ENVIRONMENTAL ANALYSIS OF CAMERON AND GRINDSTONE WATERSHEDS, MISSOURI

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Lynn King Heidenreich

Prepared by the Food & Agricultural Policy Research Institute (FAPRI)

University of Missouri
101 S. Fifth Street
Columbia, Missouri 65201
(573) 882-3576

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Background

Pesticides, nutrients and sediment threaten the quality of surface drinking water supplies in Cameron, Missouri. A Watershed Steering Committee made up of a cross-section of interests came together for the community surrounding the City of Cameron to set objectives for improving their community's water supply. Their primary goal was "to reduce agricultural non-point source pollutants to acceptable MDNR standards in untreated waters in the Cameron Reservoirs in an environmentally and economically sound manner by the year 2006." In order to reach this objective, this study was undertaken to analyze options for reducing the amount of pesticides, nutrients and sediment leaving the cropland and reaching the reservoirs. A reduction of pesticide concentrations in the raw water source would reduce the level of treatment needed to keep the finished water within State and Federal drinking water standards.

Study Area Description

Drinking water for the City of Cameron is supplied by reservoirs in two adjacent watersheds located in DeKalb and Clinton counties in northwestern Missouri north of Kansas City (see Figure 1).

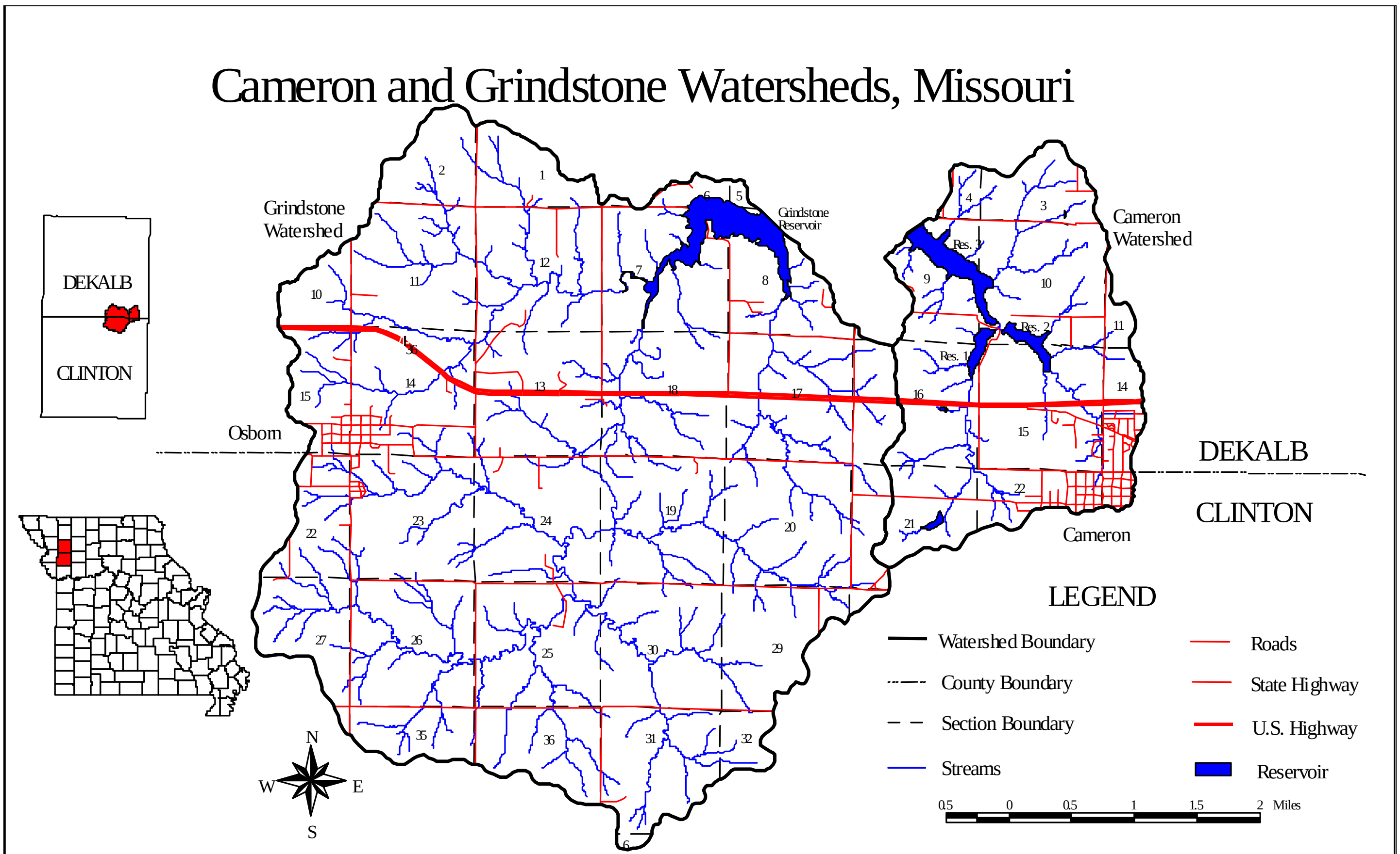


Figure 1. Location of Cameron and Grindstone watersheds.

Cameron Watershed

The Cameron Watershed covers approximately 3250 acres within the Upper Grand River Basin. The stream flows to the northwest, and supplies water to three reservoirs (see Figure 2 below).

Reservoir 1 was built in 1905, and has a surface area of approximately 17 acres, and a drainage area of 1083 acres. It is a relatively shallow lake, with a maximum depth of 14 feet. Reservoir 1 was the original water supply source for the City of Cameron.

Reservoir 2 which was built in 1939, has a surface area of approximately 31 acres, and maximum depth of approximately 27 feet. It drains an area of 1113 acres, and includes part of the City of Cameron.

Reservoir 3 was built in 1961, and is now Cameron's main source of drinking water. It has a surface area of approximately 90 acres, with a maximum depth of approximately 25 feet. Reservoir 3 drains the entire 3250-acre watershed. The older Reservoirs 1 and 2 flow into it, and serve as sedimentation basins for the newer reservoir. Reservoir 3 flows out of the watershed and joins Grindstone Creek less than a mile downstream from the Grindstone Watershed.

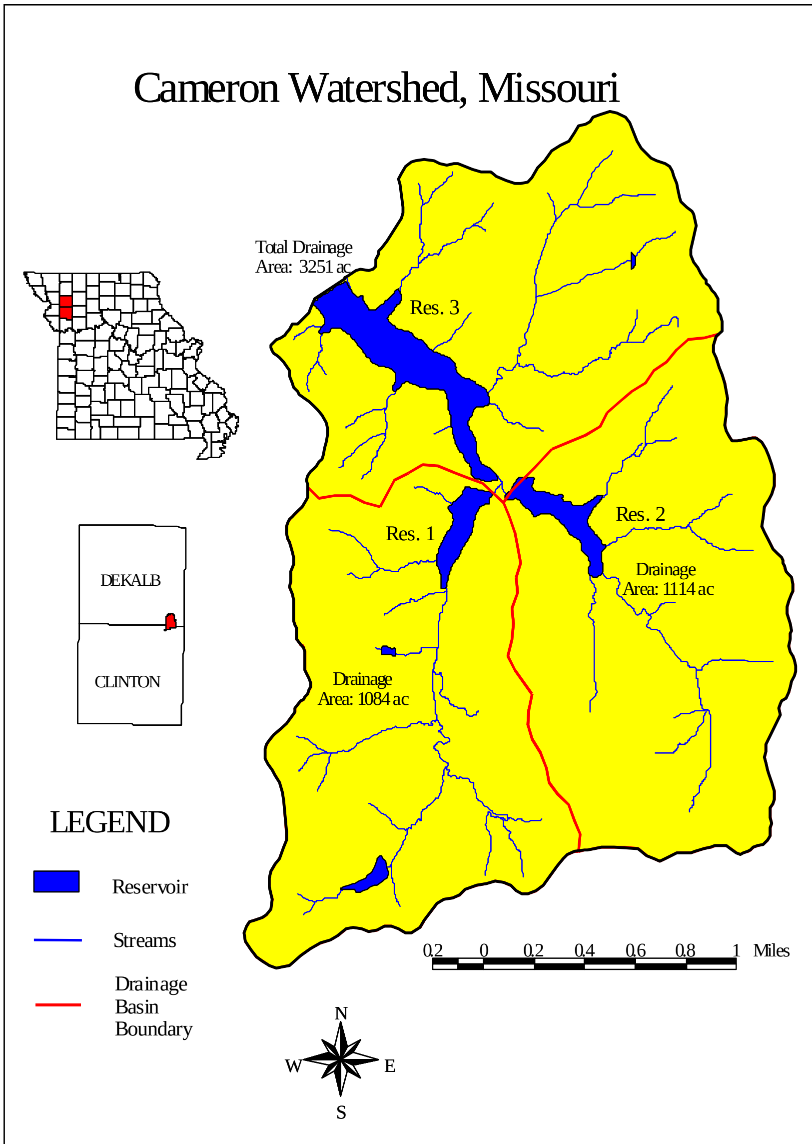


Figure 2. Drainage basin boundaries for 3 reservoirs in the Cameron watershed.

Grindstone Watershed

The Grindstone Watershed abuts the western boundary of the Cameron, and covers approximately 13,400 acres. Grindstone Creek flows in a northerly direction into the Grindstone Reservoir.

Grindstone Reservoir was built in 1991 by the City of Cameron and the Natural Resources Conservation Service as multi-purpose structure. The reservoir has a surface area of approximately 177 acres and a maximum depth of approximately 31 feet. Its uses include flood control and recreation, as well as a backup water supply for the City of Cameron. Like the Cameron Watershed, the Grindstone Watershed is part of the Upper Grand River Basin.

Water quality background

Water is pumped directly from Cameron Reservoir 3 to the water treatment plant. When the water level falls in the Cameron Reservoir, water from Grindstone Reservoir is transferred to Reservoir 3 by pipeline, where it is mixed before transfer to the water treatment plant. The water treatment plant can draw supplies directly from the Grindstone Reservoir, but water quality data compiled by Missouri Department of Natural Resources (MDNR) shows that pesticide concentrations in this reservoir tend to exceed concentrations in the Cameron Reservoir 3 at certain times of the year. Mixing Grindstone Reservoir water in the Cameron Reservoir 3 tends to result in lower concentrations of atrazine in the raw water delivered to the treatment plant than if Grindstone water were used directly.

Quarterly post-treatment water samples collected by the City of Cameron water treatment facility and analyzed by a MDNR Laboratory between September 1994 and February 1998 detected atrazine concentrations ranging from less than 0.5 ppb to 3.5 ppb. Two samples in that time frame exceeded the 3.0 ppb Maximum Contaminant Level (MCL) defined by the EPA, but because the MCL is determined by a running average of four quarterly samples, the treated water was not out of compliance with state and federal standards during that time period.

Between January and July 1995, immunoassay tests conducted at the treatment plant showed triazine in raw water from the Grindstone Reservoir 1.5 to 3 times higher than in raw water from the Cameron Reservoir 3, with concentrations ranging from 5.4 to 8.0 ppb, according to data compiled by the MDNR. The immunoassay test is not atrazine-specific, but tests for total concentration of triazines, of which atrazine is one constituent. Higher levels of triazine in the raw water require a greater level of treatment to reduce the pesticide levels to within acceptable limits in the finished water. In May 1995, the water treatment plant began utilizing Powdered Activated Carbon (PAC) in its water treatment process. However, the design limitations of the treatment plant restricted the levels of PAC that could be added in the treatment process to less than the levels required to treat the higher triazine concentrations found in the Grindstone Reservoir. (E.T. Archer Corporation Engineer's Report, January 1996). A water treatment plant expansion due for completion in late 1999 will improve the plant's PAC treatment capabilities. This will eliminate the need to mix the Grindstone water with Cameron Reservoir 3 water, and enable the direct transfer of water from Grindstone Reservoir to the treatment plant.

Soils

The Cameron and Grindstone Watersheds are located within Major Land Resource Area (MLRA) 109, with soils indicative of the Iowa and Missouri Heavy Till Plain. The soils distribution in each watershed is summarized in Table 1, with a spatial distribution shown in Figure 3 at the bottom of the page.

Table 1. **Soils distribution in the Cameron and Grindstone Watersheds**

	% of Watershed	
Soil Name	*Cameron*	*Grindstone*
Grundy silt loam, 2-5% slopes	**26**	**37**
Grundy silty clay loam, 2-5% slopes, eroded	**4**	**11**
Grundy silt loam, 5-9% slopes	**1**	**5**
Grundy silty clay loam, 5-9%, eroded	**27**	**22**
Lamoni silty clay loam, 5-9% slopes, eroded	20	5
Armstrong silt loam, 5-9% slopes	2	2
Armstrong silt loam, 5-9% slopes, eroded	4	0
Colo silty clay loam, 2-5% slopes	4	6
Kennebec silt loam, 0-2% slopes	0	4
Ladoga silt loam, 5-9% slopes	0	2
Vanmeter, Gasconade complex, 14-50% slopes	7	1
Other soils	5	5
Total	100	100

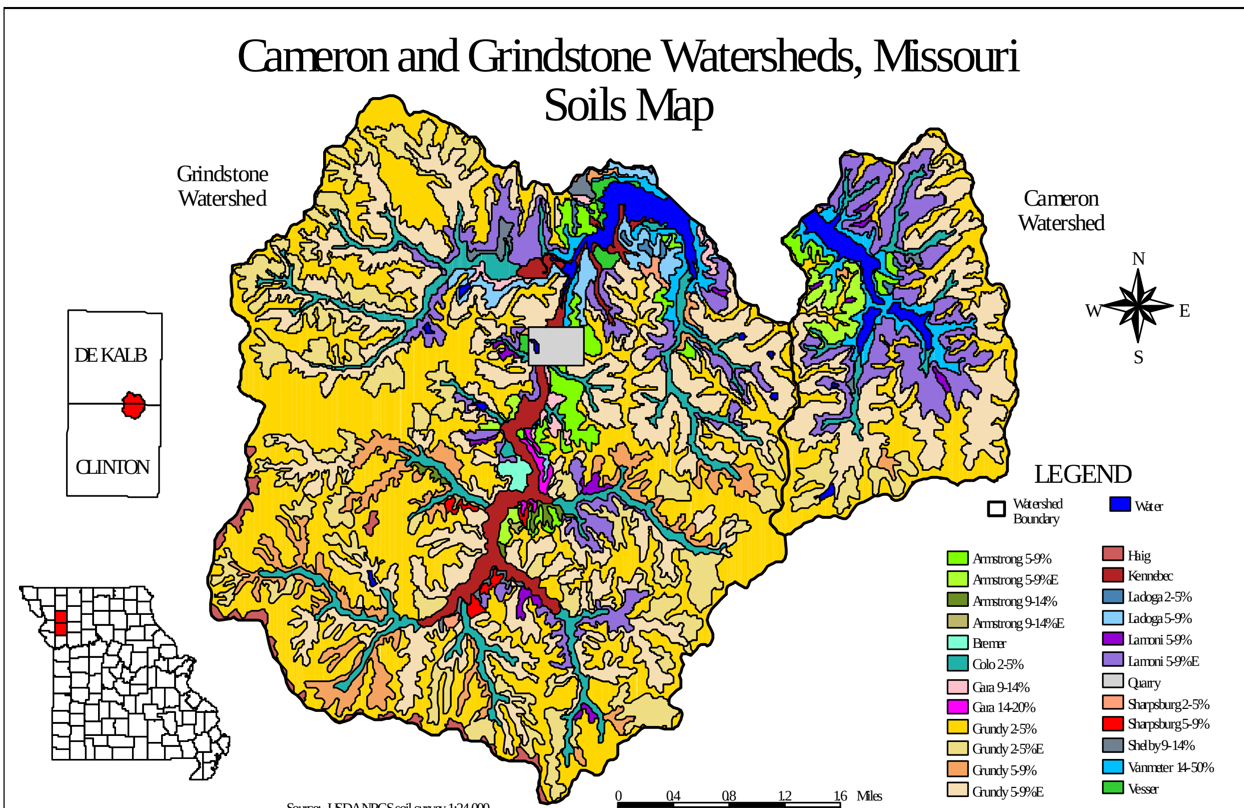


Figure 3. Soils distribution in the Cameron and Grindstone watersheds.

Land Use Distribution

Cameron Watershed

Cameron Watershed is predominantly agricultural, with 28% of the overall acreage in rotational crops and 44% in various grass covers (i.e. pasture, hay and CRP). The drainage areas for Reservoirs 1 and 2 have different land use characteristics, causing different water quality impacts in the respective reservoirs (see Table 2).

Table 2.

Drainage Areas						
	Reservoir 1		*Reservoir 2*		*Reservoir 3*	
Land Use	*Acres*	*% Area*	*Acres*	*% Area*	*Acres*	*% Area*
Cropland	537	49	142	13	896	28
Grassland	411	38	388	35	1,424	44
Forest	84	8	88	8	285	9
Urban	23	2	462	41	485	15
Water	29	3	34	3	161	5
Total	1084	100	1114	100	3,251	100

The Reservoir 1 drainage area is 49% rotational cropland, compared to 13% for the Reservoir 2 drainage area. More agricultural chemicals are used in the Reservoir 1 drainage area due to the higher rotational cropland acreage. Most of the forested area within the Cameron watershed surrounds the reservoirs, forming a buffer between the reservoirs and cropland. (see Figure 4).

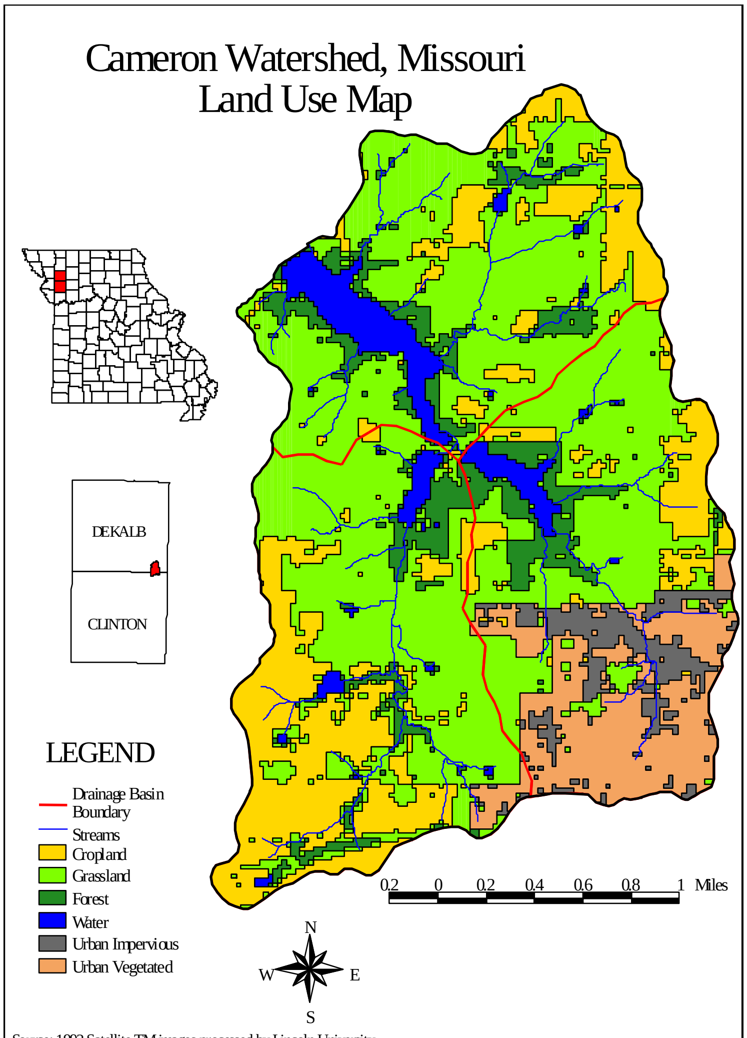


Figure 4. Land use distribution in the Cameron watershed.

Grindstone Watershed

Grindstone Watershed is also predominantly agricultural, with 48% of the land in rotational crops and 44% in various grass covers (pasture, hay and CRP) (see Table 3).

Table 3.

Land Use	*Acres*	*% Area*
Cropland	6,432	48
Grassland	5,863	44
Forest	554	4
Urban	282	2
Water	288	2
Total	13,419	100

In the Grindstone watershed, the majority of the forested area occurs as a riparian buffer along Grindstone Creek (see Figure 5).

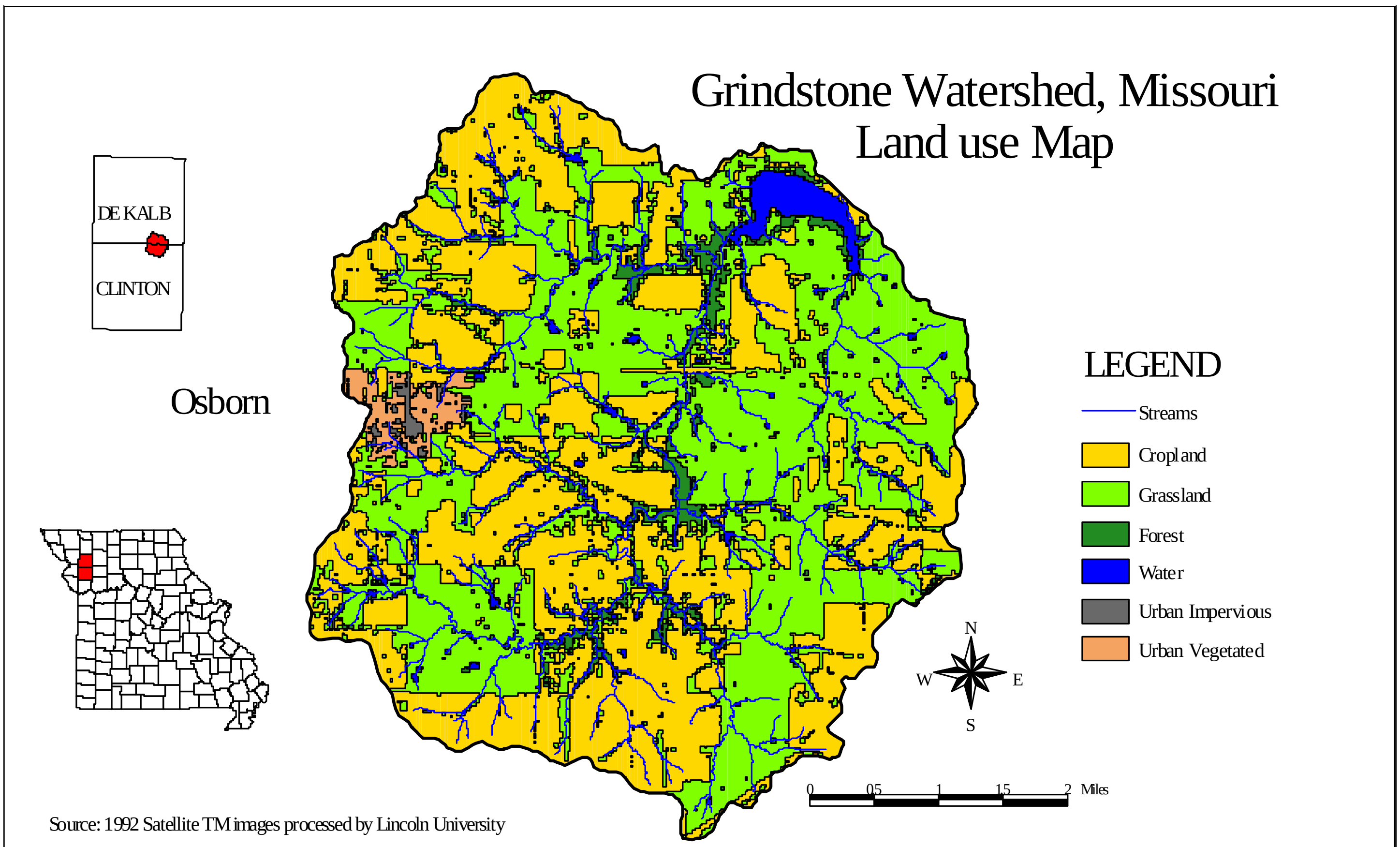


Figure 5. Land use distribution in the Grindstone watershed.

Baseline Crop Management and Distribution

Baseline Crop Management

A Representative Farm Panel, made up of five producers who operate within the watersheds, defined the most common methods of crop management used in that area. The information provided included crop rotations and tillage methods, along with type and application rates of pesticides and fertilizers. The most predominant crop rotation was a two-year corn-soybean rotation, for which the Farm Panel defined seven prevailing management systems.

The majority of the baseline crop rotations utilize no-till operations. The main herbicides used on the corn acreage as of 1997 were products containing atrazine, metolachlor, 2,4-D, prosulfuron, primisulfuron, and dicamba. Of these, atrazine caused the greatest local concern in terms of water quality impacts. Atrazine application dates varied among the seven corn-bean alternatives. The corn management practices defined by the Representative Farm Panel are described in Appendix A.

Baseline Crop Distribution

In order to determine the spatial distribution of the crop rotations over the watershed, farm-specific crop history data was collected from Farm Service Agency (FSA) records in DeKalb and Clinton counties for the years 1993 through 1996. These data confirmed the predominant corn-soybean crop rotation defined by the Representative Farm Panel and identified additional rotations. In Cameron Watershed, the main crop rotations were:

1. Corn-soybean (CB)
2. Corn-soybean-soybean (CBB)

In Grindstone Watershed, crop rotations included:

1. Corn-soybean (CB)
2. Corn-soybean-soybean (CBB)
3. Corn-corn-soybean (CCB)

One member of the Representative Farm Panel, a custom chemical applicator, worked with over 90% of the producers in the watersheds. This panel member was instrumental in defining the watershed distribution of the seven specific corn-bean rotations described by the Representative Farm Panel. Figures 6 and 7 show the crop rotation distribution for the Cameron and Grindstone watershed and subbasins. Cameron subbasins 6 and 7 are predominantly urban, and contain no rotation crops.

Alternative Crop Management and Distribution

Crop management alternatives were proposed by the local Watershed Steering Committee. Membership of the committee included several farmers from the Representative Farm Panel, District Conservationists from Clinton and DeKalb counties, the water treatment plant operator, and other local interests. The baseline and alternative corn management is summarized in Table 4. The alternatives were evaluated based on the assumption of 100% adoption of that alternative across each watershed.

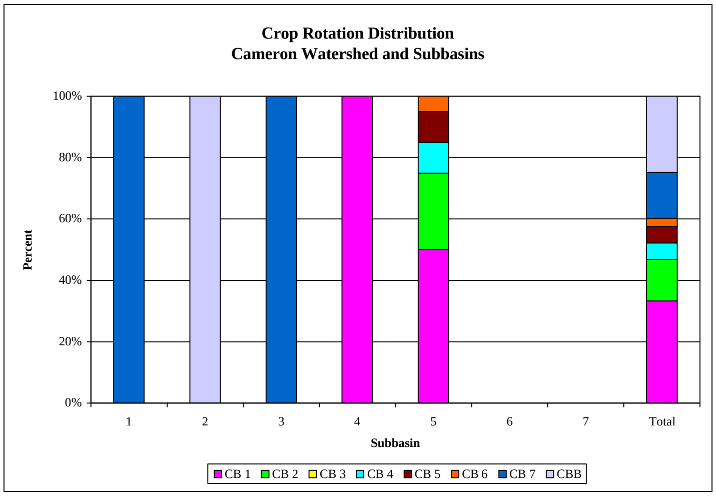


Figure 6

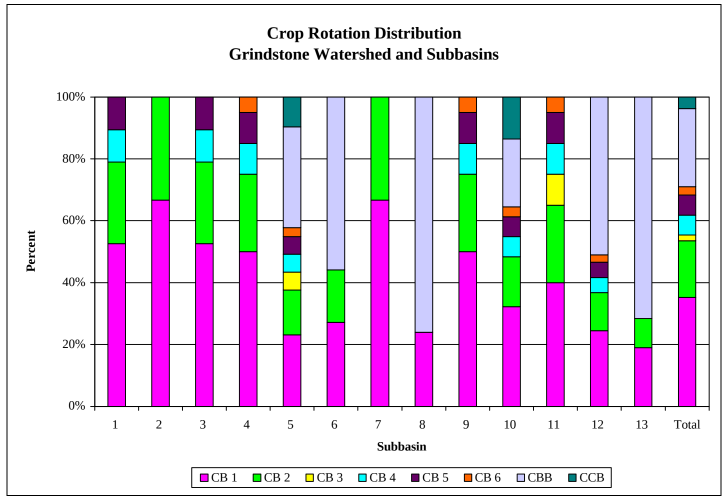


Figure 7

Two of the alternatives, split application and incorporation, were already defined in the baseline. One baseline corn-bean rotation utilized a split application of atrazine (CB 2), while another incorporated chemicals into the soil after application (CB 4) (Appendix A). These two alternatives maintained the baseline atrazine application rate of 1.60 pounds active ingredient per acre (lb a.i./ac). A third alternative, reduced Nitrogen, maintained the baseline corn-bean rotations, tillage, and atrazine application rates,

Table 4.

Crop Management	*Average Atrazine Application Rate (lb a.i./ac)*	*Average Nitrogen Application Rate (corn) (lb/ac)*	*Tillage*
Baseline	**1.60**	**117**	**95% No-till**
Split Application*	1.60	117	No-till
Incorporation*	1.60	121	Minimum till
Reduced Nitrogen	1.60	89	95% No-till
Alternative 1	0.72	125	No-till
Alternative 2a	1.00	125	No-till
Alternative 2b	0.00	125	No-till
Alternative 3	0.53	125	No-till
Alternative 4	1.34	125	No-till
Alternative 5	0.00	125	No-till
Alternative 6	1.22	125	No-till

**Existing Baseline Option*

Seven other alternatives were defined by the committee which utilized reduced amounts of atrazine and/or new weed control products. The baseline CB 1 was the most predominant rotation used by the farmers in each watershed, so the Nitrogen application rate and tillage from CB 1 was adopted for each of the seven alternatives, and only the pesticide product, rate, and timing were changed. Because Nitrogen application rates vary across the baseline rotations, imposing CB 1 application rates in the alternatives means that average Nitrogen application rates under the alternatives differ from the baseline.

Alternatives 2b and 5 were both non-atrazine options utilizing Liberty and Balance, respectively. An explanation of the proposed alternative crop management practices defined by the Watershed Steering Committee is given in Appendix B.

The evaluation of each alternative is based on the assumption that 100% of the corn acreage adopts the atrazine application rate, Nitrogen application rate and tillage defined in the alternative.

Watershed Model

A baseline environmental simulation model depicting the current conditions of the watershed was completed which accounted for the physical properties of the area (soils, climate, stream channel data, reservoir data) as well as the 1997 farming practices. The baseline simulations for each watershed were calibrated so that calculated values such as crop yield, surface runoff, sediment yield, and movement of agricultural chemicals compared well to reported values. Crop yield was compared to the average yields for Cameron and DeKalb counties for the 12-year modeling period. Surface runoff was compared to estimates by the U. S. Geological Survey (John Skelton, Carryover Storage Requirements for Reservoir Design in Missouri, Water Resources Report 27, Water Resources Division, U.S. Geological Survey, August 1971). Sediment yield was reviewed by NRCS staff, and the atrazine results were compared to data compiled by the Missouri Department of Natural Resources from several water quality sampling programs.

The calibrated models were then used to evaluate proposed alternative crop management practices and their potential impact on water quality in the Cameron and Grindstone reservoirs. The proposed alternatives utilized variations in pesticide products, application rates and timing of application, as well as changes in tillage practices.

The Cameron watershed was divided into seven subbasins for modeling purposes in order to determine which areas might be “hot spots” for pesticide, nutrient and/or sediment losses. The subbasin boundaries were selected on the basis of common soil types found within the subbasin boundaries (see Figure 8).

The Grindstone watershed was divided into thirteen subbasins in the same manner (see Figure 9 on page 12).

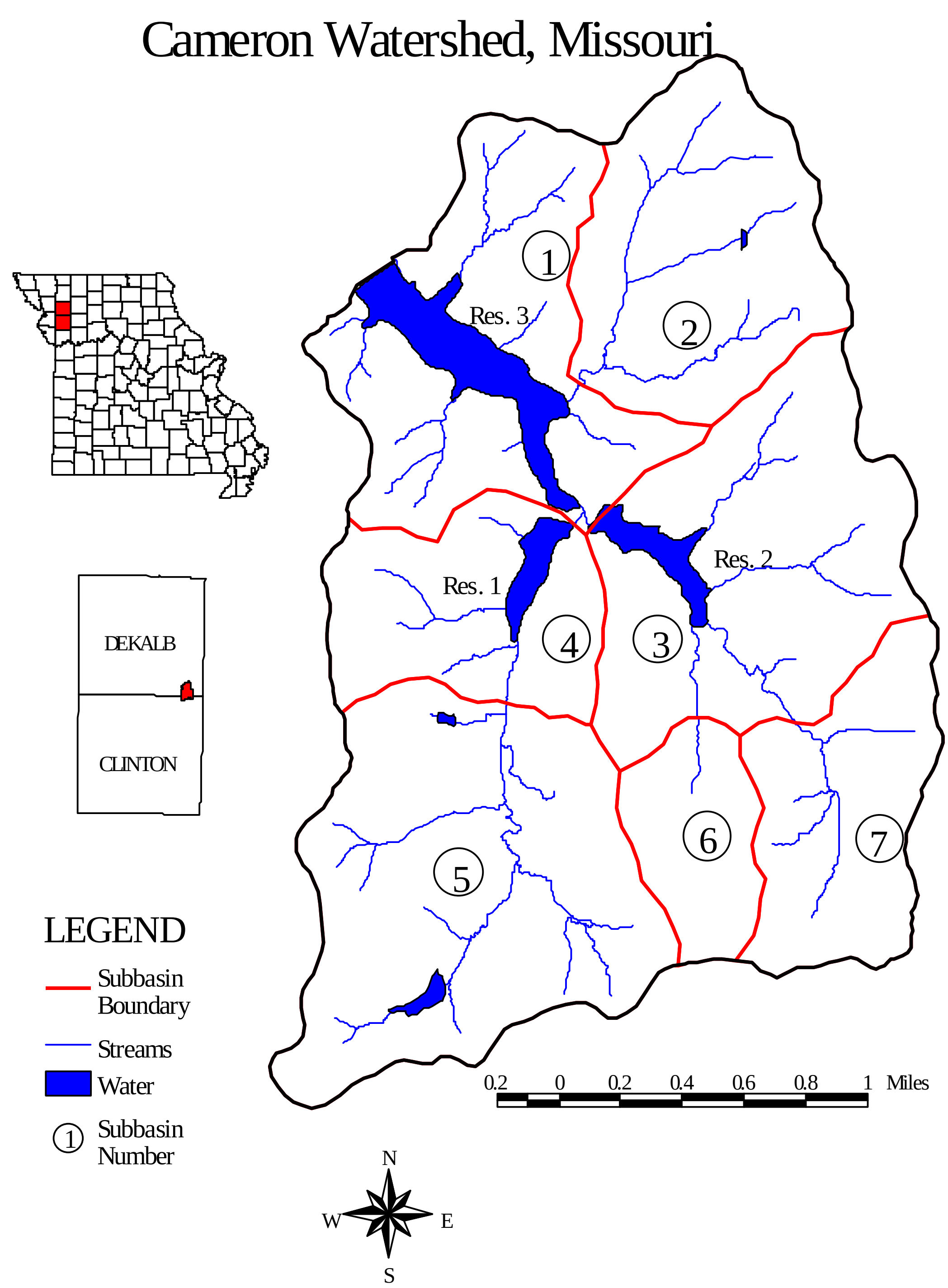


Figure 8. Subbasins for the Cameron watershed model.

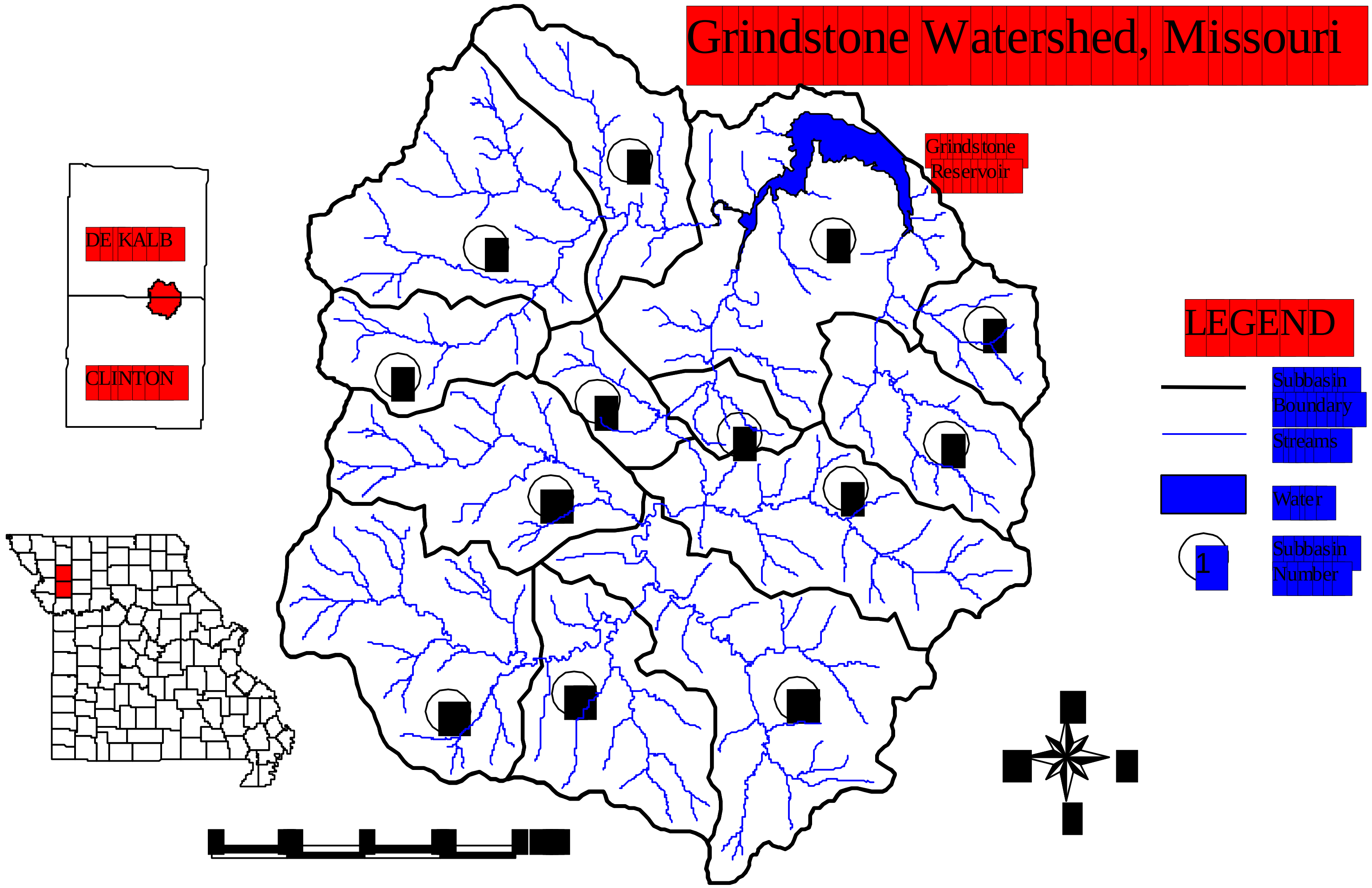


Figure 9. Subbasins for the Grindstone watershed model.

Results

Atrazine Loading

Application timing, tillage and application rate are all factors affecting the loading of atrazine to the subbasin outlets and reservoirs. Table 5 summarizes the variation in these factors for the baseline and alternatives.

Table 5. Comparison of management alternatives in Cameron and Grindstone Watersheds.

Management	Atrazine application rate (lb ai/acre)	Tillage*	Application Date
Baseline	**1.60**	**95% NT**	**3/25, 4/1, 5/2**
Incorporation	1.60	Minimum Till	3/25
Split Application	1.60	No Till	4/1, 5/2
Alternative 1	0.72	No Till	5/10
Alternative 2a	1.00	No Till	5/10
Alternative 2b	0.00	No Till	NA
Alternative 3	0.53	No Till	5/10
Alternative 4	1.34	No Till	4/1
Alternative 5	0.00	No Till	NA
Alternative 6	1.22	No Till	4/1, 5/10

Application Timing

The baseline corn management options utilize several atrazine application dates. With the exception of the split atrazine application and Alternative 6, each alternative applied atrazine on a single date.

In order to evaluate the relative atrazine loss due to application timing for the measured rainfall data, a watershed simulation was run for each of the four application dates used in the baseline or alternatives (March 25, April 1, May 2, May 10). The baseline was reconfigured so that all atrazine in each of the five simulations was applied on a single date. Measured daily rainfall (1984-1995) from a weather station near Maysville, Missouri was used for each watershed simulation.

In five of the twelve years of simulation, March had the highest amount of runoff for the months of March through May. (See Figure 10 on the following page). In four of those five years, total March runoff exceeded one inch. For 6 out of 12 years, May had the highest total runoff for the 3-month period, but only once exceeded one inch of runoff. April had the greatest total runoff in only 1 of the 12 years, never exceeding 1 inch. The average annual runoff for the region is approximately 7 inches.

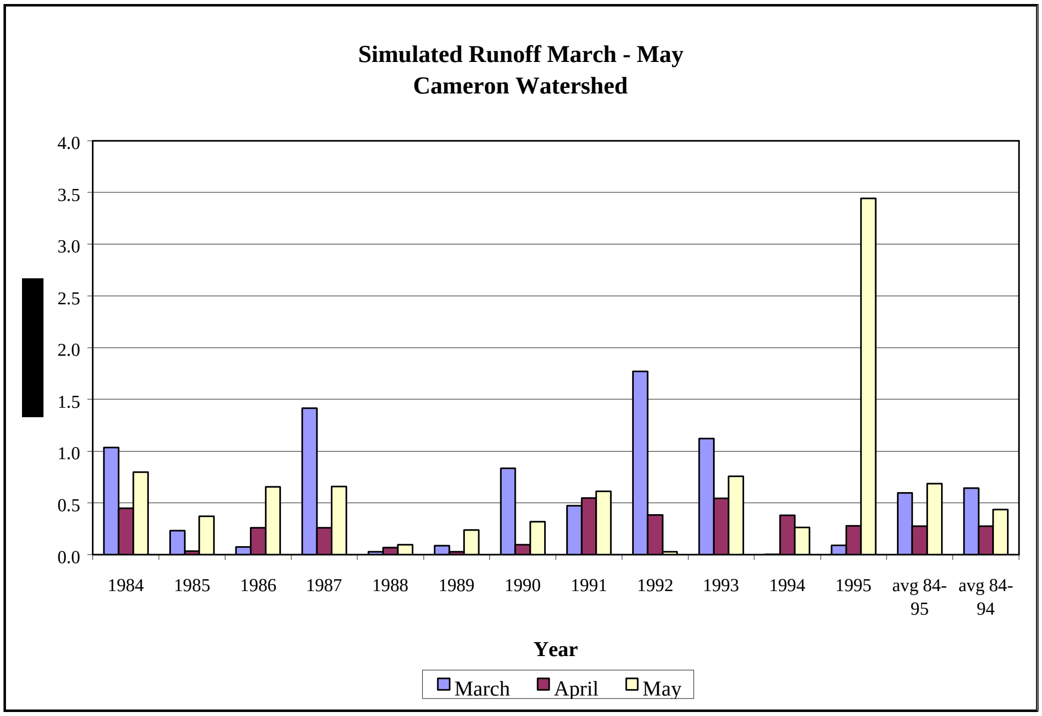


Figure 10

The amount of runoff in a given month is affected by a combination of factors, such as daily precipitation, average daily air temperature, evapotranspiration (ET) and soil water. As ET increases, soil water decreases, increasing the potential for infiltration of rainfall, which decreases the runoff (see Figure 11).

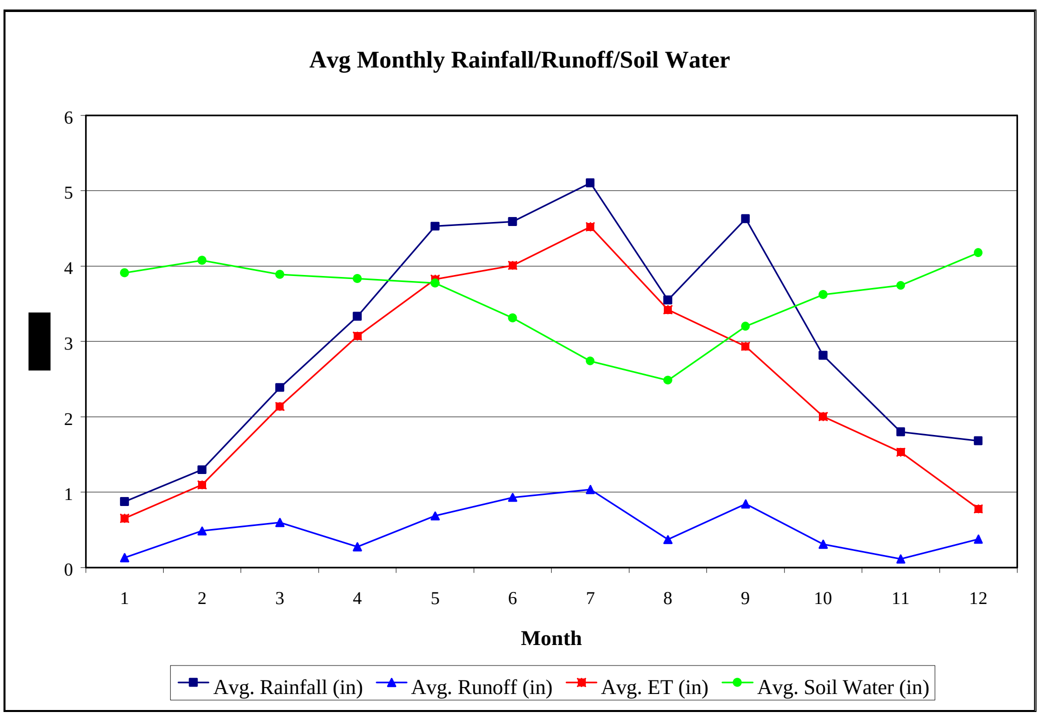


Figure 11

Atrazine is most susceptible to loss from the fields in the days immediately following application. A rainfall event in that time period can cause atrazine loss in runoff from a storm event. The higher levels of runoff in March compared to April and May means that March 25 atrazine applications produced the highest atrazine loading for this particular weather pattern. Storm events following the April 1 application produced the least loading to the subbasin outlets and reservoirs. Atrazine applications on May 2 and May 10 produced a higher loading to the reservoir than the April 1 application date. The relative atrazine loading for each application date compared to application on April 1 is shown in Figure 12.

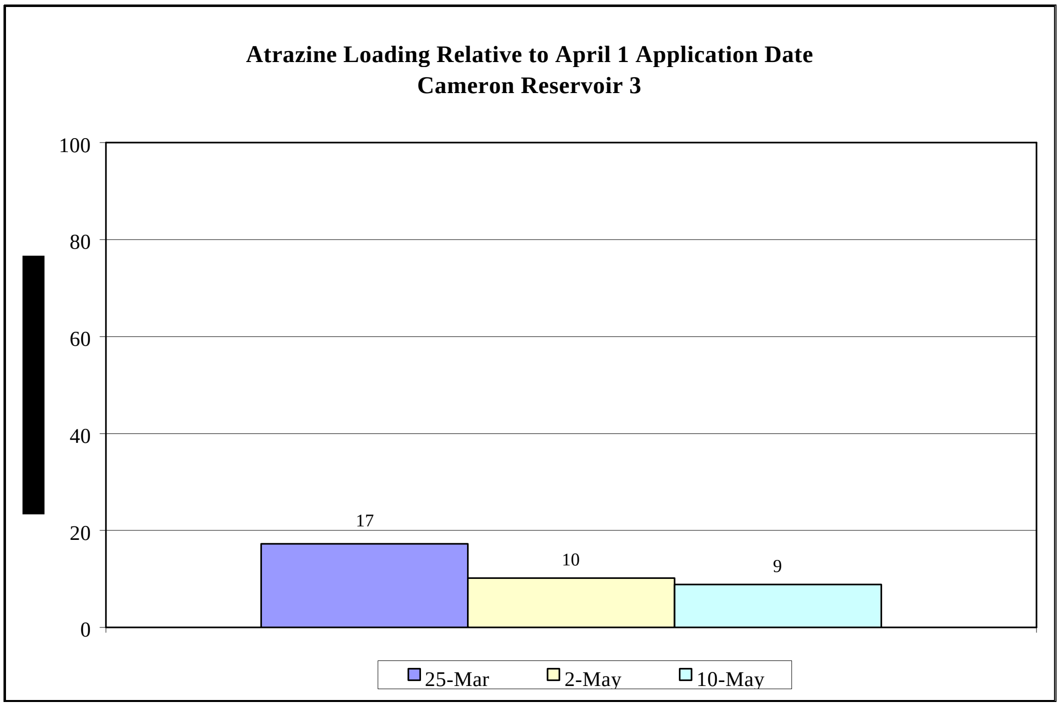


Figure 12

These results help explain some of the changes in atrazine loading to the reservoirs from the various alternatives compared to the baseline. Tables 6 and 7 compare the alternative atrazine application dates and loading to Cameron Reservoir 3 and the Grindstone Reservoir, respectively.

Table 6. Total atrazine application by date for Cameron Watershed baseline and alternatives.

Cameron Watershed	**Total Atrazine Application (lb active ingredient)**									
Application Date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	271	0	663	0	0	0	0	0	0	0
4/1	369	498	0	0	0	0	0	556	0	207
5/2	23	166	0	0	0	0	0	0	0	0
5/10	0	0	0	299	415	0	220	0	0	299
Sum	663	663	663	299	415	0	220	556	0	506
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	-11	-44	-54	-37	-100	-67	-30	-100	-28

Table 7. Total atrazine application by date for Grindstone Watershed baseline and alternatives.

Grindstone Watershed	Total Atrazine Application (lb active ingredient)									
Application Date	Baseline	*Split	*Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	1,450	0	4,799	0	0	0	0	0	0	0
4/1	3,006	3,600	0	0	0	0	0	4,020	0	1,500
5/2	240	1,200	0	0	0	0	0	0	0	0
5/10	0	0	0	2,160	3,000	0	1,590	0	0	2,160
Sum	4,696	4,799	4,799	2,160	3,000	0	1,590	4,020	0	3,660
% change in Atrazine app	0	2	2	-54	-36	-100	-66	-14	-100	-22
% change in Atrazine load	0	9	-45	-54	-37	-100	-67	-7	-100	-20
*Sum is greater than baseline because of CB3 no-atrazine influence in Grindstone baseline										

The total atrazine applications are higher than the baseline for the Grindstone watershed split application and incorporation alternatives. This is because Grindstone subbasins 5 and 11 include the baseline corn-bean option 3 (CB 3), which uses no atrazine. Each alternative assumes 100% adoption of the alternative, so some of the alternatives increased the overall atrazine applications in these subbasins.

The baseline management for each subbasin varied depending on the mix of baseline corn-bean options for that subbasin. This mix of options determined the baseline atrazine application dates and amounts for each subbasin. The atrazine application dates, amounts and loading results for each subbasin are summarized in Appendix C.

The split application alternative divided the atrazine into applications on April 1 and May 2 equaling the baseline 1.6 lb/acre. This alternative gave mixed results, reducing the average annual atrazine loading to Reservoir 3 in Cameron watershed by 11%, and increasing the loading in the Grindstone Reservoir by 9%. This mixed result is attributed to timing of the baseline atrazine applications. The baseline atrazine application dates in Cameron watershed were more susceptible to atrazine loss than the split application dates, so the split application reduced the loading to Reservoir 3. The baseline atrazine application dates in Grindstone watershed were less susceptible to atrazine loss than the split application dates, so the split application increased the loading to the Grindstone Reservoir.

This response is seen more clearly in the subbasin results (see Appendix C). Those subbasins in which the alternative atrazine application shifted to dates more susceptible to atrazine loss compared to the baseline had increased loading to the subbasin outlets (Cameron subbasins 4 and 5; Grindstone subbasins 1, 2, 3, 4, 7, 9). Those subbasins in which the alternative atrazine application shifted to less susceptible dates had decreased loading to the subbasin outlets (Cameron subbasins 1, 2, 3; Grindstone subbasins 6, 8, 10, 12, 13).

Tillage

Tillage changes between the baseline and alternatives were minimal, with the exception of the incorporation option, which utilized minimum tillage. Incorporation of the chemicals into the soil caused a substantial reduction (44-45%) in average annual atrazine loading to the reservoirs in both watersheds, without changing the baseline atrazine application rate of 1.6 lb/acre, and in spite of application on the date most susceptible to atrazine loss (March 25).

The degree of loading reduction when compared to the baseline was also related to the application dates. For example, in Cameron subbasins 1, 2 and 3 the baseline application of atrazine occurred on March 25, but was not incorporated. Incorporation of the atrazine on March 25 resulted in the largest reduction in loading from the subbasins (31% to 36%). In subbasin 4, the baseline atrazine application date was April 1, the date least susceptible to weather impacts. Incorporation of the atrazine in subbasin 4 decreased the loading from the subbasin, but the change to the more susceptible March 25 application date kept the loading reduction at only 13%.

Application Rate

The alternative corn management application rates fall into two categories: those which retain the baseline atrazine application rate of 1.6 lb a.i./acre (split and incorporation), and those which use reduced atrazine application rates (alternatives 1 through 6).

Alternatives 1-6 generally resulted in a 1:1 trend of application reduction to loading reduction. The loading at the subbasin outlets varied from the 1:1 trend depending on the relative susceptibility to atrazine loss for the alternative application dates compared to the baseline. A shift from the baseline to a more susceptible date produced smaller loading reduction, and a shift to a less susceptible date produced greater loading reduction compared to the 1:1 trend (Figures 13 and 14).

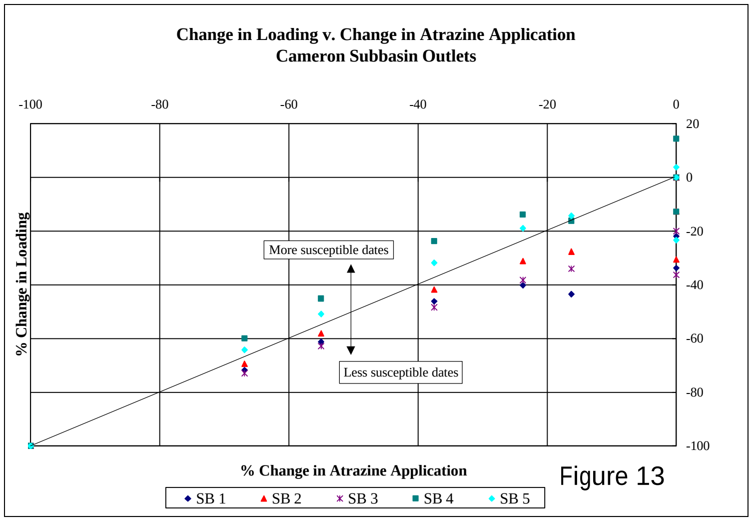


Figure 13

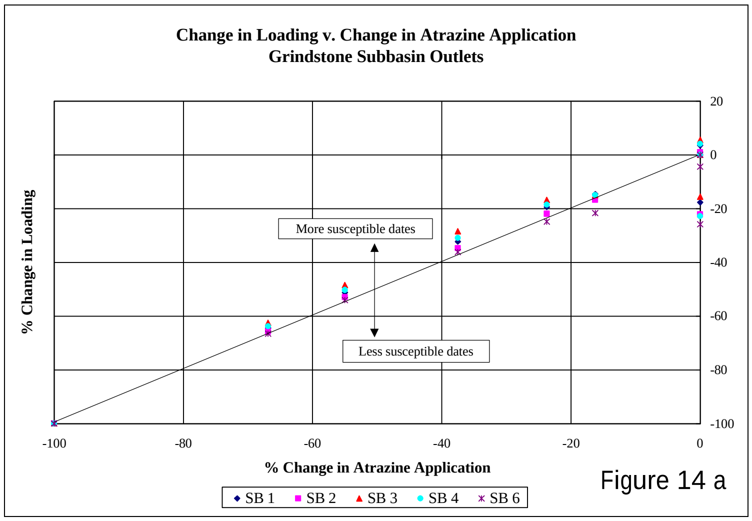


Figure 14 a

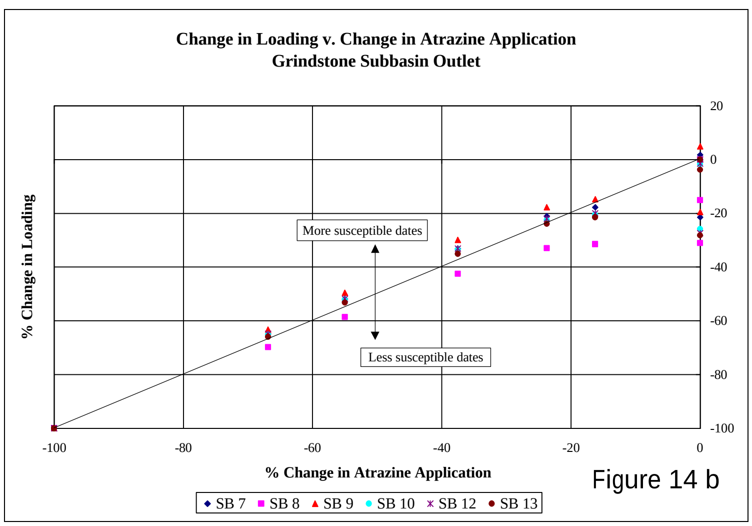


Figure 14 b

Conclusions

- Application timing has an impact on atrazine loss. Application dates which coincide with higher rainfall and runoff produce more atrazine loading than dates coinciding with less rainfall and runoff.

- Split application, in which a total of 1.6 lb a.i./ac atrazine was applied on April 1 and May 2, had mixed results depending on the timing of the baseline application. This alternative decreased the atrazine loading if the split application dates were less susceptible to atrazine loss than the baseline application dates. For example, if a farmer tended to apply atrazine on March 25 without incorporating it, then the split application would decrease the level of loading. However, if the farmer tended to apply atrazine on April 1, which had the least potential for atrazine loss, then the split application would lead to increased loading for this weather pattern.

- Incorporation is a good tool for reducing atrazine loading to subbasin outlets and reservoirs without changing the application rate (1.6 lb a.i./ac). It must be weighed against the increased sediment loading to the reservoirs.

- A reliable way to reduce atrazine loading is to decrease the atrazine application rate. A 1% average annual loading reduction for every 1% decrease in application rate can be expected, with some variation depending on the timing of the application.

<u>Nitrogen Loading</u>

The most significant changes in nitrogen loading to the Cameron and Grindstone reservoirs resulted from incorporation of the fertilizer, and from reduced nitrogen applications. The total nitrogen application for the other alternatives was not changed significantly (see Tables 8 and 9).

Table 8.

Cameron Watershed	Total Nitrogen Application (lb elemental)										
Application Date	Baseline	Split	Incorp	Reduced N	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
1/2	1,754	0	0	1,754	800	800	800	800	800	800	800
3/25	10,739	0	53,907	5,653	3,514	3,514	3,514	3,514	3,514	3,514	3,514
4/1	30,644	51,834	0	23,289	43,500	43,500	43,500	43,500	43,500	43,500	43,500
Sum	43,136	51,834	53,907	30,696	47,814	47,814	47,814	47,814	47,814	47,814	47,814
% change in N application	0.0	20.2	25.0	-28.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8
% change in N loading	0.0	5.9	-22.2	-11.7	2.4	2.4	2.4	2.4	2.4	2.4	-3.2

Table 9.

Grindstone Watershed	Total Nitrogen Application (lb elemental)										
Application Date	Baseline	Split	Incorp	Reduced N	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
1/2	8,077	0	0	8,077	8,077	8,077	8,077	8,077	8,077	8,077	8,077
3/25	74,177	0	389,956	45,052	35,473	35,473	35,473	35,473	35,473	35,473	35,473
4/1	253,604	374,958	0	192,739	290,819	290,819	290,819	290,819	290,819	290,819	290,819
Sum	335,858	374,958	389,956	245,868	334,369	334,369	334,369	334,369	334,369	334,369	334,369
% change in N application	0.0	11.6	16.1	-26.8	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
% change in N loading	0.0	2.2	-12.9	-10.8	1.1	1.1	1.1	1.1	1.1	1.1	-3.8

As with the atrazine, incorporation of the nitrogen fertilizer reduced the amount of nitrogen readily available for runoff losses due to rainfall events. Nitrogen loading to Cameron Reservoir 3 and Grindstone Reservoir decreased 22% and 13%, respectively, in spite of a net increase in nitrogen application for this alternative (see Figures 15 and 16).

A reduced nitrogen alternative was also tested in which the total baseline nitrogen application was reduced by 30 lb/acre. Everything else in the baseline was held constant. The result for this alternative was a 1 percent reduction in average annual nitrogen loading to the reservoirs for every 2.4 percent reduction in nitrogen application for both Cameron and Grindstone watersheds.

The nitrogen loading response with respect to application date has not been analyzed. A test using nitrogen application date as the only variable is suggested to determine a date-specific response pattern.

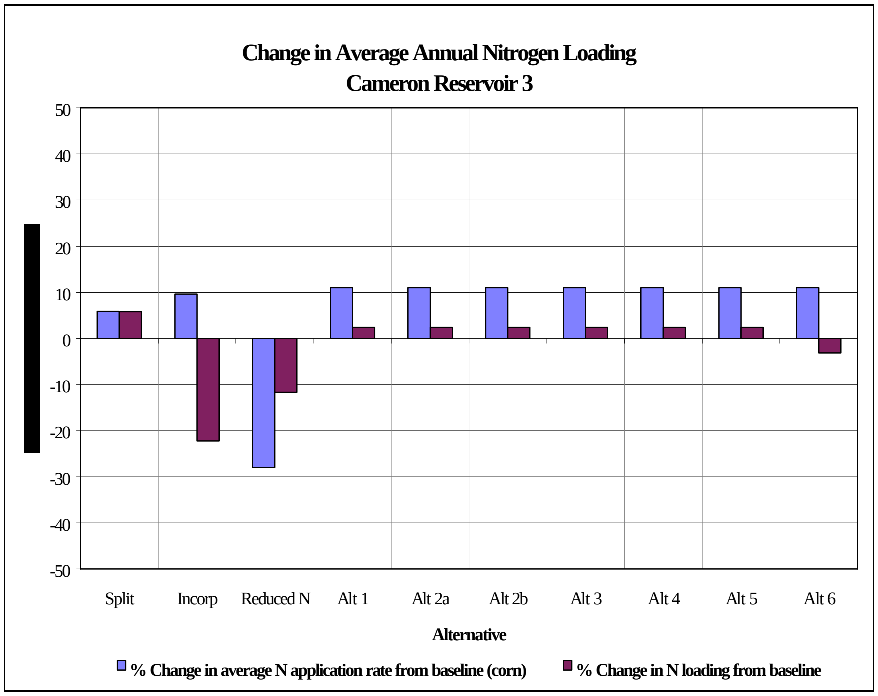


Figure 15

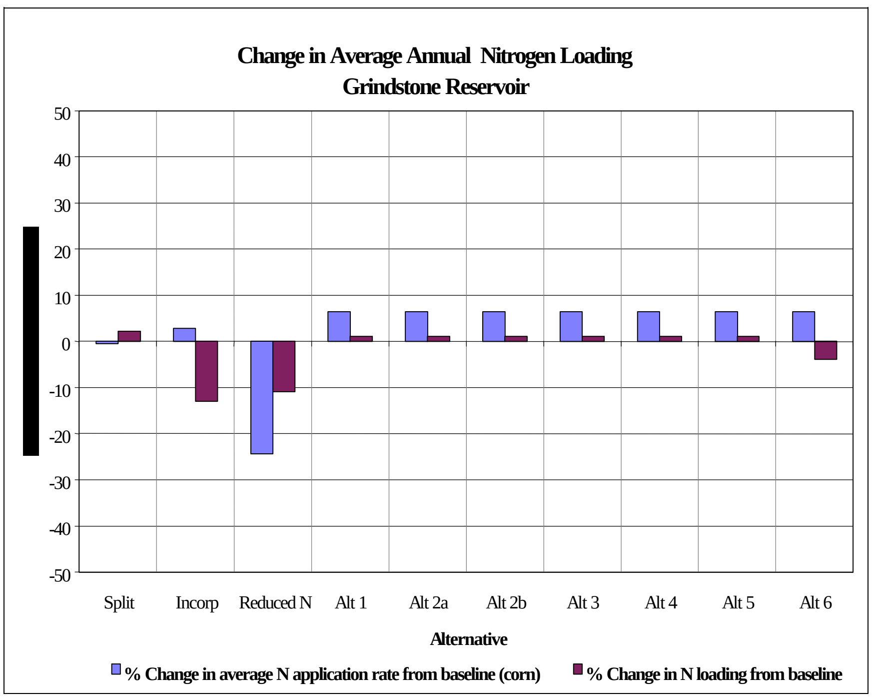


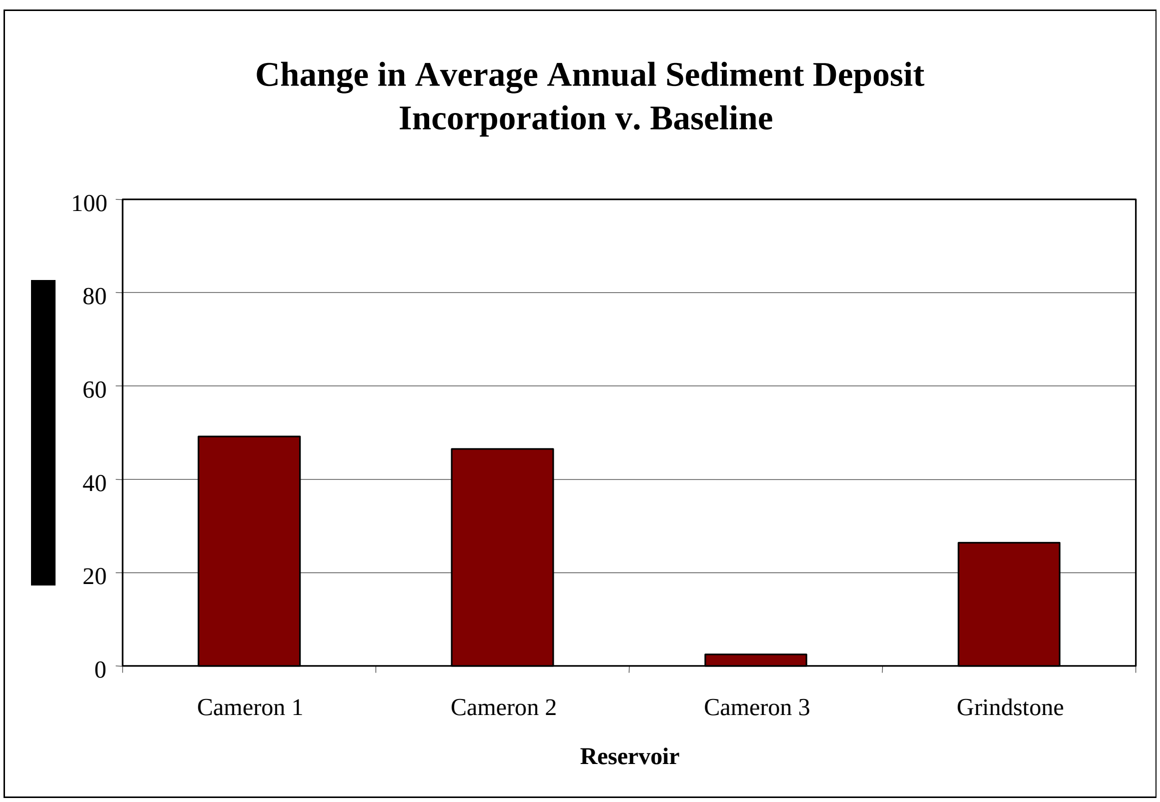
Figure 16

Sediment Yield

The baseline management options defined by the Representative Farm Panel were 95% no-till. Changes in sediment yield from the alternatives were due to changes in tillage operations. Incorporation was the only alternative that utilized 100% minimum tillage; the remainder of the alternatives were 100% no-till. As a result, the incorporation alternative was the only one to have a significant change in the amount of sediment loss from the farmland, which was then either deposited in the streams or the reservoirs.

In the Cameron watershed, Reservoirs 1 and 2 acted as settling basins to prevent the majority of the sediment from the incorporation alternative from reaching Reservoir 3. Average annual sediment deposits in Reservoirs 1 and 2 in Cameron watershed increased over the baseline by 49% and 46%, respectively, but the sediment deposit in Reservoir 3 increased by only 2.5% under incorporation. If increased sedimentation to Reservoirs 1 and 2 are not of concern to the community, incorporation would be an alternative to consider in order to decrease the atrazine loading without decreasing atrazine application rates.

Incorporation in the Grindstone watershed caused a 26% increase in average annual sediment loading to the reservoir. The remaining alternatives produced no significant change (less than 2%) in loading to the Grindstone Reservoir. The tradeoff between atrazine reduction from incorporation and increased sediment deposition in the reservoir must be considered by the community.



When printing this document, please note that you will also need to print the appendices which can be found at: F:/Home/Lynn/report/appendix. It is in Excel.

APPENDIX A

Appendix B

APPENDIX C

Baseline Corn Management Options

Baseline Option	*Tillage	Herbicide Name	Application Date	Application Rate	Active Ingredient (AI)	AI Application Rate (lb/acre)	Fertilizer Name	Application Rate (Elemental) (lb/acre)
cb1	NT	Bicep II	1-Apr	2.4 qts/acre	atrazine	1.60	Nitrogen	125
					metolachlor	2.00	Phosphorus	22
		2,4-D	1-Apr	.5 pt/acre	2,4-D	0.23		
		Exceed	1-Apr	.8 oz/acre	prosulfuron	0.02		
					primisulfuron	0.02		
		Clarity	31-May	4 oz/acre	dicamba	0.10		
cb2	NT	Bicep II	1-Apr	1.8 qts/acre	atrazine	1.20	Nitrogen	125
					metolachlor	1.50	Phosphorus	22
		Bicep II	2-May	.6 qts/acre	atrazine	0.40		
					metolachlor	0.50		
		2,4-D	2-May	.5 pt/acre	2,4-D	0.23		
cb3	MT	Broadstrike-Dual	25-Mar	2.25 pts/acre	flumetsulam		Nitrogen	130
					metolachlor	2.09	Phosphorus	22
cb4	MT	Bicep II	25-Mar	2.4 qts/acre	atrazine	1.60	Nitrogen	130
					metolachlor	2.00	Phosphorus	22
cb5	NT	Bicep II	1-Apr	2.4 qts/acre	atrazine	1.60	Nitrogen	125
					metolachlor	2.00	Phosphorus	22
		2,4-D	1-Apr	.5 pts/acre	2,4-D	0.23		
		Exceed	1-Apr	.8 oz/acre	prosulfuron	0.02		
					primisulfuron	0.02		
		Clarity	31-May	4 oz/acre	dicamba	0.10		

Baseline Option	*Tillage	Herbicide Name	Application Date	Application Rate	Active Ingredient (AI)	AI Application Rate (lb/acre)	Fertilizer Name	Application Rate (Elemental) (lb/acre)
cb6	NT	Bicep II	1-Apr	2.4 qts/acre	atrazine	1.60	Nitrogen	125
					metolachlor	2.00	Phosphorus	22
		2,4-D	1-Apr	.5 pts/acre	2,4-D	0.23		
		Exceed	1-Apr	.8 oz/acre	prosulfuron	0.02		
					primisulfuron	0.02		
		Clarity	31-May	4 oz/acre	dicamba	0.10		
cb7	NT	Bicep II	25-Mar	2.4 qts/acre	atrazine	1.60	Nitrogen	65
					metolachlor	2.00	Phosphorus	26
ccb1	NT	Bicep II	25-Mar	2.4 qts/acre	atrazine	1.60	Nitrogen	89
					metolachlor	2.00	Phosphorus	34
cbb1	NT	Bicep II	25-Mar	2.4 qts/acre	atrazine	1.60	Nitrogen	89
					metolachlor	2.00	Phosphorus	34

*NT = No-Till, MT = Minimum Tillage

Proposed Corn Management Alternatives

Proposed Alternative	*Tillage	Herbicide Name	Application Date	Application Rate	Active Ingredient (AI)	Application Rate (lb AI/acre)	Fertilizer Name	Application Rate (Elemental) (lbs/acre)
1	NT	Roundup	10-Apr	1 pt/acre	glyphosate	0.50	Nitrogen	125
		2,4-D	10-Apr	1 pt/acre	2,4-D	0.47	Phosphorus	22
		Basis Gold	10-May	14 oz/acre	atrazine	0.72		
					nicosulfuron	0.01		
					rimsulfuron	0.01		
		Clarity	10-May	4 oz/acre	dicamba	0.12		
2a	NT	Roundup	10-Apr	1 pt/acre	glyphosate	0.50	Nitrogen	125
		2,4-D	10-Apr	1 pt/acre	2,4-D	0.47	Phosphorus	22
		Liberty	10-May	28 oz/acre	glufosinate	0.22		
		Aatrex 9-0	10-May	1.1 lbs/acre	atrazine	1.00		
2b	NT	Roundup	10-Apr	1 pt/acre	glyphosate	0.50	Nitrogen	125
		2,4-D	10-Apr	1 pt/acre	2,4-D	0.47	Phosphorus	22
		Liberty	10-May	28 oz/acre	glufosinate	0.22		
		Liberty	21-May	28 oz/acre	glufosinate	0.22		
3	NT	Roundup	10-Apr	1 pt/acre	glyphosate	0.50	Nitrogen	125
		2,4-D	10-Apr	1 pt/acre	2,4-D	0.47	Phosphorus	22
		Laddok	10-May	1.67 pt/acre	atrazine	0.53		
					bentazon	0.53		
		Poast	NA	1.5 pt/acre	sethoxydim	0.28		
4	NT	Guardsman	1-Apr	4 pts/acre	atrazine	1.34	Nitrogen	125
					dimethanamide	1.17	Phosphorus	22
		2,4-D	1-Apr	1 pt/acre	2,4-D	0.47		
		Clarity	10-May	4 oz/acre	dicamba	0.12		

Proposed Alternative	*Tillage	Herbicide Name	Application Date	Application Rate	Active Ingredient (AI)	Application Rate (lb AI/acre)	Fertilizer Name	Application Rate (Elemental) (lbs/acre)
5	NT	Balance	10-Apr	2 oz/acre	isoxaslutole	0.01	Nitrogen	125
		Harness	10-Apr	1 pt/acre	acetochlor	0.88	Phosphorus	22
		Exceed	NA	0.8 oz/acre	prosulfuron	0.02		
					primisulfuron	0.02		
		Clarity	31-May	4 oz/acre	dicamba	0.10		
6	NT	Extrazine	10-Apr	2 qt/acre	atrazine	0.50	Nitrogen	125
					cyanazine	1.50	Phosphorus	22
		Basis Gold	10-Apr	14 oz/acre	atrazine	0.72		
					nicosulfuron	0.01		
					rimsulfuron	0.01		
		Clarity	10-May	4 oz/acre	dicamba	0.12		

*NT = No-Till, MT = Minimum Tillage

Cameron Watershed

Average Atrazine Application Rate (lb active ingredient/acre)									
Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
1.60	1.60	1.60	0.72	1.00	0.00	0.53	1.34	0.00	1.22

Subbasin 1 Lamoni silty clay loam, 5-9% slopes, eroded corn = 8 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	13	0	13	0	0	0	0	0	0	0
4/1	0	10	0	0	0	0	0	11	0	4
5/2	0	3	0	0	0	0	0	0	0	0
5/10	0	0	0	6	8	0	4	0	0	6
Sum	13	13	13	6	8	0	4	11	0	10
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	-22	-34	-61	-46	-100	-72	-43	-100	-40

Subbasin 2 Grundy silty clay loam, 5-9% slopes, eroded corn = 67 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	107	0	107	0	0	0	0	0	0	0
4/1	0	80	0	0	0	0	0	89	0	33
5/2	0	27	0	0	0	0	0	0	0	0
5/10	0	0	0	48	67	0	35	0	0	48
Sum	107	107	107	48	67	0	35	89	0	81
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	-13	-31	-58	-42	-100	-69	-28	-100	-31

Subbasin 3 Grundy silty clay loam, 5-9% slopes, eroded corn = 71 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	113	0	113	0	0	0	0	0	0	0
4/1	0	85	0	0	0	0	0	95	0	35
5/2	0	28	0	0	0	0	0	0	0	0
5/10	0	0	0	51	71	0	38	0	0	51
Sum	113	113	113	51	71	0	38	95	0	86
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	-20	-36	-63	-48	-100	-73	-34	-100	-38

Cameron Watershed

Average Atrazine Application Rate (lb active ingredient/acre)									
Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
1.60	1.60	1.60	0.72	1.00	0.00	0.53	1.34	0.00	1.22

Subbasin 4 Lamoni silty clay loam, 5-9% slopes, eroded corn = 35 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	0	0	56	0	0	0	0	0	0	0
4/1	56	42	0	0	0	0	0	47	0	17
5/2	0	14	0	0	0	0	0	0	0	0
5/10	0	0	0	25	35	0	19	0	0	25
Sum	56	56	56	25	35	0	19	47	0	43
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	14	-13	-45	-24	-100	-60	-16	-100	-14

Subbasin 5 Grundy silt loam, 2-5% slopes corn = 233 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	37	0	373	0	0	0	0	0	0	0
4/1	312	280	0	0	0	0	0	312	0	117
5/2	23	93	0	0	0	0	0	0	0	0
5/10	0	0	0	168	233	0	124	0	0	168
Sum	373	373	373	168	233	0	124	312	0	284
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	4	-23	-51	-32	-100	-64	-14	-100	-19

Subbasins 6 and 7 have no rotation crops, therefore no atrazine

Grindstone Watershed

Average Atrazine Application Rate (lb active ingredient/acre)									
Baseline	split	incorp	alt 1	alt 2a	alt 2b	alt 3	alt 4	alt 5	alt 6
1.60	1.60	1.60	0.72	1.00	0.00	0.53	1.34	0.00	1.22

Subbasin 1 Grundy silty clay loam, 5-9% slopes, eroded corn = 176 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	34	0	282	0	0	0	0	0	0	0
4/1	230	211	0	0	0	0	0	236	0	88
5/2	18	70	0	0	0	0	0	0	0	0
5/10	0	0	0	127	176	0	93	0	0	127
Sum	282	282	282	127	176	0	93	236	0	215
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	4	-18	-51	-32	-100	-64	-15	-100	-19

Subbasin 2 Grundy silty clay loam, 5-9% slopes, eroded corn = 68 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	0	0	109	0	0	0	0	0	0	0
4/1	99	82	0	0	0	0	0	91	0	34
5/2	10	27	0	0	0	0	0	0	0	0
5/10	0	0	0	49	68	0	36	0	0	49
Sum	109	109	109	49	68	0	36	91	0	83
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	1	-22	-53	-35	-100	-66	-17	-100	-22

Subbasin 3 Grundy silt loam, 2-5% slopes corn = 151 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	31	0	241	0	0	0	0	0	0	0
4/1	194	181	0	0	0	0	0	202	0	75
5/2	16	60	0	0	0	0	0	0	0	0
5/10	0	0	0	109	151	0	80	0	0	109
Sum	241	241	241	109	151	0	80	202	0	184
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	6	-16	-48	-28	-100	-62	-15	-100	-17

Grindstone Watershed

Average Atrazine Application Rate (lb active ingredient/acre)									
Baseline	split	incorp	alt 1	alt 2a	alt 2b	alt 3	alt 4	alt 5	alt 6
1.60	1.60	1.60	0.72	1.00	0.00	0.53	1.34	0.00	1.22

Subbasin 4 Grundy silt loam, 2-5% slopes corn = 255 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	45	0	408	0	0	0	0	0	0	0
4/1	338	306	0	0	0	0	0	342	0	128
5/2	26	102	0	0	0	0	0	0	0	0
5/10	0	0	0	184	255	0	135	0	0	184
Sum	408	408	408	184	255	0	135	342	0	311
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	4	-23	-50	-31	-100	-64	-15	-100	-19

Subbasin 5 Grundy silt loam, 2-5% slopes corn = 423 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline*	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	293	0	677	0	0	0	0	0	0	0
4/1	311	508	0	0	0	0	0	567	0	212
5/2	26	169	0	0	0	0	0	0	0	0
5/10	0	0	0	305	423	0	224	0	0	305
Sum	630	677	677	305	423	0	224	567	0	517
% change in Atrazine app	0	8	8	-52	-33	-100	-64	-10	-100	-18
% change in Atrazine load	0	2	-20	-50	-30	-100	-64	-17	-100	-19

*Baseline application rate = 1.49 lb active ingredient/acre

Subbasin 6 Grundy silt loam, 2-5% slopes corn = 91 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	62	0	146	0	0	0	0	0	0	0
4/1	75	109	0	0	0	0	0	122	0	46
5/2	8	36	0	0	0	0	0	0	0	0
5/10	0	0	0	66	91	0	48	0	0	66
Sum	146	146	146	66	91	0	48	122	0	111
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	-4	-26	-54	-36	-100	-66	-22	-100	-25

Grindstone Watershed

Average Atrazine Application Rate (lb active ingredient/acre)									
Baseline	split	incorp	alt 1	alt 2a	alt 2b	alt 3	alt 4	alt 5	alt 6
1.60	1.60	1.60	0.72	1.00	0.00	0.53	1.34	0.00	1.22

Subbasin 7 Grundy silt loam, 2-5% slopes corn = 32 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	0	0	51	0	0	0	0	0	0	0
4/1	46	38	0	0	0	0	0	43	0	16
5/2	5	13	0	0	0	0	0	0	0	0
5/10	0	0	0	23	32	0	17	0	0	23
Sum	51	51	51	23	32	0	17	43	0	39
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	2	-21	-52	-33	-100	-65	-18	-100	-21

Subbasin 8 Grundy silt loam, 2-5% slopes corn = 58 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	59	0	93	0	0	0	0	0	0	0
4/1	33	70	0	0	0	0	0	78	0	29
5/2	0	23	0	0	0	0	0	0	0	0
5/10	0	0	0	42	58	0	31	0	0	42
Sum	93	93	93	42	58	0	31	78	0	71
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	-15	-31	-59	-42	-100	-70	-31	-100	-33

Subbasin 9 Grundy silt loam, 2-5% slopes corn = 315 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	55	0	504	0	0	0	0	0	0	0
4/1	417	378	0	0	0	0	0	422	0	158
5/2	32	126	0	0	0	0	0	0	0	0
5/10	0	0	0	227	315	0	167	0	0	227
Sum	504	504	504	227	315	0	167	422	0	385
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	5	-19	-50	-30	-100	-63	-15	-100	-18

Grindstone Watershed

Average Atrazine Application Rate (lb active ingredient/acre)									
Baseline	split	incorp	alt 1	alt 2a	alt 2b	alt 3	alt 4	alt 5	alt 6
1.60	1.60	1.60	0.72	1.00	0.00	0.53	1.34	0.00	1.22

Subbasin 10 Grundy silt loam, 2-5% slopes corn = 530 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	344	0	848	0	0	0	0	0	0	0
4/1	468	636	0	0	0	0	0	710	0	265
5/2	35	212	0	0	0	0	0	0	0	0
5/10	0	0	0	381	530	0	281	0	0	381
Sum	848	848	848	381	530	0	281	710	0	646
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	-2	-26	-52	-33	-100	-65	-20	-100	-22

Subbasin 11 Grundy silt loam, 2-5% slopes corn = 315 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline*	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	55	0	504	0	0	0	0	0	0	0
4/1	363	378	0	0	0	0	0	422	0	158
5/2	30	126	0	0	0	0	0	0	0	0
5/10	0	0	0	227	315	0	167	0	0	227
Sum	449	504	504	227	315	0	167	422	0	385
% change in Atrazine app	0	12	12	-49	-30	-100	-63	-6	-100	-14
% change in Atrazine load	0	17	-9	-43	-20	-100	-58	-6	-100	-8

*Baseline application rate = 1.42 .b active ingredient/acre

Subbasin 12 Grundy silt loam, 2-5% slopes corn = 395 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	288	0	632	0	0	0	0	0	0	0
4/1	321	474	0	0	0	0	0	529	0	197
5/2	23	158	0	0	0	0	0	0	0	0
5/10	0	0	0	284	395	0	209	0	0	284
Sum	632	632	632	284	395	0	209	529	0	482
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	-1	-27	-52	-33	-100	-65	-20	-100	-22

Grindstone Watershed

Average Atrazine Application Rate (lb active ingredient/acre)									
Baseline	split	incorp	alt 1	alt 2a	alt 2b	alt 3	alt 4	alt 5	alt 6
1.60	1.60	1.60	0.72	1.00	0.00	0.53	1.34	0.00	1.22

Subbasin 13 Grundy silt loam, 2-5% slopes corn = 189 acres

	Total Atrazine Application (lb active ingredient)									
Application date	Baseline	Split	Incorp	Alt 1	Alt 2a	Alt 2b	Alt 3	Alt 4	Alt 5	Alt 6
3/25	181	0	303	0	0	0	0	0	0	0
4/1	110	227	0	0	0	0	0	253	0	95
5/2	11	76	0	0	0	0	0	0	0	0
5/10	0	0	0	136	189	0	100	0	0	136
Sum	303	303	303	136	189	0	100	253	0	231
% change in Atrazine app	0	0	0	-55	-38	-100	-67	-16	-100	-24
% change in Atrazine load	0	-4	-28	-53	-35	-100	-66	-22	-100	-24