPAS	0	0.00	w/o N rep	3121	60.4
742	46	36.29	-94.61	277	Captina	0.03	60.98	WPAS	0	0.00	w/o N rep	16749	60.4
1026	68	36.33	-94.61	33	Captina	0.05	36.58	OPAS	1	0.00	w/o N rep	1965	60.3
314	17	36.41	-94.48	18	Noark	0.06	60.98	OPAS	1	0.00	w/o N rep	1085	60.3
269	15	34.4	-94.44	132	Noark	0.05	60.98	WPAS	0	0.00	w/o N rep	7930	60.3
86	4	36.4	-94.57	30	Jay	0.02	121.95	OPAS	1	0.00	w/o N rep	1821	60.3
310	17	36.41	-94.48	51	Noark	0.06	60.98	WPAS	0	0.00	w/o N rep	3073	60.3
35	2	36.43	-94.7	136	Captina	0.04	60.98	OPAS	1	0.00	w/o N rep	8186	60.1
31	2	36.43	-94.7	158	Captina	0.04	60.98	WPAS	0	0.00	w/o N rep	9493	60.1
372	21	36.41	-94.51	59	Captina	0.04	60.98	OPAS	1	0.00	w/o N rep	3540	60.1
1023	68	36.33	-94.61	198	Captina	0.05	36.58	WPAS	0	0.00	w/o N rep	11874	60.0
270	15	34.4	-94.44	48	Captina	0.05	60.98	OPAS	1	0.00	w/o N rep	2908	60.0
311	17	36.41	-94.48	12	Captina	0.06	60.98	OPAS	1	0.00	w/o N rep	708	59.9
369	21	36.41	-94.51	222	Captina	0.04	60.98	WPAS	0	0.00	w/o N rep	13315	59.9
1045	69	36.35	-95.01	3	Peridge	0.06	24.39	OPAS	1	0.00	w/o N rep	206	59.9
603	37	36.36	-94.59	11	Captina	0.06	24.39	OPAS	1	0.00	w/o N rep	631	59.8
85	4	36.4	-94.57	46	Captina	0.02	121.95	OPAS	1	0.00	w/o N rep	2768	59.7
831	51	36.35	-94.75	1	Elsah	0.06	15.24	OPAS	1	0.54	w/o N rep	53	59.6
307	17	36.41	-94.48	59	Captina	0.06	60.98	WPAS	0	0.00	w/o N rep	3527	59.6
498	31	36.36	-94.78	4	Elsah	0.05	24.39	WPAS	0	1.00	w/o N rep	267	59.6
1043	69	36.35	-95.01	7	Captina	0.06	24.39	OPAS	1	0.00	w/o N rep	394	59.6
1040	69	36.35	-95.01	8	Captina	0.06	24.39	WPAS	0	0.00	w/o N rep	454	59.5
962	61	36.35	-94.79	1	Elsah	0.06	24.39	WPAS	0	1.00	w/o N rep	63	59.5
57	3	36.42	-94.67	366	Jay	0.02	91.46	WPAS	0	0.00	w/o N rep	21740	59.5
425	24	36.34	-94.49	46	Captina	0.05	60.98	OPAS	1	0.00	w/o N rep	2742	59.4
349	19	36.35	-94.92	27	Tonti	0.06	24.39	WPAS	0	0.00	w/o N rep	1607	59.4
168	9	36.4	-94.37	231	Noark	0.05	60.98	WPAS	0	0.00	w/o N rep	13727	59.4
61	3	36.42	-94.67	48	Captina	0.02	91.46	OPAS	1	0.00	w/o N rep	2867	59.3
606	37	36.36	-94.59	6	Peridge	0.06	24.39	OPAS	1	0.00	w/o N rep	341	59.3
623	38	36.32	-94.53	128	Captina	0.05	60.98	OPAS	1	0.00	w/o N rep	7575	59.3

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
744	46	36.29	-94.61	36	Clarksville	0.03	60.98	OPAS	1	0.54	w/o N rep	2114	59.3
408	23	36.36	-94.55	7	Peridge	0.05	24.39	WPAS	0	0.00	w/o N rep	395	59.3
901	55	36.27	-94.74	133	Clarksville	0.06	60.98	OPAS	1	0.54	w/o N rep	7871	59.2
410	23	36.36	-94.55	10	Peridge	0.05	24.39	OPAS	1	0.00	w/o N rep	573	59.2
564	35	36.32	-94.71	30	Clarksville	0.07	18.29	OPAS	1	0.54	w/o N rep	1749	59.2
952	60	36.37	-94.81	2	Clarksville	0.10	18.29	OPAS	1	0.00	w/o N rep	114	59.2
422	24	36.34	-94.49	126	Captina	0.05	60.98	WPAS	0	0.00	w/o N rep	7468	59.2
11	1	36.44	-94.67	37	Captina	0.07	60.98	OPAS	1	0.00	w/o N rep	2170	59.2
741	46	36.29	-94.61	269	Clarksville	0.03	60.98	WPAS	0	1.00	w/o N rep	15940	59.2
558	35	36.32	-94.71	95	Clarksville	0.07	18.29	WPAS	0	1.00	w/o N rep	5643	59.2
56	3	36.42	-94.67	186	Captina	0.02	91.46	WPAS	0	0.00	w/o N rep	10972	59.1
7	1	36.44	-94.67	49	Captina	0.07	60.98	WPAS	0	0.00	w/o N rep	2914	59.1
328	18	36.39	-94.47	83	Captina	0.05	60.98	WPAS	0	1.00	w alum; w/o N rep	4916	59.1
898	55	36.27	-94.74	520	Clarksville	0.06	60.98	WPAS	0	1.00	w/o N rep	30727	59.1
601	37	36.36	-94.59	34	Peridge	0.06	24.39	WPAS	0	0.00	w/o N rep	2006	59.1
620	38	36.32	-94.53	454	Captina	0.05	60.98	WPAS	0	0.00	w/o N rep	26788	59.0
331	18	36.39	-94.47	51	Captina	0.05	60.98	OPAS	1	0.00	w/o N rep	3005	59.0
169	9	36.4	-94.37	61	Captina	0.05	60.98	OPAS	1	0.00	w/o N rep	3576	59.0
1042	69	36.35	-95.01	25	Peridge	0.06	24.39	WPAS	0	0.00	w/o N rep	1487	58.9
146	8	36.37	-94.33	184	Captina	0.03	91.46	WPAS	0	1.00	w alum; w/o N rep	10835	58.8
149	8	36.37	-94.33	65	Captina	0.03	91.46	OPAS	1	0.54	w/o N rep	3812	58.8
566	35	36.32	-94.71	20	Britwater	0.07	18.29	OPAS	1	0.00	w/o N rep	1164	58.8
871	53	36.35	-94.57	7	Peridge	0.07	24.39	OPAS	1	0.00	w/o N rep	385	58.7
64	3	36.42	-94.67	44	Peridge	0.02	91.46	OPAS	1	0.00	w/o N rep	2592	58.7
560	35	36.32	-94.71	44	Britwater	0.07	18.29	WPAS	0	0.00	w/o N rep	2559	58.7
424	24	36.34	-94.49	234	Peridge	0.05	60.98	WPAS	0	0.00	w/o N rep	13734	58.7
701	44	36.3	-94.68	48	Britwater	0.04	60.98	WPAS	0	0.00	w/o N rep	2828	58.6
971	62	36.33	-94.8	19	Clarksville	0.05	36.58	OPAS	1	0.54	w/o N rep	1102	58.6
489	30	36.33	-94.39	4	Captina	0.08	36.58	OPAS	1	0.00	w/o N rep	240	58.6
846	52	36.32	-94.68	2	Clarksville	0.10	24.39	WPAS	0	1.00	w/o N rep	144	58.6
350	19	36.35	-94.92	22	Tonti	0.06	24.39	OPAS	1	0.00	w/o N rep	1279	58.6
60	3	36.42	-94.67	176	Peridge	0.02	91.46	WPAS	0	0.00	w/o N rep	10310	58.6
829	51	36.35	-94.75	0	Clarksville	0.06	15.24	WPAS	0	0.00	w/o N rep	16	58.6
514	32	36.35	-94.77	9	Clarksville	0.05	18.29	OPAS	1	0.00	w/o N rep	519	58.6
968	62	36.33	-94.8	80	Clarksville	0.05	36.58	WPAS	0	0.00	w/o N rep	4675	58.6
986	63	36.32	-94.89	6	Clarksville	0.08	18.29	WPAS	0	0.00	w/o N rep	348	58.6
463	28	36.36	-94.79	3	Clarksville	0.07	24.39	WPAS	0	1.00	w/o N rep	197	58.5
951	60	36.37	-94.81	2	Britwater	0.10	18.29	WPAS	0	0.00	w/o N rep	127	58.5
848	52	36.32	-94.68	5	Clarksville	0.10	24.39	OPAS	1	0.54	w/o N rep	266	58.5
644	41	36.33	-94.65	7	Clarksville	0.07	24.39	OPAS	1	0.54	w/o N rep	425	58.5
512	32	36.35	-94.77	27	Clarksville	0.05	18.29	WPAS	0	0.00	w/o N rep	1570	58.5
191	10	36.37	-94.41	17	Peridge	0.06	60.98	OPAS	1	0.00	w/o N rep	1003	58.5
655	42	36.3	-94.65	96	Clarksville	0.05	36.58	WPAS	0	1.00	w/o N rep	5591	58.5
346	19	36.35	-94.92	34	Clarksville	0.06	24.39	WPAS	0	0.00	w/o N rep	1974	58.4
641	41	36.33	-94.65	22	Clarksville	0.07	24.39	WPAS	0	1.00	w/o N rep	1262	58.4
867	53	36.35	-94.57	48	Peridge	0.07	24.39	WPAS	0	0.00	w/o N rep	2807	58.4
500	31	36.36	-94.78	7	Clarksville	0.05	24.39	OPAS	1	0.00	w/o N rep	400	58.4
949	60	36.37	-94.81	7	Clarksville	0.10	18.29	WPAS	0	0.00	w/o N rep	407	58.3
497	31	36.36	-94.78	9	Clarksville	0.05	24.39	WPAS	0	0.00	w/o N rep	554	58.3
130	7	36.4	-94.31	55	Captina	0.03	91.46	OPAS	1	0.54	w/o N rep	3207	58.3
961	61	36.35	-94.79	5	Clarksville	0.06	24.39	WPAS	0	0.00	w/o N rep	298	58.3
1010	66	36.36	-95.02	10	Parsons	0.07	18.29	WPAS	0	0.00	w/o N rep	577	58.3
811	50	36.27	-94.81	192	Clarksville	0.09	24.39	OPAS	1	0.00	w/o N rep	11167	58.3
389	22	36.37	-94.51	51	Captina	0.06	36.58	OPAS	1	0.00	w/o N rep	2976	58.3
516	32	36.35	-94.77	7	Britwater	0.05	18.29	OPAS	1	0.00	w/o N rep	414	58.2
809	50	36.27	-94.81	489	Clarksville	0.09	24.39	WPAS	0	0.00	w/o N rep	28456	58.2
428	24	36.34	-94.49	28	Peridge	0.05	60.98	OPAS	1	0.00	w/o N rep	1633	58.2
547	34	36.33	-94.86	22	Clarksville	0.10	24.39	WPAS	0	0.00	w/o N rep	1280	58.2
392	22	36.37	-94.51	14	Peridge	0.06	36.58	OPAS	1	0.00	w/o N rep	818	58.2
760	47	36.39	-94.84	30	Clarksville	0.09	24.39	OPAS	1	0.00	w/o N rep	1748	58.1
548	34	36.33	-94.86	25	Tonti	0.10	24.39	WPAS	0	0.00	w/o N rep	1456	58.1
987	63	36.32	-94.89	3	Britwater	0.08	18.29	WPAS	0	0.00	w/o N rep	165	58.1
758	47	36.39	-94.84	159	Clarksville	0.09	24.39	WPAS	0	0.00	w/o N rep	9229	58.1
919	56	36.38	-94.44	0	Britwater	0.08	60.98	WPAS	0	0.00	w/o N rep	23	58.0
387	22	36.37	-94.51	172	Captina	0.06	36.58	WPAS	0	0.00	w/o N rep	9959	58.0

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
34	2	36.43	-94.7	159	Clarksville	0.04	60.98	OPAS	1	0.00	w/o N rep	9196	58.0
453	27	36.36	-94.8	2	Clarksville	0.13	36.58	WPAS	0	0.00	w/o N rep	104	58.0
30	2	36.43	-94.7	290	Clarksville	0.04	60.98	WPAS	0	0.00	w/o N rep	16788	58.0
1021	68	36.33	-94.61	278	Clarksville	0.05	36.58	WPAS	0	1.00	w/o N rep	16130	57.9
126	7	36.4	-94.31	299	Captina	0.03	91.46	WPAS	0	1.00	w alum; w/o N rep	17326	57.9
587	36	36.34	-94.76	5	Britwater	0.05	60.98	OPAS	1	0.00	w/o N rep	282	57.9
746	46	36.29	-94.61	30	Tonti	0.03	60.98	OPAS	1	0.54	w/o N rep	1746	57.9
793	49	36.37	-94.73	82	Clarksville	0.07	36.58	OPAS	1	0.00	w/o N rep	4740	57.8
427	24	36.34	-94.49	28	Secesh	0.05	60.98	OPAS	1	0.54	w/o N rep	1632	57.7
186	10	36.37	-94.41	77	Secesh	0.06	60.98	WPAS	0	1.00	w/o N rep	4440	57.7
246	14	36.37	-94.66	40	Clarksville	0.03	91.46	WPAS	0	1.00	w/o N rep	2334	57.7
723	45	36.28	-94.67	92	Newtonia	0.03	91.46	WPAS	0	1.00	w/o N rep	5310	57.6
931	57	36.39	-94.94	27	Britwater	0.09	18.29	OPAS	1	0.00	w/o N rep	1545	57.6
790	49	36.37	-94.73	418	Clarksville	0.07	36.58	WPAS	0	0.00	w/o N rep	24091	57.6
101	5	36.41	-94.63	0	Britwater	0.03	36.58	WPAS	0	0.00	w/o N rep	10	57.6
454	27	36.36	-94.8	1	Britwater	0.13	36.58	WPAS	0	0.00	w/o N rep	57	57.6
657	42	36.3	-94.65	53	Britwater	0.05	36.58	WPAS	0	0.00	w/o N rep	3030	57.5
847	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	0	0.00	w/o N rep	321	57.5
849	52	36.32	-94.68	6	Britwater	0.10	24.39	OPAS	1	0.00	w/o N rep	319	57.5
535	33	36.35	-94.82	9	Clarksville	0.11	24.39	OPAS	1	0.00	w/o N rep	516	57.4
252	14	36.37	-94.66	71	Newtonia	0.03	91.46	OPAS	1	0.00	w/o N rep	4056	57.4
249	14	36.37	-94.66	74	Newtonia	0.03	91.46	WPAS	0	0.00	w/o N rep	4263	57.4
939	58	36.35	-94.85	1	Clarksville	0.15	18.29	WPAS	0	0.00	w/o N rep	44	57.4
678	43	36.36	-94.65	87	Clarksville	0.03	60.98	WPAS	0	1.00	w/o N rep	4974	57.4
532	33	36.35	-94.82	23	Clarksville	0.11	24.39	WPAS	0	0.00	w/o N rep	1312	57.3
928	57	36.39	-94.94	114	Britwater	0.09	18.29	WPAS	0	0.00	w/o N rep	6516	57.3
441	25	36.37	-94.87	13	Clarksville	0.11	24.39	WPAS	0	0.00	w/o N rep	723	57.3
442	25	36.37	-94.87	2	Britwater	0.11	24.39	WPAS	0	0.00	w/o N rep	125	57.2
129	7	36.4	-94.31	103	Noark	0.03	91.46	WPAS	0	0.00	w/o N rep	5912	57.2
940	58	36.35	-94.85	0	Britwater	0.15	18.29	WPAS	0	0.00	w/o N rep	28	57.1
565	35	36.32	-94.71	14	Clarksville	0.07	18.29	OPAS	1	0.00	w/o N rep	813	57.1
972	62	36.33	-94.8	35	Clarksville	0.05	36.58	OPAS	1	0.00	w/o N rep	1975	57.1
969	62	36.33	-94.8	99	Clarksville	0.05	36.58	WPAS	0	0.00	w/o N rep	5678	57.1
559	35	36.32	-94.71	73	Clarksville	0.07	18.29	WPAS	0	0.00	w/o N rep	4183	57.1
944	59	36.36	-94.86	4	Clarksville	0.17	18.29	WPAS	0	0.00	w/o N rep	243	57.1
515	32	36.35	-94.77	3	Clarksville	0.05	18.29	OPAS	1	0.00	w/o N rep	187	57.0
953	60	36.37	-94.81	0	Clarksville	0.10	18.29	OPAS	1	0.00	w/o N rep	23	57.0
950	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	0	0.00	w/o N rep	107	57.0
812	50	36.27	-94.81	100	Clarksville	0.09	24.39	OPAS	1	0.00	w/o N rep	5677	57.0
224	13	36.41	-94.66	50	Clarksville	0.05	60.98	OPAS	1	0.54	w/o N rep	2827	57.0
810	50	36.27	-94.81	167	Clarksville	0.09	24.39	WPAS	0	0.00	w/o N rep	9494	57.0
347	19	36.35	-94.92	19	Clarksville	0.06	24.39	WPAS	0	0.00	w/o N rep	1078	57.0
9	1	36.44	-94.67	56	Clarksville	0.07	60.98	OPAS	1	0.00	w/o N rep	3212	56.9
643	41	36.33	-94.65	97	Britwater	0.07	24.39	WPAS	0	0.00	w/o N rep	5543	56.9
6	1	36.44	-94.67	123	Clarksville	0.07	60.98	WPAS	0	0.00	w/o N rep	7009	56.8
645	41	36.33	-94.65	5	Clarksville	0.07	24.39	OPAS	1	0.00	w/o N rep	309	56.8
684	43	36.36	-94.65	61	Newtonia	0.03	60.98	OPAS	1	0.00	w/o N rep	3449	56.8
642	41	36.33	-94.65	16	Clarksville	0.07	24.39	WPAS	0	0.00	w/o N rep	911	56.8
220	13	36.41	-94.66	325	Clarksville	0.05	60.98	WPAS	0	1.00	w/o N rep	18412	56.7
115	6	36.38	-94.61	125	Newtonia	0.01	121.95	OPAS	1	0.54	w/o N rep	7112	56.7
681	43	36.36	-94.65	207	Newtonia	0.03	60.98	WPAS	0	0.00	w/o N rep	11738	56.6
113	6	36.38	-94.61	345	Newtonia	0.01	121.95	WPAS	0	0.00	w/o N rep	19562	56.6
486	30	36.33	-94.39	110	Clarksville	0.08	36.58	WPAS	0	2.00	w alum; w/o N rep	6241	56.6
87	4	36.4	-94.57	56	Newtonia	0.02	121.95	OPAS	1	0.54	w/o N rep	3184	56.6
488	30	36.33	-94.39	4	Clarksville	0.08	36.58	OPAS	1	0.54	w/o N rep	226	56.6
291	16	36.35	-94.44	80	Peridge	0.07	60.98	OPAS	1	0.00	w/o N rep	4547	56.6
777	48	36.4	-94.79	82	Clarksville	0.11	24.39	OPAS	1	0.00	w/o N rep	4610	56.6
188	10	36.37	-94.41	11	Britwater	0.06	60.98	OPAS	1	0.54	w alum; w/o N rep	636	56.5
536	33	36.35	-94.82	3	Britwater	0.11	24.39	OPAS	1	0.00	w/o N rep	192	56.5
533	33	36.35	-94.82	4	Britwater	0.11	24.39	WPAS	0	0.00	w/o N rep	247	56.4
774	48	36.4	-94.79	247	Clarksville	0.11	24.39	WPAS	0	0.00	w/o N rep	13929	56.4
997	64	36.37	-94.91	17	Britwater	0.11	36.58	WPAS	0	0.00	w/o N rep	936	56.4
996	64	36.37	-94.91	16	Clarksville	0.11	36.58	WPAS	0	0.00	w/o N rep	878	56.4
83	4	36.4	-94.57	377	Newtonia	0.02	121.95	WPAS	0	1.00	w/o N rep	21253	56.4
289	16	36.35	-94.44	271	Peridge	0.07	60.98	WPAS	0	0.00	w/o N rep	15205	56.2

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
887	54	36.42	-94.62	45	Newtonia	0.02	91.46	OPAS	1	0.54	w/o N rep	2505	56.2
501	31	36.36	-94.78	2	Clarksville	0.05	24.39	OPAS	1	0.00	w/o N rep	138	56.1
886	54	36.42	-94.62	93	Newtonia	0.02	91.46	WPAS	0	1.00	w/o N rep	5205	56.1
759	47	36.39	-94.84	51	Clarksville	0.09	24.39	WPAS	0	0.00	w/o N rep	2857	56.1
761	47	36.39	-94.84	18	Clarksville	0.09	24.39	OPAS	1	0.00	w/o N rep	1017	56.1
364	20	36.36	-94.89	36	Clarksville	0.16	24.39	OPAS	1	0.54	w/o N rep	2031	56.0
930	57	36.39	-94.94	4	Clarksville	0.09	18.29	OPAS	1	0.54	w/o N rep	212	56.0
62	3	36.42	-94.67	61	Newtonia	0.02	91.46	OPAS	1	0.54	w/o N rep	3388	56.0
869	53	36.35	-94.57	4	Britwater	0.07	24.39	OPAS	1	0.54	w/o N rep	202	55.9
362	20	36.36	-94.89	122	Clarksville	0.16	24.39	WPAS	0	1.00	w alum; w/o N rep	6819	55.9
660	42	36.3	-94.65	10	Clarksville	0.05	36.58	OPAS	1	0.00	w/o N rep	568	55.8
471	29	36.34	-94.36	111	Clarksville	0.06	60.98	WPAS	0	2.00	w alum; w/o N rep	6170	55.8
885	54	36.42	-94.62	23	Britwater	0.02	91.46	WPAS	0	0.00	w/o N rep	1281	55.8
656	42	36.3	-94.65	47	Clarksville	0.05	36.58	WPAS	0	0.00	w/o N rep	2616	55.8
58	3	36.42	-94.67	256	Newtonia	0.02	91.46	WPAS	0	1.00	w/o N rep	14297	55.8
679	43	36.36	-94.65	77	Clarksville	0.03	60.98	WPAS	0	0.00	w/o N rep	4299	55.7
227	13	36.41	-94.66	96	Newtonia	0.05	60.98	OPAS	1	0.00	w/o N rep	5331	55.6
865	53	36.35	-94.57	45	Britwater	0.07	24.39	WPAS	0	1.00	w alum; w/o N rep	2526	55.6
222	13	36.41	-94.66	152	Newtonia	0.05	60.98	WPAS	0	0.00	w/o N rep	8453	55.5
1007	66	36.36	-95.02	19	Clarksville	0.07	18.29	WPAS	0	1.00	w/o N rep	1032	55.5
474	29	36.34	-94.36	12	Clarksville	0.06	60.98	OPAS	1	1.08	w alum; w/o N rep	666	55.5
884	54	36.42	-94.62	31	Clarksville	0.02	91.46	WPAS	0	0.00	w/o N rep	1742	55.5
1017	67	36.37	-94.98	28	Clarksville	0.13	15.24	WPAS	0	1.00	w/o N rep	1528	55.5
1041	69	36.35	-95.01	16	Britwater	0.06	24.39	WPAS	0	0.00	w/o N rep	889	55.3
568	35	36.32	-94.71	19	Macedonia	0.07	18.29	OPAS	1	0.00	w/o N rep	1058	55.0
794	49	36.37	-94.73	51	Clarksville	0.07	36.58	OPAS	1	0.00	w/o N rep	2806	54.9
10	1	36.44	-94.67	38	Clarksville	0.07	60.98	OPAS	1	0.00	w/o N rep	2083	54.9
791	49	36.37	-94.73	151	Clarksville	0.07	36.58	WPAS	0	0.00	w/o N rep	8308	54.9
682	43	36.36	-94.65	85	Clarksville	0.03	60.98	OPAS	1	0.00	w/o N rep	4655	54.9
927	57	36.39	-94.94	48	Clarksville	0.09	18.29	WPAS	0	1.00	w/o N rep	2611	54.9
562	35	36.32	-94.71	73	Macedonia	0.07	18.29	WPAS	0	0.00	w/o N rep	4006	54.8
775	48	36.4	-94.79	51	Clarksville	0.11	24.39	WPAS	0	0.00	w/o N rep	2794	54.8
724	45	36.28	-94.67	75	Doniphan	0.03	91.46	OPAS	1	1.08	w/o N rep	4102	54.8
778	48	36.4	-94.79	56	Clarksville	0.11	24.39	OPAS	1	0.00	w/o N rep	3049	54.8
225	13	36.41	-94.66	62	Clarksville	0.05	60.98	OPAS	1	0.00	w/o N rep	3413	54.8
721	45	36.28	-94.67	177	Doniphan	0.03	91.46	WPAS	0	2.00	w/o N rep	9696	54.7
221	13	36.41	-94.66	164	Clarksville	0.05	60.98	WPAS	0	0.00	w/o N rep	8998	54.7
207	11	36.4	-94.99	20	Clarksville	0.10	24.39	OPAS	1	0.54	w/o N rep	1097	54.7
306	17	36.41	-94.48	50	Clarksville	0.06	60.98	WPAS	0	1.00	w/o N rep	2720	54.6
204	11	36.4	-94.99	35	Clarksville	0.10	24.39	WPAS	0	1.00	w/o N rep	1908	54.6
184	10	36.37	-94.41	63	Clarksville	0.06	60.98	WPAS	0	1.00	w/o N rep	3432	54.4
899	55	36.27	-94.74	347	Clarksville	0.06	60.98	WPAS	0	0.00	w/o N rep	18894	54.4
287	16	36.35	-94.44	195	Clarksville	0.07	60.98	WPAS	0	1.00	w/o N rep	10623	54.4
567	35	36.32	-94.71	19	Doniphan	0.07	18.29	OPAS	1	0.54	w/o N rep	1009	54.4
561	35	36.32	-94.71	50	Doniphan	0.07	18.29	WPAS	0	1.00	w/o N rep	2701	54.3
868	53	36.35	-94.57	8	Clarksville	0.07	24.39	OPAS	1	0.54	w/o N rep	437	54.3
864	53	36.35	-94.57	25	Clarksville	0.07	24.39	WPAS	0	1.00	w/o N rep	1353	54.3
421	24	36.34	-94.49	171	Clarksville	0.05	60.98	WPAS	0	1.00	w/o N rep	9285	54.2
327	18	36.39	-94.47	65	Clarksville	0.05	60.98	WPAS	0	1.00	w/o N rep	3500	54.2
602	37	36.36	-94.59	4	Clarksville	0.06	24.39	OPAS	1	0.54	w/o N rep	196	54.1
599	37	36.36	-94.59	36	Clarksville	0.06	24.39	WPAS	0	1.00	w/o N rep	1967	54.0
348	19	36.35	-94.92	12	Doniphan	0.06	24.39	WPAS	0	0.00	w/o N rep	659	54.0
661	42	36.3	-94.65	28	Doniphan	0.05	36.58	OPAS	1	0.54	w/o N rep	1487	54.0
658	42	36.3	-94.65	50	Doniphan	0.05	36.58	WPAS	0	1.00	w/o N rep	2673	54.0
725	45	36.28	-94.67	59	Macedonia	0.03	91.46	OPAS	1	0.54	w/o N rep	3197	53.9
813	50	36.27	-94.81	86	Doniphan	0.09	24.39	OPAS	1	0.00	w/o N rep	4626	53.9
722	45	36.28	-94.67	100	Macedonia	0.03	91.46	WPAS	0	1.00	w/o N rep	5396	53.8
619	38	36.32	-94.53	233	Clarksville	0.05	60.98	WPAS	0	1.00	w/o N rep	12507	53.8
902	55	36.27	-94.74	499	Doniphan	0.06	60.98	OPAS	1	0.54	w/o N rep	26837	53.8
900	55	36.27	-94.74	586	Doniphan	0.06	60.98	WPAS	0	1.00	w/o N rep	31508	53.8
973	62	36.33	-94.8	45	Doniphan	0.05	36.58	OPAS	1	0.54	w/o N rep	2427	53.7
970	62	36.33	-94.8	47	Doniphan	0.05	36.58	WPAS	0	1.00	w/o N rep	2505	53.7
1027	68	36.33	-94.61	29	Doniphan	0.05	36.58	OPAS	1	0.54	w/o N rep	1532	53.5
1024	68	36.33	-94.61	198	Doniphan	0.05	36.58	WPAS	0	1.00	w/o N rep	10555	53.4
386	22	36.37	-94.51	202	Clarksville	0.06	36.58	WPAS	0	1.00	w/o N rep	10755	53.4

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
1039	69	36.35	-95.01	13	Clarksville	0.06	24.39	WPAS	0	0.00	w/o N rep	667	53.3
32	2	36.43	-94.7	186	Doniphan	0.04	60.98	WPAS	0	1.00	w/o N rep	9869	53.1
37	2	36.43	-94.7	154	Doniphan	0.04	60.98	OPAS	1	0.54	w/o N rep	8192	53.1
762	47	36.39	-94.84	6	Doniphan	0.09	24.39	OPAS	1	0.00	w/o N rep	340	53.1
251	14	36.37	-94.66	42	Macedonia	0.03	91.46	OPAS	1	0.00	w/o N rep	2235	53.1
247	14	36.37	-94.66	95	Macedonia	0.03	91.46	WPAS	0	0.00	w/o N rep	5012	53.0
537	33	36.35	-94.82	2	Taloka	0.11	24.39	OPAS	1	0.00	w/o N rep	130	53.0
705	44	36.3	-94.68	20	Macedonia	0.04	60.98	OPAS	1	0.00	w/o N rep	1031	52.9
1025	68	36.33	-94.61	39	Clarksville	0.05	36.58	OPAS	1	0.54	w/o N rep	2061	52.7
1022	68	36.33	-94.61	216	Clarksville	0.05	36.58	WPAS	0	1.00	w/o N rep	11391	52.7
747	46	36.29	-94.61	37	Taloka	0.03	60.98	OPAS	1	0.54	w alum; w/o N rep	1938	52.6
680	43	36.36	-94.65	107	Macedonia	0.03	60.98	WPAS	0	0.00	w/o N rep	5615	52.6
683	43	36.36	-94.65	94	Macedonia	0.03	60.98	OPAS	1	0.00	w/o N rep	4919	52.6
702	44	36.3	-94.68	63	Macedonia	0.04	60.98	WPAS	0	0.00	w/o N rep	3293	52.6
226	13	36.41	-94.66	59	Doniphan	0.05	60.98	OPAS	1	0.54	w/o N rep	3109	52.5
38	2	36.43	-94.7	112	Macedonia	0.04	60.98	OPAS	1	0.00	w/o N rep	5844	52.4
662	42	36.3	-94.65	23	Macedonia	0.05	36.58	OPAS	1	0.00	w/o N rep	1226	52.2
250	14	36.37	-94.66	33	Doniphan	0.03	91.46	OPAS	1	0.54	w/o N rep	1721	52.1
743	46	36.29	-94.61	469	Taloka	0.03	60.98	WPAS	0	1.00	w alum; w/o N rep	24402	52.1
12	1	36.44	-94.67	23	Doniphan	0.07	60.98	OPAS	1	0.54	w/o N rep	1210	51.9
659	42	36.3	-94.65	56	Macedonia	0.05	36.58	WPAS	0	0.00	w/o N rep	2925	51.9
796	49	36.37	-94.73	41	Doniphan	0.07	36.58	OPAS	1	0.00	w/o N rep	2136	51.8
8	1	36.44	-94.67	44	Doniphan	0.07	60.98	WPAS	0	0.00	w/o N rep	2270	51.8
605	37	36.36	-94.59	3	Nixa	0.06	24.39	OPAS	1	0.00	w/o N rep	176	51.7
406	23	36.36	-94.55	7	Nixa	0.05	24.39	WPAS	0	0.00	w/o N rep	338	51.6
1044	69	36.35	-95.01	4	Nixa	0.06	24.39	OPAS	1	0.00	w/o N rep	227	51.5
13	1	36.44	-94.67	28	Macedonia	0.07	60.98	OPAS	1	0.00	w/o N rep	1454	51.4
373	21	36.41	-94.51	48	Nixa	0.04	60.98	OPAS	1	0.00	w/o N rep	2474	51.4
370	21	36.41	-94.51	152	Nixa	0.04	60.98	WPAS	0	0.00	w/o N rep	7801	51.3
114	6	36.38	-94.61	30	Taloka	0.01	121.95	OPAS	1	0.00	w/o N rep	1519	51.3
33	2	36.43	-94.7	184	Taloka	0.04	60.98	WPAS	0	0.00	w/o N rep	9444	51.2
797	49	36.37	-94.73	80	Macedonia	0.07	36.58	OPAS	1	0.00	w/o N rep	4088	51.2
112	6	36.38	-94.61	227	Taloka	0.01	121.95	WPAS	0	0.00	w/o N rep	11553	50.9
792	49	36.37	-94.73	230	Macedonia	0.07	36.58	WPAS	0	0.00	w/o N rep	11667	50.8
604	37	36.36	-94.59	4	Taloka	0.06	24.39	OPAS	1	0.00	w/o N rep	195	50.7
271	15	34.4	-94.44	22	Nixa	0.05	60.98	OPAS	1	0.00	w/o N rep	1115	50.6
332	18	36.39	-94.47	23	Nixa	0.05	60.98	OPAS	1	0.00	w/o N rep	1148	50.5
312	17	36.41	-94.48	22	Nixa	0.06	60.98	OPAS	1	0.00	w/o N rep	1086	50.5
267	15	34.4	-94.44	110	Nixa	0.05	60.98	WPAS	0	0.00	w/o N rep	5542	50.5
329	18	36.39	-94.47	89	Nixa	0.05	60.98	WPAS	0	0.00	w/o N rep	4511	50.4
624	38	36.32	-94.53	45	Nixa	0.05	60.98	OPAS	1	0.00	w/o N rep	2242	50.4
170	9	36.4	-94.37	149	Nixa	0.05	60.98	OPAS	1	0.00	w/o N rep	7482	50.4
308	17	36.41	-94.48	109	Nixa	0.06	60.98	WPAS	0	0.00	w/o N rep	5503	50.3
390	22	36.37	-94.51	18	Nixa	0.06	36.58	OPAS	1	0.00	w/o N rep	917	50.3
426	24	36.34	-94.49	78	Nixa	0.05	60.98	OPAS	1	0.00	w/o N rep	3915	50.3
166	9	36.4	-94.37	728	Nixa	0.05	60.98	WPAS	0	0.00	w/o N rep	36577	50.2
621	38	36.32	-94.53	314	Nixa	0.05	60.98	WPAS	0	0.00	w/o N rep	15759	50.2
189	10	36.37	-94.41	33	Nixa	0.06	60.98	OPAS	1	0.00	w/o N rep	1640	50.2
1008	66	36.36	-95.02	26	Clarksville	0.07	18.29	WPAS	0	1.00	w/o N rep	1304	50.2
423	24	36.34	-94.49	480	Nixa	0.05	60.98	WPAS	0	0.00	w/o N rep	24053	50.1
388	22	36.37	-94.51	201	Nixa	0.06	36.58	WPAS	0	0.00	w/o N rep	10072	50.1
185	10	36.37	-94.41	123	Nixa	0.06	60.98	WPAS	0	0.00	w/o N rep	6166	50.1
290	16	36.35	-94.44	53	Nixa	0.07	60.98	OPAS	1	0.00	w/o N rep	2647	50.0
487	30	36.33	-94.39	274	Nixa	0.08	36.58	WPAS	0	0.00	w/o N rep	13679	49.9
288	16	36.35	-94.44	317	Nixa	0.07	60.98	WPAS	0	0.00	w/o N rep	15765	49.8
490	30	36.33	-94.39	9	Nixa	0.08	36.58	OPAS	1	0.00	w/o N rep	463	49.4
82	4	36.4	-94.57	292	Taloka	0.02	121.95	WPAS	0	1.00	w alum; w/o N rep	14431	49.4
84	4	36.4	-94.57	174	Nixa	0.02	121.95	WPAS	0	0.00	w/o N rep	8458	48.5
63	3	36.42	-94.67	88	Nixa	0.02	91.46	OPAS	1	0.00	w/o N rep	4250	48.4
131	7	36.4	-94.31	18	Nixa	0.03	91.46	OPAS	1	0.00	w/o N rep	879	48.4
59	3	36.42	-94.67	324	Nixa	0.02	91.46	WPAS	0	0.00	w/o N rep	15658	48.3
150	8	36.37	-94.33	24	Nixa	0.03	91.46	OPAS	1	0.00	w/o N rep	1136	48.3
127	7	36.4	-94.31	155	Nixa	0.03	91.46	WPAS	0	0.00	w/o N rep	7498	48.2
147	8	36.37	-94.33	131	Nixa	0.03	91.46	WPAS	0	0.00	w/o N rep	6307	48.2
88	4	36.4	-94.57	34	Nixa	0.02	121.95	OPAS	1	0.00	w/o N rep	1610	47.8

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)	Per hectare shadow price ($/ha.)
475	29	36.34	-94.36	68	Nixa	0.06	60.98	OPAS	1	0.00	w/o N rep	3265	47.7
472	29	36.34	-94.36	384	Nixa	0.06	60.98	WPAS	0	0.00	w/o N rep	18226	47.5
918	56	36.38	-94.44	1	Clarksville	0.08	60.98	WPAS	0	0.00	w/o N rep	28	46.5
1009	66	36.36	-95.02	35	Nixa	0.07	18.29	WPAS	0	1.00	w alum; w/o N rep	1510	43.5
923	56	36.38	-94.44	0	Clarksville	0.08	60.98	HAY	0	0.00	w/o N rep	3	10.3
924	56	36.38	-94.44	1	Britwater	0.08	60.98	HAY	0	0.00	w/o N rep	1	1.1
954	60	36.37	-94.81	0	Water	0.10	18.29	OPAS	0	0.00	w/o N rep	-13	-32.6
538	33	36.35	-94.82	5	Water	0.11	24.39	OPAS	0	0.00	w/o N rep	-157	-32.6
543	33	36.35	-94.82	6	Water	0.11	24.39	HAY	0	0.00	w/o N rep	-231	-37.7
446	25	36.37	-94.87	2	Water	0.11	24.39	HAY	0	0.00	w/o N rep	-60	-37.7
1003	64	36.37	-94.91	2	Water	0.11	36.58	HAY	0	0.00	w/o N rep	-86	-37.7
925	56	36.38	-94.44	0	Water	0.08	60.98	HAY	0	0.00	w/o N rep	-7	-37.7
443	25	36.37	-94.87	4	Water	0.11	24.39	WPAS	0	0.00	w/o N rep	-168	-38.5
205	11	36.4	-94.99	24	Water	0.10	24.39	WPAS	0	0.00	w/o N rep	-938	-38.5
534	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0	0.00	w/o N rep	-188	-38.5
455	27	36.36	-94.8	2	Water	0.13	36.58	WPAS	0	0.00	w/o N rep	-76	-38.5

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VITA

Tihomir Ancev

Candidate for the Degree of

Doctor of Philosophy

Thesis: OPTIMAL ALLOCATION OF WASTE MANAGEMENT PRACTICES WITH ECONOMIC IMPLICATIONS FOR POLICIES TO REGULATE PHOSPHORUS POLLUTION IN THE EUCHA-SPAVINAW WATERSHED

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Skopje, Macedonia, On March 23, 1969.

Education: Graduated from "Dr. Pance Karagjozov" Secondary School in Skopje, Macedonia in June 1987; received Bachelor of Science degree in Agriculture from University Saints Cyril and Methodius, Skopje, Macedonia in July, 1992; received Master of Science degree in Economics from the University of Iceland, Reykjavik, Iceland in October, 1997. Completed the requirements for the Doctor of Philosophy degree with a major in Agricultural Economics at Oklahoma State University in August, 2003.

Experience: Raised in a city of Skopje, Macedonia. Employed as an agronomist by the Experimental Farm of the Faculty of Agriculture in Skopje, Macedonia, 1992-1993. Employed as a commercial manager by the Representative Office of Makhteshim–Agan in Skopje, Macedonia, 1993-1997. Employed as a consultant by the ANC in Skopje, Macedonia, 1998-2000. Employed as a graduate research assistant by the Oklahoma State University, 2001-to present.

Professional Memberships: American Agricultural Economics Association, Southern Agricultural Economics Association, Western Agricultural Economics Association, European Association of Agricultural Economists, Association of Environmental and Resource Economists.