CHARITON VALLEY BIOMASS PROJECT

Environmental Strategies Plan

Prepared for:
The United States Department of Energy
Contract Number: DE-FC36-96GO10148

Submitted by:
Chariton Valley RC&D
19229 Highway 5
Centerville, Iowa 52544-8922

Prepared by:
Antares Group Incorporated
4351 Garden City Drive, Suite 301
Landover, Maryland 20785

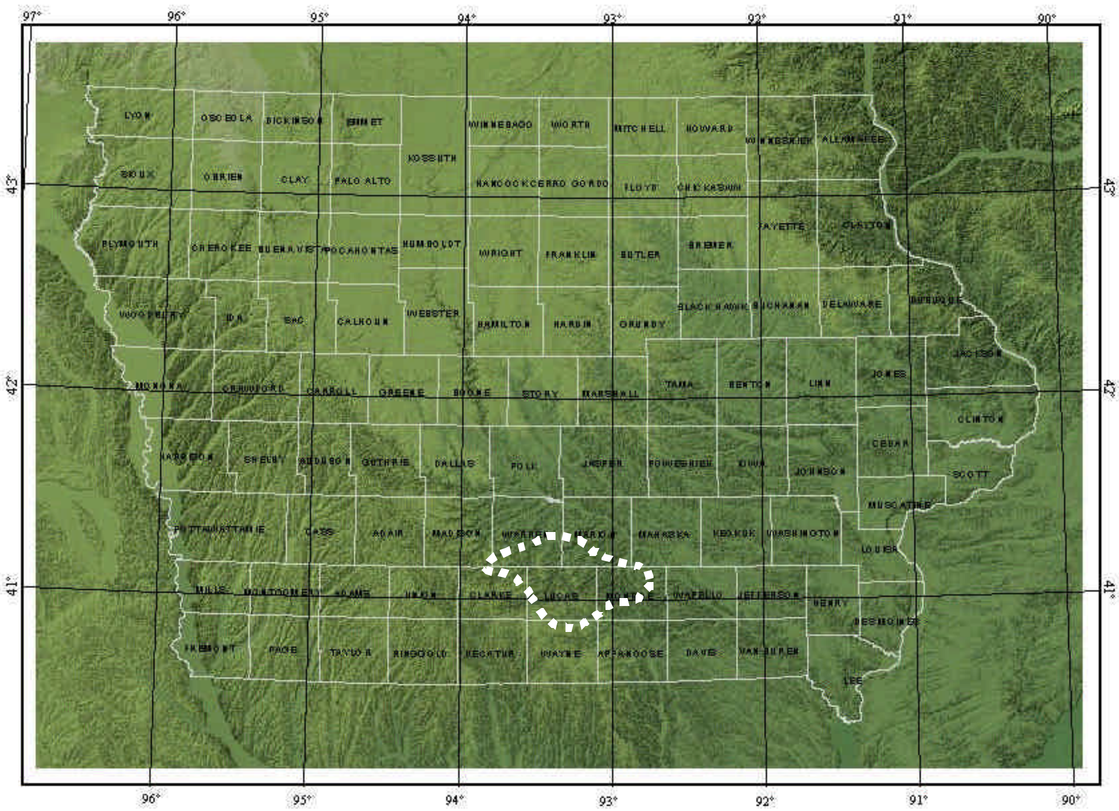
April 26, 2002

Chariton Valley Biomass Project (Phase I)
Deliverable 5 – Environmental Strategies Plan

EXECUTIVE SUMMARY

The primary goal of the Chariton Valley (CV) Biomass Project is to demonstrate biomass (switchgrass) and coal cofiring technology with a vision of developing markets for energy crops in southern Iowa. This report outlines the research completed to date on the environmental effects of switchgrass production in Chariton Valley, Iowa. The goal is to cofire the switchgrass with coal at the Ottumwa Generating Station (OGS). Approximately 2,000 tons of biomass material was cofired in the first test campaign, and as many as 6,000 tons will be cofired during the second round of testing. The researchers' goal is to identify land in the watershed on which producing switchgrass for biomass would have the greatest potential beneficial impacts on biodiversity. This report begins by discussing research conducted at the farm level: soil quality, water quality, wildlife impacts, fuel quality, and carbon sequestration. It then discusses the environmental impacts at OGS and concludes with an overview of the applicable federal and/or state legislation affecting farm activity. Exhibit 1 shows the watershed location in southern Iowa.

Exhibit 1



Soil Quality

Erosion Impacts

In 2000, GIS analysis determined that converting 53,649 acres to switchgrass production could reduce annual soil erosion by nearly 95% (from 390,049 to 17,746 tons/year). Research also found that more stable aggregates (mixture/cluster) indicated better soil quality and established switchgrass has about 75% stable aggregates whereas row crop fields have about 34%.[1] In addition, about half of established switchgrass fields were found to have gullies but only less than 0.5 Mg/ha-yr. of soil is lost due to gullies. Research has found that switchgrass may not provide adequate protection against gully erosion, primarily due to its growth habit as a bunch grass. As a result, steps should be taken to prevent gully erosion at susceptible locations, for example, planting grasses that are more sod forming. (CVRCD/TR#12, 1/00-3/00)

Research using the Soil and Water Assessment Tool (SWAT) in 2001 found that the switchgrass scenario reduced sediment yield by 55% relative to the baseline condition. Switchgrass produced average sediment yields twice that of pasture, but a magnitude less than land in row crop production. Researchers concluded that due to this effect, additional soil conservation practices may be needed to prevent excessive erosion from occurring on highly erosive soils when growing switchgrass. (Neppel, et.al., 2001)

Nitrogen Fertilization

Field experiments began in 1998 using mature, established 'Cave-in-Rock' switchgrass fields in southern Iowa. Five replications (the number of times a particular test is reproduced) were used at each location; each replication included four randomly assigned plots representing four nitrogen fertility treatments of 0, 56, 112, and 224 kg N/ha. Results showed no difference between 56 and 112 kg N/ha or between 112 and 224 kg N/ha, and increasing nitrogen application above 112 kg N/ha did not result in further yield increases averaged across the three years or in 2000. Thus, the recommended fertilization rate for switchgrass biomass production in this area is between 56 and 112 kg N/ha. (Brummer, C., et.al., 2001)

Research is expected to continue until the end of 2004. Specific plans are to test reed canarygrass side-by-side with switchgrass in large plots, better explain soil quality by investigating gullies, aggregate stability, and epipedon[2] construction/destruction, and continue to analyze yield, management, and soil data collected from 22 fields harvested annually for biomass.

Water Quality

Rathbun Lake provides water to more than 60,000 residents in 18 counties. Its watershed consists of around 354,000 acres, where 60% of the land is used for row crop production, 25% is used for pasture and hayland, and one-third is highly erodible cropland, nearly half of which is enrolled in the Conservation Reserve Program (CRP). The lake has been contaminated by agricultural non-point source pollution due to soil loss from highly erodible land; sediment containing farm chemicals is filling the lake three times faster than originally anticipated. Large-scale switchgrass production would impact three of the major sources of water quality impairment currently threatening the lake:

- sediment and chemicals from cropland—annual erosion on the highly erodible cropland can exceed 30 tons per acre; the problem is likely to worsen as CRP acres are returned to row crop production
- gully erosion—a source of soil loss on 21,000 acres of land; nearly 90% of sediment from gully erosion reaches the lake
- soil loss from pasture and hayland—70% of this land is degraded due to mismanagement and it loses nearly 15 tons of soil, per acre, per year

[1] Switchgrass promotes aggregation of soil particles, and a higher number of aggregates equates to better soil quality.
[2] Epipedon is the surface horizon of the soil that is most affected by human activity.

Significant progress was made in the development and application of the Soil and Water Assessment Tool (SWAT). SWAT is a biophysical, semi-distributed, continuous, daily time step model designed to simulate water yield, sediment deliver, and nutrient and pesticide loading from large, ungaged watersheds. It is used to evaluate the potential impacts of alternative land conversion scenarios on water quality and it will be able to quantify these impacts in terms of sediment and agricultural chemicals that may impair water quality in the Lake. Major findings from research completed in 2001 are listed below:

- The switchgrass scenario reduced sediment yield 55% relative to the baseline scenario
- Sediment-bound phosphorous and nitrogen are reduced 36% and 39%, respectively, comparing the switchgrass scenario relative to the baseline scenario
- Soluble phosphorous and nitrogen are reduced 26% and 38%, respectively, comparing the switchgrass scenario relative to the baseline scenario
- Sediment-bound atrazine (a herbicide) and soluble atrazine quantities delivered to Rathbun Lake are reduced 83% and 86%, respectively, comparing the switchgrass scenario relative to the baseline scenario
- The predicted reductions in sediment, nutrients, and atrazine are a result of the effects of changing land use and also in the combinations of land use and soils (HRUs) simulated by the model

One study used a linear rainfall simulator to assess sediment runoff and runoff water quality. Six replicates were studied: newly planted switchgrass following soybeans (NSG), established mature switchgrass of 13 years (OSG), and no-till corn following soybeans (NTC). Samples were collected during two periods: 1) in May 2000 starting with NPS and ending with OSG; and 2) from late June 2000 starting with NTC and ending in late July with NPS. Conclusions are as follows:

- In both periods, NSG and OSG were beneficial in reducing sediment, inorganic nitrogen, and total phosphorus loss and metolachlor contamination in runoff when compared to NTC
- OSG contributed significantly more organic nitrogen to runoff than either of the other treatments in the early sampling period
- Atrazine contamination in period 1 runoff was reduced from NSG to OSG
- For most parameters, NSG was less effective at preventing nutrient loss or herbicide contamination; however, NSG provided significant improvements over NTC for sediment loss, total phosphorous, TKN during adequate moisture conditions, and metolachlor
- Researchers believe that stands of mature switchgrass offer the best protection from sediment and nutrient loss and herbicide contamination of runoff that may threaten water quality

GIS analysis identified 53,649 acres to be targeted for conversion from row crop to switchgrass production. Researchers also completed the report *A Preliminary Assessment of the Potential Water Quality Impact of Producing Switchgrass Biomass in the Rathbun Lake Watershed*. Sixty-one 14-digit hydrologic units (a watershed) were delineated and their potential for impacting water quality is as follows:

- 16 units with very high potential, 15 with high potential, and 30 with low and moderate potential, caused by sediment
- 6 units with very high potential, 12 with high potential, and 43 with low and moderate potential, caused by agricultural chemicals

- 10 units with both a high and/or very high potential, due to sediment and agricultural chemicals

Assuming an average per unit size of 5,804 acres multiplied by 39 units, researchers concluded that targeting switchgrass on land with high and/or very high potential for water quality impairment could reduce this threat up to 226,356 acres.

Research is expected to end in early 2002. Specific plans are to continue to develop and apply SWAT to evaluate switchgrass' potential impacts on water quality, and interpret the field data and laboratory analyses of runoff samples collected from rainfall simulations.

Wildlife Impacts

Fieldwork was completed in the year 2001 and the research should be completed in early 2002. This included research on: nest searches, breeding bird surveys, placement and monitoring of artificial nests, and vegetation measurements in biomass fields with different harvest treatments. Twenty-one switchgrass fields were equally divided into non-harvest, strip harvest, and total harvest plots and the conclusions were (CVRCD/TR#12, 1/00-3/00; Murray, L., 2001):

- abundance (# of birds):
  - grasshopper sparrows prefer total harvest fields and short, sparse vegetation
  - sedge wren and northern harrier most abundant in non-harvest fields
  - pheasant abundance was greatest in non-harvest fields and estimates of upland sandpiper and bobolink abundances were greatest in strip-harvest fields
  - within strip-harvest fields, red-winged blackbird, song sparrow, common yellowthroat, and sedge wren were observed more frequently in uncut than cut strips in at least one year; the grasshopper sparrow was the only species that preferred cut strips to uncut strips
  - the mean number of birds per 100 ha was greater in 1999 than 2000 for barn swallows and grasshopper sparrows; bird abundance was greater in 2000 than 1999 for red-winged blackbirds, common yellowthroats, and dickcissels
  - common yellowthroats, red-winged blackbirds, and sedge wrens were more abundant in fields with denser vegetation and a greater percent coverage of grasses other than switchgrass, but barn swallows, grasshopper sparrows, meadowlarks, and song sparrows were more abundant in fields with sparser vegetation
- edge abundance: 9 species more abundant 0-25 m from edge than 25-50 m from edge (edge refers to the boundary of the harvested area)
- nest:
  - common yellowthroat and red-winged blackbird nest success is higher in non-harvest fields; grasshopper sparrow in cut areas; northern harrier in uncut areas
  - red-winged blackbirds and common yellowthroats accounted for 56% and 28% of the nests found, respectively
  - 44% of all nests were successful; in both 1999 and 2000, the proportion of nests that were successful was greatest in non-harvest fields
- predators (e.g., foxes, coyotes, hawks) may travel near the edge in harvested strips, and ring-necked pheasants were more abundant in non-harvest fields versus complete harvest fields in the winter; they accounted for 78% of failures of nests with known fates
- strip-harvest is similar to non-harvest, and perimeter habitat affects bird use

- harvesting switchgrass in alternating cut and uncut strips is more beneficial to the winter bird community than harvesting them completely
- switchgrass fields grown for biomass provide habitat for grassland birds, and nest success rates in the fields should support stable bird populations

The 1999 preliminary Rathbun Lake Watershed report found that 27% of the watershed (94,884 acres) has a high potential for wildlife quality improvement, 57% (203,221 acres) has a moderate potential, and 16% (55,939 acres) has a low potential. In addition, of the 189,327 acres with favorable soil characteristics for perennial grasses, approximately 51,000 acres are located on land that has a high potential for wildlife quality improvement.

Fuel Quality

Research found that cell wall content of switchgrass was not altered greatly due to year, location, or fertility status, and those changes that are observed are not easily explained. Elemental analysis showed that differences were immaterial regarding biofuel quality; neither location nor nitrogen fertilization rate had a substantial impact on composition. Research also found that the Tilletia maclaganii fungi is the major cause of switchgrass declining yields, and ten new potentially pathogenic fungi were discovered that were not previously found in switchgrass production in Iowa. Recommendation is to rotate currently infected field to another crop or forage grass for minimum of three years, and establish cultivar trial at an infested location. In general, overwintering material in the field results in slightly better biofuel, from an energy standpoint per unit dry weight, but the decline in yield during that time appears to more than offset the improved energy quality.

Carbon Sequestration

Research completed in the year 2001 concluded that soil carbon content varies significantly and systematically in accordance with landscape position, soil properties, and land use. Specifically, pastures were found to have the highest soil organic carbon content, old and medium-aged switchgrass fields were found to have the second most, and young switchgrass and row crop fields were found to have the least. According to a pastures analysis, the soil organic carbon content of pasture pedons ranges from 7.4 to 24.6 kg m^{-2} m^{-1}, and 67% and 52% of the soil organic carbon was found in the top 0.5 and 0.2 m, respectively. Researchers do not think switchgrass results in the maximum soil organic carbon contents in the Chariton Valley although rates of carbon sequestration are impressive (e.g., 1.5 tons per acre per year) in switchgrass stands about 5 to 15 years old.

In 1999, the report *A Comparison of Life Cycle Greenhouse Gas Emissions from Switchgrass and Coal for Electric Generation* was completed and it concluded that converting row crop land to switchgrass production will yield higher GHG emissions benefits than if CRP land (fallow land) was converted. This is because CRP land is not actively managed and is already sequestering a significant amount of carbon. In addition, it concluded that cofiring 5% switchgrass with coal (on a heat-input basis) may reduce GHG emissions on a CO_2-equivalent basis by nearly 177,000 tons per year, if the land was previously used for row crop production.

Another report from 1999, *Soil Carbon Sequestration Potential in the Chariton River Watershed, Iowa*, found that soil carbon sequestration potential depends on inherent soil properties and management. The following conclusions were reached: 44% of the land has a high potential for carbon sequestration, 36% has moderate potential, and 20% has low potential.

Research is expected to continue until the end of 2003. Specific plans are to review emissions data and incorporate it into the final version of the GHG Emissions Life Cycle report scheduled for 2002, and analyze landscape assessments and soil cores collected from fields in the project area for measuring carbon fluctuation.

Applicable Federal/State Regulations

FIFRA is a federal law regulating pesticides. It requires all pesticides sold or distributed in the U.S. to be registered by the EPA. Unregistered pesticides may be used under certain circumstances. This project received a special use permit to use atrazine with switchgrass production. Registration requires EPA to examine the ingredients of the pesticide; the particular site or crop on which it is to be used; the amount, frequency and timing of its use; and the storage and disposal practices. A pesticide also has to be used only according to the directions on the label.

The federal Clean Water Act authorizes EPA to regulate nonpoint sources of water pollution, such as runoff from agricultural and forestry operations. States are authorized to develop a management program for nonpoint source discharges. The federal Clean Water Action Plan required states to create Unified Watershed Assessments to identify: watersheds needing restoration, watersheds needing preventive action, or pristine or sensitive watersheds in federal lands needing an extra measure of protection. The Chariton Valley biomass project assisted the state in developing its Action Plan for the Chariton Valley watershed. EPA's Watershed Protection Approach is a strategy with the premise that many water quality and ecosystem problems are best solved at the watershed level rather than at the individual water body or discharger level. It includes stakeholder involvement, multiple agency input, and monitoring and data gathering. The project received a grant from EPA to provide an assessment of the Rathbun Lake watershed; a draft will be submitted to EPA in early 2002.

The Conservation Reserve Program is a voluntary federal program that offers annual rental payments, incentive payments for certain activities, and cost-share assistance to establish approved cover on eligible cropland. The program encourages farmers to plant long-term resource-conserving covers to improve soil, water, and wildlife resources. Assistance is available in an amount equal to a maximum of 50% of the participant's costs in establishing approved practices. In the year 2000, the federal government authorized the CRP to conduct pilot projects where biomass would be harvested on CRP land and used for energy production. The terms of the project specify harvesting frequency and size, and stipulate that the biomass cannot be used for any commercial purposes other than energy production. The Chariton Valley biomass project is one of these pilot efforts.

OGS faces several federal regulations pertaining to air emissions: opacity, sulfur dioxide, particulate matter, fugitive dust, and nitrogen oxides. These limitations can apply to both individual emissions points and total OGS emissions. It also has to address stormwater pollution and ash management and disposal issues. In addition, the state of Iowa has a renewables set aside (its Alternative Energy Law) where investor-owned utilities have to purchase a total of 105 MW of generation from renewable sources. There is also a state mandate requiring all utilities to offer green power options to their customers beginning January 1, 2004. Finally, the global warming debate around carbon sequestration and a newly instituted carbon credit exchange may impact switchgrass/coal cofiring and the operations at OGS.

1.0 INTRODUCTION

1.1 Overview of Chariton Valley Biomass Project

The primary goal of the Chariton Valley (CV) Biomass Project is to develop markets for energy crops in southern Iowa. A feasibility study identified herbaceous switchgrass as an attractive bio-fuel for cofiring with coal at the Ottumwa Generating Station (OGS), thus presenting an opportunity for developing and sustaining a market for energy crops in southern Iowa. The development of gasification technologies was subsequently added to the cofiring approach.

The CV Biomass Project is coordinated by the Chariton Valley Resource Conservation and Development (CVRCD) organization. CVRCD is a non-profit corporation that receives technical assistance from the USDA's Resource Conservation and Development Program. The stated purpose of the RC&D Program "…is to accelerate the conservation, development, and utilization of natural resources, to improve the general level of economic activity, and to enhance the environment and standard of living in authorized RC&D areas."

1.2 Objectives

To help it achieve its goal of commercial biomass energy generation in southern Iowa, the CV Biomass Project has outlined the following objectives:

1. To design, install, and test modifications to OGS that will allow the use of biomass to generate energy
2. To conduct field research and development to improve the agronomic, economic, and environmental aspects of producing and using biomass for energy generation
3. To work with cooperating farmers to produce biomass for energy generation on at least 4,000 acres of land
4. To determine the technical and economic feasibility of cofiring and gasification technologies for energy generation
5. To address market development issues, including contractual agreements, required to support the use of biomass to generate energy

1.3 Project Approach

This approach is designed to provide benefits at both OGS site and the farm. As a coal-fired power plant, OGS emits NO_X, SO_2, CO_2, and particulate matter. By replacing a portion of the coal with the switchgrass bio-fuel, these emissions can be reduced. Regarding land benefits, 10% of the approximately 1.4 million acres of cropland in the Chariton Valley are in the Conservation Reserve Program (CRP) and 64% is considered highly erodible. (CVRCD/TR#1, 9/96-12/96) Growing switchgrass as a biofuel on CRP land has been widely supported because it was thought to thrive in an environmentally benign way across the soil-landscapes of the Chariton Valley while at the same time not competing with traditional farm crops. (Brummer, et.al, 2001) Introducing switchgrass crop can address two pressing issues: 1) if switchgrass uses less chemicals, the Rathbun Lake watershed's current water quality problems from agricultural nonpoint source pollution may be reduced; and 2) farmers in this watershed are relatively poor, so steady income from using switchgrass as a fuel can be economically beneficial to them. (CVRCD/TR#4, 7/97-12/97)

1.4 Project Status

Planning for the Chariton Valley Biomass Project began in 1991. From November 2000 through January 2001, Alliant Energy conducted the Phase I cofire test at its OGS site. During this period, an estimated 1,269 tons of biomass was cofired. The report for the first cofire test campaign will be completed during 2002.

1.5 Project Partners

The CV Biomass Project participants include: Alliant Power; Chariton Valley RC&D, Inc.; Energy Research Corporation; Iowa Department of Agriculture and Land Stewardship; Iowa Department of Natural Resources; Soil and Water Conservation Districts; Iowa Farm Bureau Federation; Iowa Energy Center; Iowa State University (ISU); John Deere Works; Leopold Center for Sustainable Agriculture; National Renewable Energy Laboratory (NREL); Oak Ridge National Laboratory; Prairie Lands Bio-Products, Inc.; R.W. Beck; U.S. Department of Agriculture; U.S. Department of Energy; Vermeer Manufacturing Company; Hazen Research; Mostardi-Platt, TR Miles Consulting; and Antares Group Inc.

2.0 OVERVIEW OF ENVIRONMENTAL STRATEGIES PLAN AND IMPACTS

2.1 Overview of Environmental Strategies Planning

The purpose of the environmental strategies planning effort is to understand the environmental impacts of producing and using biomass for energy generation. The researchers' goal is to identify land in the watershed on which producing switchgrass for biomass would have the greatest potential beneficial impact on biodiversity, in terms of water quality protection, wildlife habitat improvement, soil carbon sequestration, and overall soil quality. (CVRCD/TR#9, 4/99-6/99)

2.2 Report Outline

The report is organized as follows:

<u>Environmental Impacts Associated with Switchgrass Farm</u> – discusses the soil quality, carbon sequestration, water quality, habitat/wildlife, biodiversity, and fuel quality issues associated with growing switchgrass.

<u>Environmental Impacts At OGS</u> – discusses the greenhouse gas emissions, local air emissions, ash, and stormwater issues associated with cofiring switchgrass at OGS coal-fired plant.

<u>Summary Tables</u> – highlights of where the environmental impact occurs, progress and outstanding issues, and a project timeline.

<u>Applicable State and Federal Regulation</u> – provides overview of regulation pertaining to feedstock production and electricity generation.

3.0 ENVIRONMENTAL ISSUES ASSOCIATED WITH SWITCHGRASS FARM

3.1 Soil Quality

Soil quality affects switchgrass production and conversely, switchgrass production affects soil quality. This report focuses primarily on the latter—how switchgrass production affects soil quality. However, this section will conclude with a brief overview of the research being conducted on the effect of soil quality on switchgrass.

3.1.1 <u>Progress & Results to Date</u>

Nitrogen Fertilization

"Field experiments began in 1998 using mature, established 'Cave-in-Rock' switchgrass fields in Lucas and Wayne counties in southern Iowa. Five replications at each location were used for analysis. Each replication was 200' wide and between 100' and 400' long, the variable length being necessary to allow incorporation of summit, backslope, and swale landscape positions within each plot. Each replication included four randomly assigned plots, representing four nitrogen fertility treatments of 0, 56, 112, and 224 kg N/ha; each plot was 50' wide and covered all three landscape positions. In 1998 and 1999, plots were subsampled throughout the year for biomass yield and quality measurements using a 1 sq.meter quadrat. In autumn 1998, 1999, and 2000, total plot biomass was harvested by mowing and baling the entire plot area. Within each plot, soil samples of the 'A' horizons taken at five points across the landscape. Additionally, 30 1-meter deep cores were taken across all plots.

Exhibit 1 –Fertilizer being applied to a switchgrass field

Results showed that nitrogen fertilization increased biomass when averaged across the three years. In 2000, the most striking response came with the addition of 56 kg/ha, with no difference between 56 and 112 kg/ha, or between 112 and 224 kg/ha. The 224 kg/ha level was higher than 56, however. Across the three years, improvements in yield were realized by sequential increases of N from 0 to 56 kg/ha and from 56 to 112 kg/ha. Increasing nitrogen application above 112 kg/ha did not result in further yield increases averaged across the three years or in 2000. Thus, the recommended fertilization rate for switchgrass biomass production in this region of southern Iowa should be between 56 and 112 kg/ha." (Brummer, C., et.al., 2001)

Exhibits 3 and 4 show the composition and analysis of switchgrass from these experimental plots, at the various nitrogen fertilizer rates.

Exhibit 3

Table II.3. Proximate and ultimate analyses of switchgrass biomass for 1998, 1999, and 2000 in two southern Iowa locations and at four nitrogen fertilization rates.

	Ash	Volume matter	Fixed C	BTU	C	H	N	O	S
	--- % Dry weight ---								
Year									
1998	4.10	80.56	15.34	7950	48.25	5.26	0.25	42.08	0.062
1999	4.86	78.35	16.79	7943	46.94	5.52	0.25	42.40	0.063
2000	4.12	78.73	17.14	7795	47.56	5.56	0.68	42.02	0.063
LSD (5%)	0.34	0.44	0.29	52	0.30	0.10	0.06	0.31	ns
Location									
Lucas	4.64	78.87	16.49	7876	47.45	5.44	0.38	42.03	0.060
Wayne	4.08	79.55	16.37	7917	47.71	5.45	0.41	42.31	0.065
LSD (5%)	ns	0.36	ns	ns	ns	ns	ns	ns	ns
Nitrogen Level									
0	4.74	78.96	16.31	7880	47.37	5.48	0.38	42.00	0.071
100	4.41	79.29	16.30	7897	47.52	5.44	0.39	42.19	0.062
200	3.93	79.39	16.68	7911	47.86	5.42	0.41	42.32	0.055
LSD (5%)	0.34	ns	0.29	ns	0.30	ns	ns	ns	0.012

Harvest dates: November 1998, September 1999, and October 2000.

Exhibit 4

Table II.4. Elemental analysis of switchgrass biomass harvested in October 1999 and 2000 from two southern Iowa locations and at three nitrogen fertilization rates.

					Two-year average							
		By year			By location			By nitrogen level (kg ha^{-1})				Overall
Element	Unit	1999	2000	LSD	Lucas	Wayne	LSD	0	112	224	LSD	mean
Constituents determined using INAA on dry vegetation												
Au	Ppb	4.39	0.32	0.77	1.93	2.79	ns	2.97	2.32	1.79	ns	2.36
Ba	Ppm	19.83	16.72	2.72	20.33	16.22	ns	16.00	16.92	21.92	3.60	18.28
Br	Ppm	16.24	12.98	3.22	12.25	16.97	ns	16.61	16.33	10.89	4.19	14.61
Co	Ppm	0.36	0.16	0.07	0.23	0.29	ns	0.25	0.29	0.23	ns	0.26
Cl	Ppm	1003	767	190	1091	680	ns	928	877	850	ns	885
Cr	Ppm	0.45	0.19	0.26	0.29	0.36	ns	0.39	0.34	0.23	ns	0.32
Fe	%	0.008	0.002	0.003	0.006	0.004	ns	0.004	0.006	0.004	ns	0.005
K	%	0.56	0.53	ns	0.57	0.52	ns	0.54	0.56	0.53	ns	0.54
Mo	Ppm	0.61	0.33	0.15	0.21	0.74	0.18	0.54	0.51	0.37	ns	0.47
Na	Ppm	33.37	30.37	2.46	32.13	31.61	ns	30.87	34.12	30.63	ns	31.87
Zn	Ppm	18.72	17.11	ns	18.44	17.39	ns	18.42	17.08	18.25	ns	17.92
La	Ppm	0.10	0.02	0.02	0.06	0.07	ns	0.07	0.06	0.06	ns	0.06
Constituents determined using ICP on fused and acid-digested vegetation												
SiO_2	%	57.97	54.59	2.57	55.38	57.18	ns	57.96	57.11	53.77	3.50	56.28
Al_2O_3	%	0.20	0.24	0.04	0.24	0.20	ns	0.20	0.25	0.21	ns	0.22
Fe_2O_3	%	0.17	0.14	ns	0.16	0.15	ns	0.13	0.14	0.19	0.04	0.15
MnO	%	0.25	0.20	ns	0.22	0.23	ns	0.22	0.20	0.26	ns	0.23
MgO	%	4.39	4.42	ns	3.82	4.99	0.41	4.29	4.44	4.50	ns	4.41
CaO	%	7.48	7.48	ns	6.97	7.99	0.48	7.01	7.34	8.09	0.59	7.48
Na_2O	%	0.31	0.04	0.18	0.20	0.15	ns	0.10	0.26	0.16	ns	0.18
K_2O	%	10.83	13.47	1.08	11.58	12.72	ns	11.47	12.35	12.63	ns	12.15
TiO_2	%	0.009	0.021	0.003	0.017	0.013	ns	0.014	0.016	0.015	ns	0.015
P_2O_5	%	3.45	3.33	ns	4.35	2.42	0.39	3.82	3.36	2.98	0.48	3.39
LOI[†]	%	14.05	15.94	ns	16.62	13.38	2.74	14.29	13.92	16.78	ns	15.00
Ba	ppm	418.56	409.83	ns	428.28	400.11	ns	358.33	366.25	518.00	81.34	414.19
Sr	ppm	253.22	254.50	ns	276.06	231.67	20.29	234.08	250.67	276.83	24.85	253.86
Zr	ppm	13.22	14.89	1.18	13.72	14.39	ns	14.42	13.58	14.17	ns	14.06

Table II.4. Elemental analysis of switchgrass biomass harvested in October 1999 and 2000 from two southern Iowa locations and at three nitrogen fertilization rates.

					Two-year average							
		By year			By location			By nitrogen level (kg ha^{-1})				Overall
Element	Unit	1999	2000	LSD	Lucas	Wayne	LSD	0	112	224	LSD	mean
Ag	ppm	0.52	0.00	0.38	0.18	0.31	ns	0.16	0.44	0.14	ns	0.25
Cu	ppm	4.67	68.00	10.02	27.44	45.22	10.02	37.17	35.25	36.58	ns	36.33
Zn	ppm	20.67	330.61	42.89	183.06	168.22	ns	162.83	163.33	200.75	ns	175.64
Constituents determined using INAA on ashed vegetation												
Au	ppb	65.89	4.11	13.39	25.56	44.44	ns	38.42	33.50	33.08	ns	35.00
Ba	ppm	272.22	327.78	53.11	307.78	292.22	ns	266.67	256.67	376.67	69.32	300.00
Br	ppm	151.39	147.22	ns	115.28	183.33	ns	156.50	159.67	131.75	ns	149.31
Ca	ppb	5.60	6.59	0.58	5.72	6.48	ns	5.74	5.98	6.58	ns	6.10
Co	ppm	5.67	5.00	ns	4.17	6.50	1.47	5.67	5.50	4.83	ns	5.33
Cr	ppm	7.00	8.22	ns	7.28	7.94	ns	7.92	8.50	6.42	ns	7.61
Fe	%	0.09	0.12	0.01	0.11	0.10	ns	0.10	0.10	0.11	ns	0.10
K	%	11.35	16.18	1.20	13.50	14.03	ns	12.97	13.75	14.58	ns	13.77
Mo	ppm	10.33	8.44	ns	2.78	16.00	3.12	10.00	10.42	7.75	ns	9.39
Na	ppm	264.61	311.94	35.68	308.11	268.44	ns	282.50	308.25	274.08	ns	288.28
Rb	ppm	53.00	52.94	ns	44.56	61.39	ns	49.83	55.92	53.17	ns	52.97
Zn	ppm	352.22	452.78	63.09	388.33	416.67	ns	380.83	377.50	449.17	ns	402.50
La	ppm	1.71	1.92	ns	1.73	1.89	ns	1.75	1.66	2.03	ns	1.81
Sm	ppm	0.22	0.27	0.04	0.22	0.27	ns	0.26	0.20	0.28	0.06	0.24

†LOI=Lost on ignition.

Erosion Impacts

In 2000, GIS analysis identified 53,649 acres of land in the watershed to be targeted for conversion to switchgrass production. Exhibit 5 shows existing land for switchgrass production and Exhibit 6 shows potential land for conversion to switchgrass production. The analysis determined that converting this land from row crop to switchgrass production could reduce annual soil erosion from 390,049 to 17,746 tons/year. It could also reduce the amount of sediment delivered to the Lake and other water resources in the watershed from 118,647 to 5,185 tons/year. This assessment was based primarily on watershed land use data, soil properties that indicate a high potential for surface runoff and leaching, soil erosion calculations based on the Revised Universal Soil Loss Equation, and sediment delivery potential estimated with the USDA Natural Resources Conservation Service's erosion and sediment delivery procedure.

Recent research using the Soil and Water Assessment Tool (SWAT) in 2001 found that the switchgrass scenario reduced sediment yield by 55% relative to the baseline condition. Switchgrass produced average sediment yields twice that of pasture, but a magnitude less than land in row crop production. Researchers concluded that due to this effect, additional soil conservation practices might be needed to prevent excessive erosion from occurring on highly erosive soils when growing switchgrass. (Neppel, et.al., 2001)

Additional Findings

Research found that about half of established switchgrass fields have gullies and less than 0.5 Mg/ha-yr. of soil is lost due to gullies. There is no correlation between stand quality and gully presence. Research has found that switchgrass may not provide adequate protection against gully erosion, primarily due to its growth habit as a bunch grass. As a result, steps should be taken to prevent gully erosion at susceptible locations, for example, planting grasses that are more sod forming. (CVRCD/TR#12, 1/00-3/00)

Exhibit 5

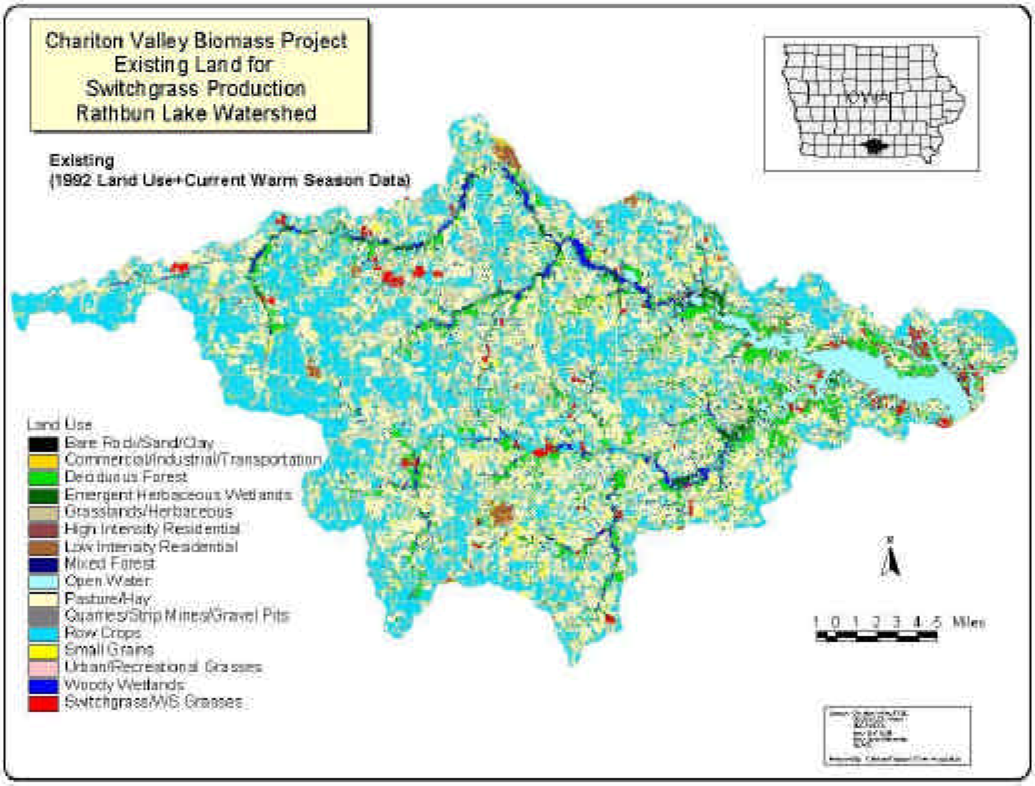
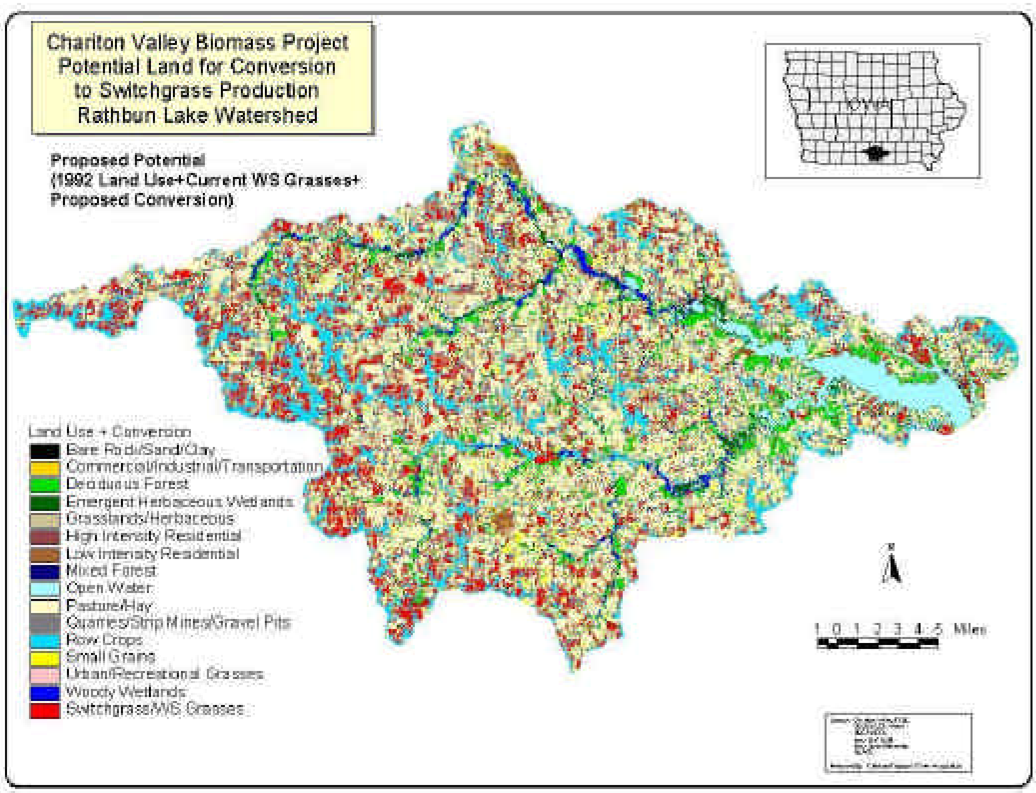


Exhibit 6



- More stable aggregates generally indicate better soil quality because it promotes water infiltration & retention, gas exchange, and ease of root growth. Research found that established switchgrass has about 75% stable aggregates, whereas row crop fields have about 34%. (CVRCD/TR#12, 1/00-3/00)
- An Alabama study found that plots that were previously planted with switchgrass generally provided higher yields of grain from corn and soybeans, and higher yields of cotton, than adjacent plots that were not planted with switchgrass. In the second year, total biomass for all crops was higher for plots that had been previously planted in switchgrass, although the difference in yields varied among crops and years. (Morrison, et.al., 2001)

1996-1999 Progress

- Research completed in 1996 recommended 60 lbs./A of nitrogen for economic switchgrass production, possibly up to 90 lbs./A depending on higher yielding varieties, land values and other costs, and prices for the biomass product. (CVRCD/TR#1, App.4, 9/96-12/96)
- Two plantings of twenty switchgrass cultivars and experimental germplasms were established in spring 1997; one planting failed due to herbicide damage. In October 1997, plots were rated for leaf disease symptoms and stand and no significant differences were apparent among entries. Plots were mowed to limit the weed competition. (CVRCD/TR#5, 1/98-4/98)
- In 1997, undertook surface sampling and hand sampling of plots on CRP land and began to analyze nitrogen levels and soil pH. In the surface soil analysis, two sites did not show significant erosion, but one site showed poor ground cover. In 1998 and 1999, plans are to undergo intensive surface sampling and hand and deep core the sampled plots. (CVRCD/TR#5, 1/98-4/98)

Effect of Soil Quality on Switchgrass Production

Despite a well-developed farm culture, the biggest production limitation has been finding crops suitable for the existing soil resource. In the four-county area, soils productivity averages a score of 50 on a scale of 5-95. This limitation is due to several soil groups that are highly erosive, shallow to root restrictive zones, and/or extremely wet, and the wide range of soil types within a given region. Switchgrass appears to be a crop that can flourish even with these soil conditions. (CVRCD/TR#1, 9/96-12/96)

"In field level trials, switchgrass ('Cave-in-Rock') yields were found to be relatively low when starting from long-term, poorly managed stands. However, yields improved to nearly 2 tons/acre after two years of fertilization with 112 kg N/ha and weed control. Alamo and several other lowland ecotypes produced the most biomass, higher than Cave-in-Rock, which is the normally recommended cultivar for southern Iowa. These trials suggest that higher yields are possible under optimum management and with superior cultivars. A cautionary note is that the lowland cultivars have not experienced a severe winter, and their winter hardiness may not be sufficient under those conditions. In all cases, switchgrass quality appears adequate for a biofuel; variation among cultivars exists, suggesting that further improvements in quality are possible. Preliminary evaluation of reed canarygrass suggests that two harvests, one in late spring and the other after frost, yield the most biomass." (Brummer, C., et.al., 2001)

3.1.2 Current and Future Strategies for Monitoring and Assessing Impacts

- Plans are to test reed canarygrass side-by-side with switchgrass in large plots, and to determine field level yields and quality of reed canarygrass. (Brummer, et.al., 2001)

- Soil quality has to be better explained through more investigations of gullies, aggregate stability, epipedon construction/destruction, as well as mass balance of long-term erosion and sedimentation across a landscape. (CVRCD/TR#12, Att.12, 1/00-3/00)

- Analysis is underway of yield, management, and soil data collected from 22 fields harvested for biomass during 2000-2001. (CVRCD/TR, 4/01-6/01; 7/01-9/01)

- When the project began, switchgrass was evaluated based on productivity/yield and environmental quality. Environmental quality indices include: rates of soil erosion, runoff characteristics, and overall soil tilth. Sixteen fields were studied, each one being managed according to one of four fertility regimes. The four regimes varied by fertilizer input—no additional fertilizer and minimal, recommended, and high inputs of nitrogen, phosphorous, and potassium. Indices were monitored by on- and off-field changes, and four non-switchgrass fields were also studied (two used for row crop and two used as pasture). It is expected that ten soil-landscape units will be identified and each will respond uniquely to the fertility regimes. It is projected that switchgrass production will be more environmentally suited to CV than row crop and marginally better than pasture. (CVRCD/TR#1, 9/96-12/96)

- GIS has been used to show political boundaries, infrastructure, land/field information, and ground cover. These digital data layers will be overlaid on soils formation for spatial analysis. Given data availability, GIS can be used to gauge how much carbon is removed from the atmosphere during different types of crop production.

3.2 Carbon Sequestration

3.2.1 Progress & Results to Date

Latest Findings

Traditional agricultural systems (e.g., row crops) lose sequestered carbon. Alternative cropping schemes help stop the ongoing loss of soil carbon and may even increase it. Using perennial grasses (e.g., switchgrass) as the predominant species within a field has been found to promote high rates of soil carbon gain. (CVRCD/TR#8, 10/98-1/99) The research cited below studied these issues.

The latest research used pedological principles as the framework to quantitatively establish soil carbon contents at the field level in the Chariton River watershed and across landscapes and soils only in pastures. Three basic relationships were examined individually and collectively: soil carbon content and soil morphology, soil carbon content and landscape properties, and soil carbon content and "long term" (at least 10 years) land use history. The pastures analysis examined seven pastures of varying quality. Conclusions are as follows (Burras and McLaughlin, 2002, 2000):

- Average soil organic carbon content in the Chariton Valley was 12 kg m^{-2} m^{-1}, which corresponds to 53.4 tons per acre-40 inches
- Carbon content varies considerably with landscape position and land use; positions typically having the least soil organic carbon content are shoulders and backslopes
- Highest soil organic carbon content is generally found under pastures; old and medium-aged switchgrass fields contain the second most organic carbon and the least amount is found in young switchgrass and row crop fields
- Soil organic carbon sequestration was found to occur under switchgrass production in one, or some combination of, the following ways:
  - The sequestration rate can occur at such a slow linear rate that for the first several years it is impossible to detect any gain with the methods employed
  - The sequestration rates are curvilinear with the rate rapidly increasing after 5 years
  - Normal spatial variability masks soil organic carbon gains for long time periods
- Soil organic carbon content of pasture pedons ranges from 7.4 to 24.6 kg m^{-2} m^{-1}
- 67% and 52% of the soil organic carbon was found in the top 0.5 and 0.2 m, respectively
- Researchers do not think switchgrass results in the maximum soil organic carbon contents in the Chariton Valley although rates of carbon sequestration are impressive (e.g., 1.5 tons per acre per year) in switchgrass stands about 5 to 15 years old

In October 1999, the Center for Global and Regional Environmental Research completed a report entitled *A Comparison of Life Cycle Greenhouse Gas Emissions from Switchgrass and Coal for Electric Generation*. It concluded that if land is in CRP use (fallow land) prior to switchgrass production, the GHG emissions benefits are not as high as if the land was in row crop production. This is because fallow CRP land is not actively managed and thus is already sequestering a significant amount of carbon, whereas land in row crop production is actively managed and uses nitrogen. For more details on the report's findings, refer to Section 4.1.1 in this report.

In mid-1999, Iowa State University completed a preliminary assessment of the potential carbon sequestration impacts of switchgrass production, entitled *Soil Carbon Sequestration Potential in the Chariton River Watershed, Iowa*. This established a basis for future research and helped identify lands where switchgrass production could increase carbon sequestration. Preliminary conclusions include:

- The potential to sequester soil carbon across the watershed is thought to depend on two factors: inherent soil properties and management. Important soil properties are (a) past erosion, (b) slope characteristics, (c) soil drainage class, (d) parent material, (e) inherent fertility, and (f) natural morphological characteristics. These factors were put into an equation and used with available soil databases to develop soil mapping units that represent their relative carbon sequestration potential.
- Approximately 156,096 acres (44.1%) of the land in the watershed are assessed as having a *high* potential for carbon sequestration.
- Approximately 126,048 acres (35.6%) of the land in the watershed are assessed as having a *moderate* potential for carbon sequestration.
- Approximately 71,900 acres (20.3%) of the land in the watershed are assessed as having a *low* potential for carbon sequestration.

Additional Research

An Alabama study found that soil carbon increased over a three-year period in land that had been converted from annual row crops to switchgrass that was managed for energy. (Morrison, et.al., 2001)

"A study done in Alabama was aimed at determining the effect of different cultural practices on soil carbon sequestration under switchgrass. Results showed that nitrogen application, row spacing, harvest frequency, and switchgrass cultivar did not change soil organic carbon in the short-term (2-3 years) after switchgrass establishment. However, after 10 years switchgrass soil organic carbon was 45% and 28% higher at depths of 0-15 cm and 15-30 cm, respectively, compared with fallowed soil in an adjacent area. Researchers concluded that several years of switchgrass culture will be required to realize a soil carbon sequestration benefit." (Ma, et.al., 11/1999)

"A study done in Alabama was aimed at determining the impact of agricultural management practices, such as row spacing and nitrogen application rate, on carbon partitioning within the switchgrass-soil system. Results indicate that carbon storage in switchgrass roots was higher with wide than narrow rows, and increased with nitrogen application rates. Carbon storage in shoots was 14.4% higher with 80-cm than 20-cm row spacing. Annual application of 24 kg of nitrogen per hectare increased carbon storage in shoots by 207% and 27% when compared with annual applications of 0 and 112 kg of nitrogen per hectare, respectively. Rate of carbon increase in roots (72%) was higher than in shoots (49%) between 1995 and 1996. It appears that carbon partitioning to roots plays an important role in carbon sequestration by switchgrass." (Ma, et.al., 1/2001)

"A study done in Alabama was aimed at determining carbon dynamics subsequent to switchgrass establishment and the impact of cultural practices (row spacing and harvest frequency) on carbon biogeochemical characteristics in a sandy loam soil and a clay loam soil. Results indicated that soil carbon characteristics changed over time after switchgrass establishment. Researchers concluded that soil carbon accumulation is positively related to root input. It appears that switchgrass establishment may…be a means of improving soil quality." (Ma, et.al., 9/1999)

3.2.2 Current and Future Strategies for Monitoring and Assessing Impacts

- Cooperative agreements were developed with ISU for research to be conducted to complete the scope "Soil Carbon and Quality in Grundy and Clarinda Soil Map Units, Chariton Valley, Iowa." ISU researchers have met with biomass project staff to plan and initiate research activities to be completed in 2002. (CVRCD/TR, 10/01-12/01)
- Project partners and ISU researchers are developing the scope "Switchgrass Production in Iowa: Economic Analysis, Soil Suitability, and Varietal Performance," that will include activities to continue these tasks. (CVRCD/TR, 10/01-12/01)
- All fieldwork and laboratory analysis of soil cores collected has been completed. University of Iowa researchers have continued to review the emissions data collected during the first cofire test campaign. This data will be incorporated into the final version of the report *Comparison of Life Cycle Greenhouse Gas Emissions from Switchgrass and Coal for Electric Generation* which is due to be completed in 2002. (CVRCD/TR, 4/01-6/01; 7/01-9/01)

- Performed landscape assessments including surveying for elevation measurements and the collection of GPS coordinates for the research fields and sample locations. (CVRCD/TR#13, 4/00-9/00)
- Conducted laboratory analysis of more than 200 soil cores collected from fields in project area. (CVRCD/TR#13, 4/00-9/00)
- Evaluate the applicability of using soil color as a way to document soil carbon content. Some researchers found the correlation between soil color and soil carbon content to be as high as 0.9. (Burras, C.L., et. al.)

3.3 Water Quality

Rathbun Lake, on the Chariton River, is one of Iowa's most important water resources. Located in the south central part of the state, the lake supplies one of the nation's largest rural water systems, providing water to more than 60,000 residents in 18 counties. It also provides flood protection, fish and wildlife habitat, and recreational opportunities to more than one million visitors annually. The lake, however, has been contaminated by agricultural nonpoint source pollution due to soil loss from highly erodible land. Sediment containing farm chemicals is filling the lake at a rate three times faster than originally anticipated.

The lake's watershed comprises approximately 354,000 acres. Most of the land (60%) is used for row crop production (corn and soybeans) and 25% of the land is used for pasture and hayland. One-third is highly erodible cropland, nearly half of which (56,000 acres) is currently enrolled in the CRP. The six counties located in the watershed are among the poorest in Iowa and almost 60% of its producers are considered to be small scale/limited resource (socially disadvantaged) farmers. (CVRCD/TR, 7/97-12/97)

Exhibit 7 – Rainfall simulator

There are six sources of water quality impairment threatening Rathbun Lake; large-scale switchgrass production would impact the first three. (CVRCD/TR, 7/97-12/97)

1. *Sediment and Chemicals From Cropland*—60% of the land use in the watershed is cropland. More than half of this amount (133,000 acres) is highly erodible. Annual sheet and rill erosion on the highly erodible cropland can exceed 30 tons per acre. Runoff from cropland area is the major source of water quality impairment because it transports sediments and chemicals into the lake. This problem is likely to worsen as CRP acres are released and put into row crop production; under current conditions, almost 80% of the released CRP acres will be converted to row crop production.
2. *Gully Erosion*—Gully erosion is a problem on highly erodible, sloping, or poorly managed land. It is a source of soil loss on at least 21,000 acres of land in the watershed. As much as 90% of sediment from gully erosion reaches the lake.
3. *Soil Loss From Pasture and Hayland*—Pasture and hayland consists of cool season grasses, however, 70% of this land is in a degraded condition due to mismanagement. With ground cover as low as 50% in some areas, and half the vegetation as weeds, this land suffers as much as 15 tons of soil loss per acre, per year.

4. *Shoreline and Stream Bank Erosion*—Water level fluctuations are common in the flood control storage area of the watershed, mainly due to storms and water release guidelines designed to protect flooding. The resulting wave erosion affects much of the 180 miles of shoreline, thus exacerbating the lake's sedimentation problems.
5. *Waste From Livestock Operations*—The watershed is home to 300 livestock operations, many of which are potential sources of contaminants. Only a few of these facilities have an animal waste management system or utilization plan that satisfies DNR's minimum waste control requirements. As a result, animal waste from these facilities is suspected of causing excessive algae growth and increased bacteria levels.
6. *Waste Water and Sediment From Residential Areas*—Wastewater and sediment from residential areas, while not primary sources of water quality impairment, are issues that require special attention and approaches to water quality protection.

3.3.1 Progress & Results to Date

Exhibit 8 – Runoff testing and analysis

GIS analysis identified 53,649 acres of land in the watershed to be targeted for conversion to switchgrass production for biomass. The analysis determined that converting this land from row crop production to switchgrass production could reduce annual soil erosion from 390,049 to 17,746 tons per year. It could also reduce the amount of sediment delivered to the Lake and other water resources in the watershed from 118,647 to 5,185 tons per year. This preliminary assessment was based primarily on land use data for the watershed, soil properties that indicate a high potential for surface runoff and leaching, soil erosion calculations based on the Revised Universal Soil Loss Equation, and sediment delivery potential estimated with the USDA Natural Resources Conservation Service's erosion and sediment delivery procedure.

Significant progress was made in the application of the Soil and Water Assessment Tool (SWAT) in 2001. SWAT is a biophysical, semi-distributed, continuous, daily time step model designed to simulate water yield, sediment deliver, and nutrient and pesticide loading from large, ungaged watersheds. It is used to evaluate the potential impacts of alternative land conversion scenarios on water quality and it will be able to quantify these impacts in terms of sediment and agricultural chemicals that may impair water quality in the Lake. The model was calibrated (with a period of 1966 to 1986) and validated and used to study the water quality effects of changing land use and management practices from baseline conditions to one of growing switchgrass for biomass production. The model was able to rank 61 subbasins of Rathbun Lake watershed for sediment production, nutrient runoff, and atrazine runoff. Major findings from the SWAT modeling are listed below (Neppel, et.al., 2001):

Major Findings

- The switchgrass scenario reduced sediment yield 55% relative to the baseline scenario.
- Sediment-bound phosphorous and nitrogen are reduced 36% and 39%, respectively, comparing the switchgrass scenario relative to the baseline scenario.
- Soluble phosphorous and nitrogen are reduced 26% and 38%, respectively, comparing the switchgrass scenario relative to the baseline scenario.
- Sediment-bound atrazine and soluble atrazine quantities delivered to Rathbun Lake are reduced 83% and 86%, respectively, comparing the switchgrass scenario relative to the baseline scenario.
- The predicted reductions in sediment, nutrients, and atrazine are a result of the effects of changing land use and also in the combinations of land use and soils (HRUs) simulated by the model.

One study used a linear rainfall simulator to assess sediment runoff and runoff water quality. Researchers selected three fields in Wayne County, Iowa for their consistent soil type, slope (5-7%), and availability of water supply used for rainfall simulation. The study consisted of six replicates each of the following three treatments: newly planted switchgrass following soybeans (NSG), established mature switchgrass of thirteen years (OSG), and no-till corn following soybeans (NTC). Samples were collected during two periods: 1) in May 2000 starting with NPS and ending with OSG; and 2) from late June 2000 starting with NTC and ending in late July with NPS. Conclusions are as follows (Kost, J., et.al., 2002):

- In both periods, new and established switchgrass were beneficial in reducing sediment loss, inorganic nitrogen loss, total phosphorus loss, and metolachlor contamination in runoff when compared to NTC
- OSG contributed significantly more organic nitrogen to runoff than either of the other treatments in the early sampling period
- Atrazine contamination in period 1 runoff was reduced from NSG to OSG
- For most parameters, NSG was less effective at preventing nutrient loss or herbicide contamination; however, NSG provided significant improvements over NTC for sediment loss, total phosphorus, TKN during adequate moisture conditions, and metolachlor
- Researchers believe that stands of mature switchgrass offer the best protection from sediment and nutrient loss and herbicide contamination of runoff that may threaten water quality

Another assessment used GIS to analyze soil properties and the potential for runoff and leaching. This approach identified approximately 117,000 acres out of the 354,000-acre watershed as land with a relatively high potential for water quality impairment due to runoff and leaching. After using available land cover information to refine this approach, initial results identified approximately 20,000 acres of land in row crops that, if targeted for conversion to biomass production, may reduce the potential for water quality impairment. (CVRCD/TR#12, 1/00-3/00)

Researchers have taken the following approach to assess the water quality implications of switchgrass production in the watershed (Neppel, et.al., 2001):

- Used SWAT, a biophysical, semi-distributed model designed to simulate water yield, sediment delivery and nutrient pesticide loading from large, ungauged watersheds; GIS is necessary to manage the volume of data required by a project of this size
- Prepared GIS coverages of soil, land use, and digital elevation model

- Used weather data from 4 local stations
- Interviewed local land use experts to generalize the management and cultural practices for each of the major land uses
- Compared the annual SWAT model water yield to the observed data from the Chariton River mainstream and its tributaries; model efficiency parameters were calculated
- Explored alternative land use targeting strategies to elucidate their impacts on hydrology and water quality relative to the baseline (current) conditions; one scenario was to grow switchgrass for biomass production on selected highly erosive soils within the watershed

By mid-1999, researchers completed a preliminary assessment of the potential water quality impacts of producing switchgrass for biomass; the report is titled *A Preliminary Assessment of the Potential Water Quality Impact of Producing Switchgrass Biomass in the Rathbun Lake Watershed*. This report established a basis for future research helped identify land that would reduce the potential for water quality impairment from agricultural non-point pollution. The Iowa Department of Natural Resources determined that the Lake's ability to fully support all of its designated uses is threatened. Using switchgrass as biomass is expected to reduce the potential for water quality impairment in the area.

Results of the preliminary assessment of the potential water quality impact of producing switchgrass are summarized below (CVRCD/TR#9, 4/99-6/99):

- Sixty-one 14-digit hydrologic units have been delineated in the watershed, based on USDA instruction. Units range in size from 2,589 acres to 16,430 acres, with an average per unit size of 5,804 acres. These units were assessed as follows:
  - 16 have been determined to have a <u>very high</u> potential for water quality impairment caused by sediment; they comprise around 31.5% of the watershed.
  - 15 have a <u>high</u> potential for water quality impairment caused by sediment; they comprise around 22.7% of the watershed.
  - 30 have a <u>low and moderate</u> potential for water quality impairment caused by sediment; they comprise around 45.8% of the watershed.
  - 6 have a <u>very high</u> potential for water quality impairment caused by agricultural chemicals; they comprise around 8.5% of the watershed.
  - 12 have a <u>high</u> potential for water quality impairment cause by agricultural chemicals; they comprise around 16.8% of the watershed.
  - 43 have a <u>low and moderate</u> potential for water quality impairment caused by agricultural chemicals; they comprise around 74.7% of the watershed.
  - 10 have <u>both a high and/or very high</u> potential for water quality impairment caused by sediment and agricultural chemicals; they comprise around 14.1% of the watershed.

Targeting switchgrass on land in hydrologic units with a high and/or very high potential for water quality impairment caused by sediment or agricultural chemicals may reduce the threat these contaminants impose to water resources in the watershed. The project has developed the capability to provide sub-watershed level guidance in terms of identifying land for switchgrass development.

For example, an analysis of the 4,108-acre South Walker Branch unit identified 668 acres of land (16% of the sub-watershed) with soils that are highly erosive, have high chemical surface runoff loss potential, and/or high chemical leaching loss potential. The analysis also identified 128 acres of land located within 100 meters of streams and 200 meters of Rathbun Lake, with soils that are highly erosive, have a high chemical surface runoff loss potential, and/or high chemical leaching loss potential.

Exhibit 9

Conclusions from the SWAT modeling

- Switchgrass for biomass production can be an environmentally friendly practice. However, excessive soil erosion may still occur on some highly erosive soils. The use of atrazine as part of the management practice schedule will continue to contribute to the environmental loading of this pesticide.
- Quantities of sediment-bound pollutants are aligned with sediment yield.
- A geographic information system used in this study enabled the user to manipulate large quantities of data, visualize data relationships, and develop output maps to convey information to others.
- SWAT is an appropriate tool for this study and other large watershed- or basin-scale analyses. Appropriate field-scale models used in conjunction with SWAT will improve the overall predictive capability of SWAT by providing more detailed, process-oriented input for simulation.

3.3.2 Current and Future Strategies for Monitoring and Assessing Impacts

- ISU researchers and other project partners will continue to develop and apply SWAT to evaluate the potential impacts on water quality of switchgrass production for biomass. SWAT model outputs related to the amounts of sediment, herbicides, and fertilizer in runoff from land managed for the production of switchgrass compared to row crops continue to be evaluated, and any necessary modifications to model parameters applied. (CVRCD/TR, 4/01-6/01; 7/01-9/01)

- ISU researchers continued to interpret the field data and laboratory analyses of runoff samples collected from the rainfall simulations completed at selected times during the 2000 growing season. Rainfall simulations were conducted on land managed for the production of switchgrass and row crops. The data interpretation and sample analyses will provide an indication of the relative amounts of sediment and farm chemicals in runoff from land used to produce biomass compared with land in row crop production. (CVRCD/TR, 4/01-6/01; 7/01-9/01)

- Created the Rathbun Land & Water Alliance (RLWA), a locally based non-profit organization formed to address the lake's water quality issues. Members include local landowners, elected officials, and representatives from public agencies and private organizations. (CVRCD/TR#4, Att.6, 7/97-12/97)

- The project received a grant from EPA to provide an assessment of the Rathbun Lake watershed; a draft will be submitted to EPA in early 2002.

3.4 Habitat/Wildlife Impacts

3.4.1 Progress & Results to Date

Researchers completed activities related to the second year of field surveys. The fieldwork included nest searches, breeding bird surveys, placement and monitoring of artificial nests, and vegetation measurements in biomass fields with different harvest treatments. Data entry and analysis is underway. Researchers collected red-winged blackbirds to conduct diet analysis, and made plans to potentially expand the diet analysis research to include the collection of ring-neck pheasant crops during the fall and winter. They also continued to use field survey results to develop a GIS model to help establish a switchgrass establishment that improves wildlife habitat. These efforts will be integrated with results from the water quality analysis.

Iowa State University completed a study of 21 switchgrass fields in Appanoose, Lucas, Monroe, and Wayne counties. The fields were divided into 7 non-harvest plots, 7 strip harvest plots, and 7 total harvest plots. Results are outlined below (CVRCD/TR#12, 1/00-3/00; Murray, L., 2002, 2001):

- 47 species of breeding birds were observed; the five most common were: common yellowthroat, barn swallow, grasshopper sparrow, red-winged blackbird, and song sparrow
- Researchers placed 264 artificial nests and found that for the common yellowthroat species, the non-harvest plots had a 50% success rate, strip harvest plots had a 37% success rate, and total harvest plots had a 40% success rate; for the red-winged blackbird

species, non-harvest plots had a 69% success rate, strip harvest had a 36% success rate, and total harvest had a 33% success rate.

- Conclusions were as follows:
  - Abundance (# of birds):
    - grasshopper sparrows prefer total harvest fields and short, sparse vegetation
    - sedge wren and northern harrier most abundant in non-harvest fields
    - pheasant abundance was greatest in non-harvest fields and estimates of upland sandpiper and bobolink abundances were greatest in strip-harvest fields
    - within strip-harvest fields, red-winged blackbird, song sparrow, common yellowthroat, and sedge wren were observed more frequently in uncut than cut strips in at least one year; the grasshopper sparrow was the only species that preferred cut strips to uncut strips
    - the mean number of birds per 100 ha was greater in 1999 than 2000 for barn swallows and grasshopper sparrows; bird abundance was greater in 2000 than 1999 for red-winged blackbirds, common yellowthroats, and dickcissels
    - common yellowthroats, red-winged blackbirds, and sedge wrens were more abundant in fields with denser vegetation and a greater percent coverage of grasses other than switchgrass, but barn swallows, grasshopper sparrows, meadowlarks, and song sparrows were more abundant in fields with sparser vegetation
  - Edge abundance: 9 species more abundant 0-25 m from edge than 25-50 m from edge (edge refers to the boundary of the harvested area)
  - Nest:
    - common yellowthroat and red-winged blackbird nest success is higher in non-harvest fields; grasshopper sparrow in cut areas; northern harrier in uncut areas
    - red-winged blackbirds and common yellowthroats accounted for 56% and 28% of the nests found, respectively
    - 44% of all nests were successful; in both 1999 and 2000, the proportion of nests that were successful was greatest in non-harvest fields
  - Predators (e.g., foxes, coyotes, hawks) may travel near the edge in harvested strips, and ring-necked pheasants were more abundant in non-harvest fields versus complete harvest fields in the winter; they accounted for 78% of failures of nests with known fates
  - Strip-harvest similar to non-harvest, perimeter habitat affects bird use
  - Harvesting switchgrass in alternating cut and uncut strips is more beneficial to the winter bird community than harvesting them completely
  - Switchgrass fields grown for biomass provide habitat for grassland birds, and nest success rates in the fields should support stable bird populations

Exhibit 10 – Grasshopper sparrow, red-winged blackbird, and common yellowthroat nest

In mid-1999, a preliminary assessment of the potential wildlife habitat impacts of producing switchgrass for biomass was completed; the report is titled *A Preliminary Assessment of the Potential Wildlife Habitat Impact of Producing Switchgrass Biomass in the Rathbun Lake Watershed*. (CVRCD/TR#9, 4/99-6/99) The positive impacts of switchgrass on soil and water quality have been researched and confirmed, but there has not been as much research on switchgrass' impact on wildlife. The preliminary assessment found that:

- 94,884 acres (26.8% of the watershed) have a high potential for wildlife habitat quality improvement
- 203,221 acres (57.4% of the watershed) have a moderate potential for wildlife habitat quality improvement
- 55,939 acres (15.8% of the watershed) have a low potential for wildlife habitat quality improvement
- 189,327 acres in the watershed have soil characteristics favorable for establishing, improving, and maintaining perennial grasses; approximately 51,000 acres of these soils are located on land in the watershed as having a high potential for wildlife habitat quality improvement

Additional Research

"In general, switchgrass fields support a more diverse and abundant bird community than rowcrop fields. Total-harvest switchgrass fields create suitable habitat for grasshopper sparrows, but the removal of residual vegetation reduces northern harrier and sedge wren abundance in total-harvest fields. Strip-harvest fields do not attract grasshopper sparrows into cut strips because of the species' area requirements. Strip-harvest of biomass fields in southern Iowa should be considered, however, because the residual vegetation remaining in uncut strips provides benefits to other bird species. Another option is a mixture of non-harvest and total-harvest fields; because the presence of both habitats would benefit grasshopper sparrows, sedge wrens, and northern harriers." (Murray and Best, 2001)

3.4.2 Current and Future Strategies for Monitoring and Assessing Impacts

- ISU researchers and biomass project staff continued to developed a GIS model. The database has been completed and incorporated into the GIS. Model runs have been completed for priority species including common yellowthroat, grasshopper sparrow, horned lark, ring-necked pheasant, red-winged blackbird, sedge wren, vesper sparrow, brown-headed cowbird, killdeer, dickcissel, meadowlarks, and field sparrow. Model results include the change in number of species, species gained and lost, species abundance numbers, change in number of species nesting, and nesting species gained and lost as a result of converting land from row crops to biomass production. Analysis and interpretation of the model runs are underway. (CVRCD/TR, 4/01-6/01; 7/01-9/01)

- Conducted field surveys including nest searches, breeding bird surveys, placement and monitoring of artificial nests, and vegetation measurements in biomass fields w/different harvest treatments. (CVRCD/TR#13, 4/00-9/00)

- Collected red-winged blackbirds to conduct diet analysis. (CVRCD/TR#13, 4/00-9/00)

3.5 Fuel Quality

3.5.1 Progress & Results to Date

Cell wall components, nitrogen content, and ash

"Field experiments begun in 1998 studied established 'Cave-in-Rock' switchgrass fields in Lucas and Wayne counties in southern Iowa. Results found that cell wall constituents differed among years, but the importance of these differences is not clear. Harvest in 1999 occurred at the end of September, a month or more before the other years, and that could have caused lower cell wall content values because soluble material had not been leached as severely. The most significant differences are that lignin (ADL) was lower and cellulose was higher in 2000 than in the other years. This may be related to the yield improvement seen in 2000. Otherwise, the differences among years followed no clear trend. As values, determined as a byproduct of the cell wall digestion process, were about 5%.

The two locations, Lucas and Wayne counties, were generally quite comparable for these traits, both averaged across years and in 2000. Nitrogen in the plants, as determined using the Kjeldahl method, and ADL were slightly higher in Wayne, but this difference does not appear to be biologically important. Among nitrogen fertilization levels, higher nitrogen rates generally led to higher concentrations of cell wall components (except hemicellulose). No discernable trend was evident among nitrogen levels for nitrogen concentration or ash content. The main conclusion from these data is that the cell wall content of switchgrass biomass does not appear to be altered greatly due to year, location, or fertility status, and those changes that are observed are not easily explained. Certainly, increases in yield do not appear to have major effects on cell wall constituents.

Proximate and ultimate analysis showed that differences occurred among years for all traits except sulfur, based on biomass samples collected at harvest time. Like the cell wall results, the differences among years do not show any clear trend. As was highest in 1999, nitrogen levels were highest in 2000, and BTU content was lowest in 2000; whether these results were related to environmental variation or to the higher yields obtained in 2000 is unknown. Regardless, the differences are all relatively small, and probably would have little (if any) impact on using switchgrass as a biofuel. Differences for these traits among nitrogen fertilization rates were similarly small.

Elemental analysis showed that the concentration of a number of elements differed between 1999 and 2000, but the differences are probably immaterial regarding biofuel quality. Neither location nor nitrogen fertilization rate had a substantial impact on composition. However, chlorine varied by location, with Wayne having roughly the levels of Lucas, but both of these levels are within acceptable ranges for power plants.

The values of particular elements vary between analyses because samples for the different analyses were prepared differently, being conducted on ashed samples, dry vegetation, or acid digested vegetation and because the different analysis types may result in loss or underestimation of particular elements. However, in general, the values are comparable.

Large differences for most traits were observed among sampling dates. Based on subsample yields (plot yields were taken at multiple times), maximum dry matter yield appears to have accumulated by September; thus, delaying harvest until frost serves only to lower the water content of the herbage. Earlier harvests, if the material was acceptably dry, would expedite work in autumn when weather is unpredictable. The leaf fraction of the harvested material declined through November. This probably helps explain why nitrogen in the plant tissue declined throughout the year, reaching its low point by November, with little additional loss over winter. Similarly, cellulose, lignin, ash, and digestibility fell as the plants matured. Perhaps most interestingly, Cl, N, P, and S ions were substantia lly lower in March than November, which may be important for feedstock quality.

In general, overwintering material in the field results in slightly better biofuel, from an energy standpoint per unit dry weight, but the decline in yield during that time appears to more than offset the improved energy quality." (Brummer, C., et.al., 2001)

Exhibit 11 shows the fuel composition of two switchgrass harvests in Lucas County, Iowa.

Exhibit 11 - Fuel Analysis for Lucas County, IA Switchgrass Samples

	Fall Harvest 10/96	Spring Harvest 4/97
	Proximate (w%) as received	
Moisture	7.88	6.51
Ash	4.53	2.93
Volatiles	72.97	78.38
Fixed Carbon	14.62	12.18
Higher Heating Value (Btu/lb.)	7,370	7,485
	Ultimate (w%) as received	
Moisture	7.88	6.51
Carbon	44.70	46.16
Hydrogen	5.57	5.25
Nitrogen	0.29	0.26
Sulfur	0.05	0.05
Ash	4.53	2.93
Oxygen	36.98	38.84
Chlorine	0.08	<0.01
	Elemental Ash Analysis (w% of fuel) as received	
SiO	3.09	4.82
Al_2O_3	0.022	0.058
HO_2	<0.0004	0.003
Fe_2O_3	0.028	0.051
CaO	0.295	0.768
MgO	0.126	0.118
Na_2O	0.009	0.006
K_2O	0.380	0.210
P_2O_5	0.240	0.156
503	0.082	0.075

Diseases

A sampling of 17 fields identified the fungi Tilletia maclaganii as the major cause of declining switchgrass yields and found ten new potentially pathogenic fungi not previously reported on switchgrass in Iowa: alternaria alternata, biopolaris sp., colletotrichum graminicola, fusarium (3 species), penicillium sp., phoma sp., pseudoseptoria sp., and trichoderma sp. Smut and rust diseases were also found. Smut was found in 15 of 17 fields. Recommendations are to recognize it as a serious threat to biomass and seed production, rotate fields with high incidence to another crop or forage grass, establish variety trial needs in an infested location. (Munkvold, G.P., et.al., 2000; CVRCD/TR#12, 1/00-3/00)

Miscellaneous

A biomass cropping system with switchgrass and legumes is being tested to determine its acceptability from a fuel quality standpoint. The goal of the *Improved Switchgrass Biomass Production in Iowa: Cropping System Alternatives* project was to provide landowners with the knowledge and skills needed to establish and manage biomass cropping systems. Alternative biomass cropping systems have been established with cooperating producers on over 500 acres. These systems consisted of corn as a companion crop with switchgrass, legumes with switchgrass, cool season grasses for hay and biomass, and switchgrass seed and biomass production. ISU researchers have evaluated biomass cropping systems in pilot-scale trials. Technical assistance and demonstration activities have also been completed to inform and educate interested individuals regarding the project.

3.5.2 Current and Future Strategies for Monitoring and Assessing Impacts

- To reduce the incidence of disease, it is recommended that field currently infested with T. maclaganii should be rotated to another crop or forage grass for at least three years, and a cultivar trial should be established at an infested location. Research on diseases is expected to continue through FY2002.

- ISU researchers are analyzing and interpreting biomass cropping system research results that will be included in a report scheduled for March 2002.

- Field data and samples for the following trials will be collected during 2002 and continue in the subsequent years:

  – Three sets of switchgrass variety
  – Reed canarygrass accessions
  – Switchgrass fertility plots
  – Reed canarygrass fertility plots
  – Two sets of side-by-side switchgrass and reed canarygrass plots
  – Switchgrass plots to evaluate the effects of lime application

3.6 Geographic Information Systems (GIS)

GIS has been used to support the full range of agronomic activity and environmental impacts research. It is a ubiquitous tool, so this section is a compilation of the map and database information collected for this project.

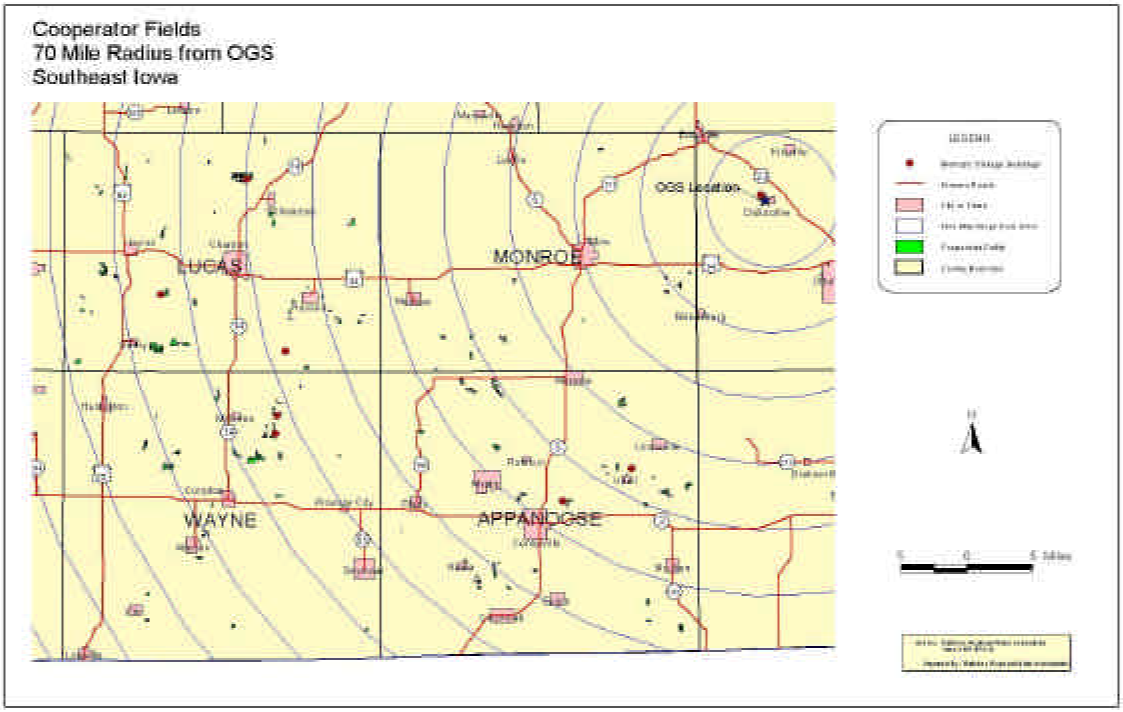
3.6.1 Progress & Results to Date

Maps and a database were created for landowners cooperating in the project (see Exhibit 12 for an example). The maps show the size and location of fields made available to the project by these landowners. This enables researchers to combine the use of fields with other available coverages and databases such as topography and soils.

Information on the GIS map can include:

- The four-county project area and the Rathbun Lake watershed, including county boundaries, cities and towns, major roads, and principal water resources
- Relative locations and distances for the project area and OGS, including field boundaries, 5-mile concentric circles around OGS that cover the entire project area, and field's physical relationship to roads, water bodies, and other fields
- Project research plots (fertility trials) in Lucas and Wayne (Millerton) counties
- Soil associations for project area and Rathbun Lake watershed; soil mapping units to help with soil-related interpretations
- Hydrologic units and water quality monitoring sites in Rathbun Lake watershed

Exhibit 12



The GIS database contains the following information for cooperating producers and biomass land fields:

- Landowner name, address, and phone number
- Field number, field location, and field size
- Expiration date of any CRP contract on the land
- Plot sizes and locations
- Conditions prior to planned treatments
- Treatments applied to the plots
- Measurements of treatment responses
- Whether the land is currently planted with switchgrass, and if so, the date of establishment
- Crop production data
- Switchgrass yield
- Soil loss estimations
- Fertilizer rates
- Project research plots
- Soil mapping units

The soil associations, water quality monitoring sites, and databases have been used to assist ISU with soil suitability and carbon sequestration research, and in preliminary assessments of water quality, wildlife habitat, and carbon sequestration impacts of producing switchgrass for biomass. ISU has also been given assistance with GIS and GPS technologies, with soil suitability research being conducted as part of the project.

3.6.2 Current and Future Strategies for Monitoring and Assessing Impacts

- Apply GIS and GPS technologies to assist with feedstock supply development and research in the areas of soil suitability, water quality, wildlife habitat, and carbon sequestration. (CVRCD/TR#9, 4/99-6/99)

- Maintain, improve, and expand current map coverages and databases as needed. (CVRCD/TR#9, 4/99-6/99)

4.0 ENVIRONMENTAL ISSUES AT OTTUMWA GENERATING STATION

4.1 GHG Emissions

4.1.1 Progress & Results to Date

In October 1999, the Center for Global and Regional Environmental Research completed a report entitled *A Comparison of Life Cycle Greenhouse Gas Emissions from Switchgrass and Coal for Electric Generation*. The researchers conducted a modified life cycle analysis that compared switchgrass cultivation and its use as a power plant fuel to the coal life cycle. The switchgrass portion included: primary, direct emissions (e.g., emissions from farming activities and fertilizer application, energy expended during power plant on-site fuel preparation and combustion); primary, indirect emissions (e.g., emissions from fuel combusted in agricultural machinery and in transporting the fuel); and secondary emissions (e.g., GHG emissions from fertilizer/herbicide). The coal portion included: primary direct emissions (coal mining, transport); primary indirect emissions (coal refining and preparation); and secondary emissions (transport from mine to rail loading, rail transport to power plant, and transport of combustion waste). The major conclusions are:

- Cofiring 5% switchgrass with coal (on a heat-input basis) may reduce GHG emissions on a CO_2-eq. basis by nearly 177,000 tons per year, if the land was previously used for row crop production. This estimate excludes nitrous oxide (N_2O) emissions from harvesting and transporting switchgrass; if N_2O was included in the analysis, the GHG benefits of cofiring will likely be reduced by 10%.
- Fallow land currently enrolled in the CRP sequesters a significant amount of CO_2 and stores it as organic carbon in the soil. Thus, if land use changes from CRP to switchgrass for energy, it is less favorable than if land was previously in row crop production. If CRP land was converted to switchgrass production, 122,000 tons of CO_2-eq. may be reduced a year.
- Over the life cycle, the largest savings in GHG emissions is due to avoiding the combustion of 5% of the coal at the power plant. For a mature crop of switchgrass, GHG emissions are reduced by 338 lbs. of CO_2-eq./MMBtu of thermal energy produced for land that was previously in corn, and 259 lbs. of CO_2-eq./MMBtu for land that was previously in the CRP program.

4.1.2 Current and Future Strategies for Monitoring and Assessing Impacts

An updated life cycle analysis is expected in 2002. Emissions results from NREL's analysis of the first cofiring campaign at OGS will be incorporated when available along with results from ISU soil carbon sequestration research.

4.2 Local Air Emissions

4.2.1 Progress & Results to Date

The first switchgrass cofiring campaign at OGS included a "baseline (coal-only)" period in October 2000. This was followed by a cofiring campaign that lasted from November 29, 2000 until the end of January 2001. During the first campaign test burn, more than 1,200 tons of switchgrass were combusted at rates of up to 12.5 tons/hour with intermittent periods as high as 16 tons/hour.

Exhibit 13 – Transporting switchgrass to power plant

Exhibit 14 – Ottumwa Generating Station

In April 2002, NREL will be releasing a report describing the boiler performance and air pollution monitoring results from the first campaign. This forthcoming report will likely offer several conclusions. Analysis of the boiler emissions during Campaign #1 was problematic; during the co-fire stack testing, a problem unrelated to the switchgrass testing caused high CO levels in the flue gas, but further flue gas sampling showed that CO emissions were not significantly affected by cofiring. The SO_2 emissions, based on continuous emissions monitoring (CEM) data, decreased during cofiring due to the lower sulfur content of the switchgrass. Nitrogen oxide levels were higher on average during cofiring, but upsets in the feed-handling system may have contributed to these higher levels. Although CEM measurements of opacity showed little difference between cofiring and coal-only operation, no firm conclusions could be reached during Campaign #1 regarding PM and PM_{10} emissions because of measurement problems.

The emissions results of the first campaign will be discussed in more detail in Deliverable #4—Environmental Permit Plan (expected in May 2002), however, the section below provides a general discussion of how switchgrass composition/quality affects atmospheric emissions during cofiring.

4.2.2 <u>Current and Future Strategies for Monitoring and Assessing Impacts</u>

The second cofire test campaign was initiated in the year 2001. Several milestones will be reached during this test campaign: completion of the final engineering design of permanent modifications that will allow the cofiring of biomass at a rate of up to 25 tons per hour; installation and optimization of equipment and modifications at OGS for a permanent 12.5 biomass cofiring system; and cofiring of up to 6,000 tons of biomass material. The objectives for the second cofire test campaign include:

1. Prepare the final engineering design for modifications at OGS that will allow the installation and operation of an automated 25 tons per hour biomass cofiring system.
2. Install equipment and modifications at OGS that will allow continual operation of an automated 12.5 tons per hour biomass cofiring system.
3. Develop and implement a plan to evaluate and optimize the continual operation of an automated 12.5 tons per hour biomass cofiring system in preparation for the third cofire test campaign. Commissioning of the 12.5 tons per hour cofiring system is scheduled to occur in 2003.

4. Prepare a comprehensive test plan for the third campaign that will assess the impacts of continuous biomass cofiring on OGS operations and performance.

Alliant and project partners plan to conduct a third test campaign before proceeding to commercialization. This additional test would be used to verify that the finalized design is capable of operation over a long duration, without significantly affecting boiler performance, and to demonstrate what environmental performance could be expected during commercialized switchgrass cofiring. This third and final test campaign is tentatively scheduled to begin by the end of 2003. Specifically, the objectives of the Third Campaign would be to continuously process and fire up to 25,000 tons of biomass (2,000 hours of cofiring), and:

1. Assess the full-scale and long-term impacts on OGS including boiler operation, precipitator performance, and ash characteristics based on the continual operation of the automated 12.5 tons per hour biomass cofiring system.
2. Evaluate the performance of the integrated delivery and handling systems required to support full-scale operation of the biomass cofiring system.
3. Install equipment and perform modifications at OGS that will allow continual operation of an automated 25 tons per hour biomass cofiring system (25 tph is the commercial-scale target).

Effect of Switchgrass Composition/Quality on Atmospheric Emissions During Cofiring

During Campaign #1, switchgrass samples were collected from the debaler, eliminator, and baghouse; switchgrass nodes were also collected from various locations. Hazen Research and NREL analyzed the switchgrass samples on an "as received" basis, a "dry" basis, and a "dirt-free" basis. For the purposes of this report, switchgrass samples are discussed on an "as received" basis. The average composition of switchgrass collected from the debaler is given in Exhibit 15, along with the average "milled" coal composition.

The combustion properties of switchgrass and coal follow from the fuel characteristics given above. According to this analysis, SO_2 emissions during cofiring will be lower than during coal-only operation. The heating value-adjusted sulfur contents of the two fuels (lb. SO_2/MMBtu) suggest that SO_2 emissions will be 66% lower for each kWh of biopower produced (at 5% cofiring on a heat input basis, this translates into about a 3.3% reduction in SO_2 emissions per kWh produced at the OGS). This conclusion is based upon a direct displacement evaluation of SO_2 emissions and ignores boiler efficiency effects. Boiler efficiency effects will likely be small for the low-levels of cofiring planned at OGS. The higher hydrogen content of switchgrass is a detriment from a boiler efficiency standpoint, but its relatively low moisture content is a benefit. The moisture content depends on the ability to keep switchgrass protected from rain during the fuel supply and processing steps. More information about boiler efficiency effects will be obtained in future cofiring campaigns at OGS.

The low fuel-bound nitrogen content of switchgrass relative to coal suggests that NO_X emissions will be reduced during cofiring. However, NO_X generation is complex—nitrogen from the combustion air (and the air used in the pneumatic switchgrass feed) contributes to thermal NO_X production. In general, factors such as fluid mechanics, reaction kinetics, heat release, and local stoichiometry also influence NO_X generation. The high volatile carbon content of switchgrass suggests that the combustion will be partially staged, thus reducing NO_X emissions. Such beneficial effects are usually offset by the high efficiency with which biomass nitrogen is converted to NO_X, due to the chemical form of nitrogen in biomass. It is noted that the possible tendency of herbaceous biomass ash to deactivate the catalyst in selective catalytic NO_X reduction systems is not an issue because OGS is not equipped with a catalytic system. The ultimate impact of switchgrass cofiring on OGS NO_X emissions can only be determined by further testing.

The fuels' mercury contents were analyzed but are not shown above. Their contents are quite low, so cofiring coal and switchgrass at OGS is not expected to substantially change mercury emissions.

Exhibit 15 - Average Compositions of Switchgrass in the Debaler and Milled Coal (as received basis)

Component/ Characteristic	Unit	Switchgrass	Milled Coal
Proximate Analysis			
Moisture	%	6.34	16.42
Ash	%	5.35	7.06
Volatile	%	73.84	34.28
Fixed Carbon	%	14.48	42.25
TOTAL	**%**	**100.00**	**100.00**
Ultimate Analysis			
Moisture	%	6.34	16.42
C	%	45.33	56.28
H	%	4.74	3.49
N	%	0.53	0.97
S	%	0.11	0.43
Ash	%	5.35	7.06
O	%	37.61	15.36
TOTAL	%	100.00	100.00
HHV	Btu/lb.	7,458	9,616
Volatile/Fixed Carbon Ratio	unit-less	5.10	0.81
Other Characteristics			
Cl	%	0.13	<0.01
Na_2O[1]	%	0.003	0.08
K_2O	%	0.758	0.00
Alkali	lb./MMBtu	1.01	0.18
Ash	lb./MMBtu	7.19	7.34
SO_2	lb./MMBtu	0.30	0.89

[1] Soda ash is added to the milled coal at OGS in order to improve the performance of the electrostatic precipitator. In some cases, the soda ash was added prior to laboratory analysis. Thus, the average sodium content of the milled coal has been altered.

Finally, it is noted that harvest timing influences the alkali content of switchgrass, which ultimately affects emissions and ash deposition on boiler heat exchange surfaces. The higher alkali and chlorine contents of switchgrass, relative to coal, suggest that deposition may be more of a problem during cofiring. Research at BYU suggests a simple rule of thumb to avoid corrosion problems—on a molar basis the fuel alkali plus chlorine concentration should be less than 20% of the fuel sulfur concentration. At 5% switchgrass cofiring (on a heat input basis), the characteristics in Exhibit 15 would suggest that the fuel alkali plus chlorine concentration is only 18% of the sulfur concentration. This means that corrosion/deposition may not be a critical issue for switchgrass cofiring at OGS. Data on the corrosion/deposition implications of cofiring will be gathered during future cofiring campaigns.

Control of Fugitive Dust Emissions from Switchgrass Processing

After switchgrass is delivered to OGS, it will be crushed in a pulverizer prior to being pneumatically conveyed to the boiler for cofiring. Switchgrass processing can create a significant dust problem if control strategies are not implemented. A dust collection system, manufactured by Camfil Farr (Jonesboro, Arkansas) was installed to control the fugitive dust during the first cofire test campaign. During the test, fugitive dust was collected by the baghouse(s) and routed back to the pneumatic transfer to be fed to the boiler system. The only switchgrass to escape OGS was stray strands that fell off the trucks in transit and unloading strays that were contained and controlled locally. If it is considered a problem in the future, truckloads of switchgrass can be tarped/covered during transit to minimize stray losses (this technique is used in straw-fired energy facilities in Denmark).

4.3 Ash

4.3.1 Progress & Results to Date

Exhibit 16 – Fly Ash Silo

The first cofiring test was conducted from November 2000 through January 2001; approximately 1,269 tons of biomass was cofired and fuel and ash samples were taken.

The largest potential solid waste issue that Alliant will face in this project is how switchgrass cofiring will affect the composition of the unit's fly ash. The sale and management of fly ash for concrete admixture markets is an important part of the OGS revenue stream. A typical ash disposal cost is about $20/ton. A typical concrete admixture market price for fly ash is about $25/ton. Presently, Alliant sells fly ash to concrete companies during the construction season and makes c-stone during the non-construction season, typically November-March. Cofiring the switchgrass prevented Alliant from selling the fly ash because of the ASTM C618 issue and quality concerns. The 725 MW-facility produces about 300-350 tons of fly ash per day, so disposing of cofired fly ash could net a change in the revenue cost stream from fly ash management of nearly $2 million annually. Project partners are planning research and testing to resolve this issue to allow cofired fly ash to be sold into current high-value markets.

Currently, the ASTM C618 standard precludes the sale of commingled coal/biomass fly ash as a cement aggregate (this is the highest-value market for fly ash); the text actually precludes the sale of cofired ash because it specifies "coal fly ash" in the standard's scope. Until this standard is changed or a comparable market for this ash is identified, or the state DOT approves/certifies the cofired fly ash as a cement admixture, this issue will remain important to the project's economics.

4.3.2 Current and Future Strategies for Managing Ash

Bottom ash, economizer ash, and fly ash samples were collected and analyzed during Campaign #1. Exhibit 17 shows the fly ash composition, averaged across various hopper locations and collection times, for coal-only operation and cofiring. The cofiring rate varied throughout Campaign #1, so these data should be interpreted with caution.

The chemical requirements for fly ash to meet the ASTM C618 standard are given in Exhibit 18. Comparing the fly ash compositions to the ASTM chemical requirements leads to the conclusion that the fly ash produced can be characterized as a Class C fly ash. Exhibit 18 shows that fly ash compositions from coal-only operation are not substantially different from coal-switchgrass operation; this is due in part to the relatively low cofiring rate. The ASTM standard also has physical requirements for fineness, strength, LOI, moisture, soundness, and uniformity. Preliminary information suggests that the cofired ash will also meet these requirements.

Exhibit 17 - Average Composition of Coal-Only and Cofired Fly Ash

Component/ Characteristic	**Units**	**Average Coal-Only Fly Ash**	**Average Cofired Fly Ash**
LOI (as received)	%	0.55	0.29
Na-Na_2O (as received)	%	0.14	0.22
K-K_2O (as received)	%	0.01	0.01
SiO_2	%	34.85	33.12
Al_2O_3	%	22.75	22.73
TiO_2	%	1.47	1.42
Fe_2O_3	%	5.37	5.49
CaO	%	23.53	23.02
MgO	%	4.35	4.30
Na_2O	%	2.45	2.66
K_2O	%	0.48	0.56
P_2O_5	%	1.94	2.14
SO_3	%	1.28	1.53
Cl	%	<0.01	<0.01
CO_2	%	0.04	0.08
TOTAL	**%**	**98.50**	**97.04**
As	mg/kg	25.43	28.70
Ba	mg/kg	6254.00	6367.50
Cr	mg/kg	93.20	85.50
Cd	mg/kg	1.91	1.99
Pb	mg/kg	62.60	64.03
Hg	mg/kg	<0.1	<0.1
Ag	mg/kg	<1	<1
Se	mg/kg	9.50	9.36

Exhibit 18 - Chemical and Physical Requirements For Fly Ash Under ASTM C618

Characteristic	**Mineral Admixture Class**	
	F	**C**
$SiO_2 + Al_2O_3 + Fe_2O_3$	70.0	50.0
SO_3, max %	5.0	5.0
Moisture Content, max %	3.0	3.0
LOI, max %	6.0	6.0

Ongoing discussions with ASTM could result in a revised ASTM C618 standard by as early as 2003. Project partners are also working with state agencies to accept the use of cofired ash in the state of Iowa.

4.4 Stormwater

4.4.1 Progress & Results to Date

The addition of switchgrass cofiring does not add any wastewater issues that OGS does not already experience with its coal-only operation. This project, however, does introduce two minor stormwater regulatory issues that are being addressed with the Iowa Department of Natural Resources (IDNR).

The first issue is that a stormwater construction permit may be needed during the construction phase of Campaigns #2 and #3. Timing and the final design footprint will ultimately determine this need because the regulatory construction acreage threshold is changing from 5 acres to 1 acre in Iowa beginning March 2003. Once the facilities are operational and the construction activities have finally stabilized, the construction permits will be terminated and the facility's industrial stormwater pollution prevention plan will be updated. The second issue is that Alliant is planning to construct an additional berm around the on-site switchgrass storage/processing area at OGS. This may require Alliant to either amend its existing National Pollution Discharge Elimination System (NPDES) permit or its stormwater NPDES permit with the IDNR. Neither of these permit items are considered to be impediments to project progress.

4.5 Additional Environmental Issues

Solid Waste

In addition to the ash management issue, the only other solid waste issue created by switchgrass cofiring at OGS is the need to dispose of the twine that bounds the switchgrass bales. This twine will be collected and either disposed or recycled.

Noise Issues

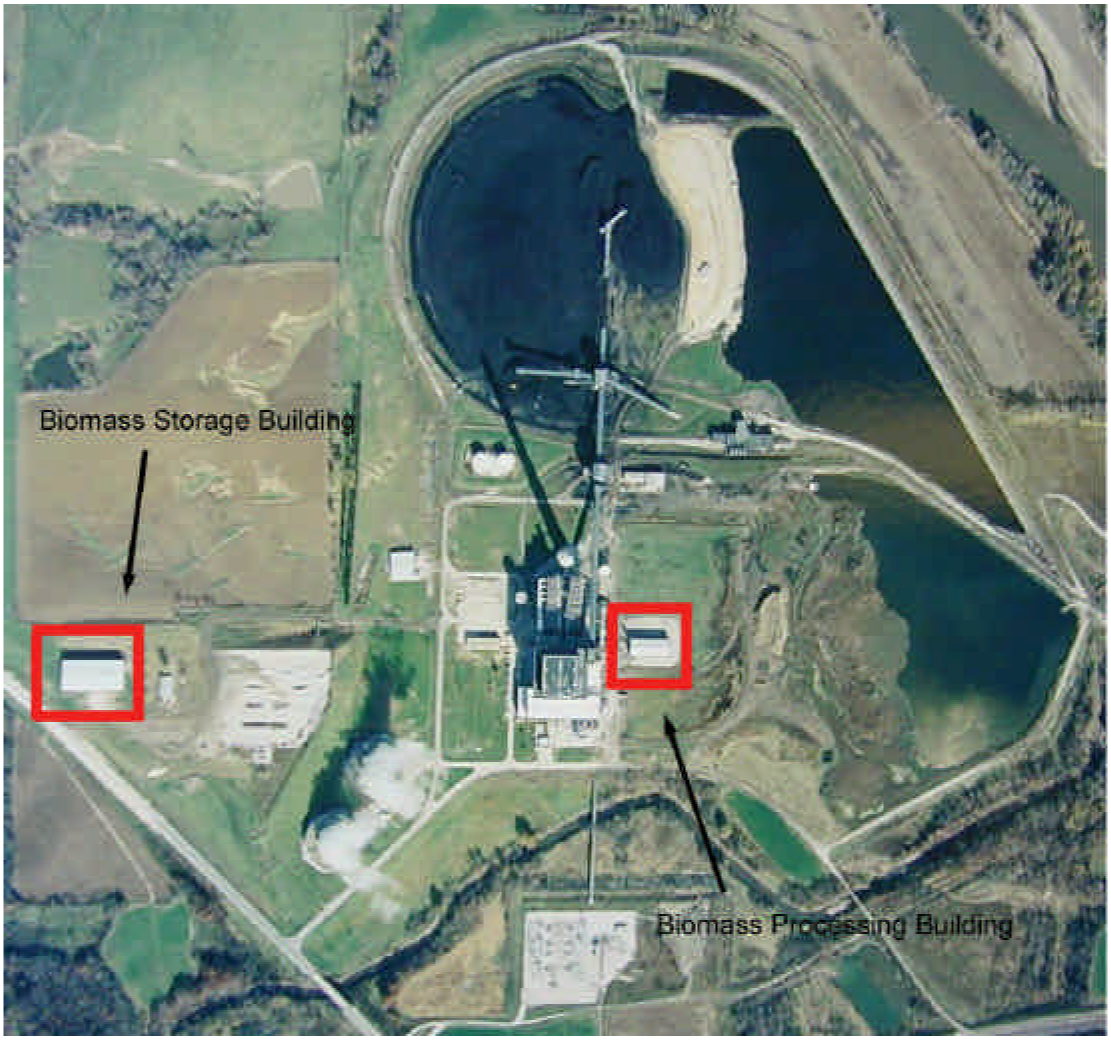
The switchgrass project at OGS does not create any additional, significant noise problems.

Visual Impacts

The switchgrass project at OGS does not create any additional, significant visual impact.

Exhibit 19

Exhibit 20



5.0 SUMMARY TABLES

The following two tables summarize the major issues associated with studying the environmental impacts of switchgrass production. The first table shows where each environmental impact occurs, at either the farm-level or OGS site. The second table provides highlights of the progress to date and the outstanding research issues. Exhibit 21 provides a project timeline.

WHERE DOES THE IMPACT OCCUR?

Environmental Impact	At Farm	At OGS
Air Emissions		X
Soil Quality	X	
Carbon Sequestration	X	
Water Quality	X	
Habitat/Wildlife	X	
Fuel Quality	X	
Solid Waste		X
Ash		X
Stormwater		X

PROGRESS AND OUTSTANDING RESEARCH ISSUES

Environmental Impact	Progress	Outstanding Research Issues
Air Emissions	Life cycle research found that cofiring switchgrass at 5% rate could reduce GHG emissions on a CO_2-eq. basis by nearly 177,000 tons/yr. Research found that cofiring could also reduce SO_2 and NO_X emissions.	An updated life cycle analysis is expected in 2002. Another cofiring test is scheduled for 2003, and researchers will gather additional emissions data. NREL's cofiring emissions results will be incorporated when available.
Soil Quality	Research shows that switchgrass production can significantly reduce erosion and 56 to 112 kg N/ha are optimal nitrogen fertilization rates	Research will continue until end of 2004; plans are to test reed canarygrass side-by-side with switchgrass, and investigate gullies, aggregate stability, and epipedon construction/destruction
Carbon Sequestration	Research found that converting row crop to switchgrass production will yield higher GHG emissions benefits than if CRP land is converted and that 80% of the land has high or moderate potential to sequester carbon. Research completed in the year 2000 concluded that soil carbon content varies significantly and systematically in accordance with landscape position, pedon properties, and land use. Soil organic carbon content of pasture	Research will continue until the end of 2003; plans are to review emissions data and incorporate it into final life cycle report and analyze landscape assessments and soil cores for carbon fluctuation.

	pedons ranges from 7.4 to 24.6 kg m^{-2} m^{-1}. Researchers do not think switchgrass results in the maximum soil organic carbon contents in the Chariton Valley.	
Water Quality	Research found that converting row crop production to switchgrass could reduce the potential for water quality impairment on more than 226,000 acres. Research using the SWAT model found that sediment delivery, phosphorous, nitrogen, and atrazine were reduced with switchgrass production. Based on analysis using a rainfall simulator, researchers believe that stands of mature switchgrass offer the best protection from sediment and nutrient loss and herbicide contamination.	Research will end in early 2002; plans are to continue to apply SWAT and interpret field data and laboratory analyses from rainfall simulations
Wildlife	Fieldwork was completed in 2000 and found that 84% of the watershed has a high or moderate potential for wildlife quality improvement if switchgrass is produced. Researchers found that switchgrass fields grown for biomass provide habitat for grassland birds, and nest success rates in the fields should support stable bird populations.	Research should be completed in early 2002.
Fuel Quality	Research found that cell wall content of switchgrass was not altered greatly due to year, location, or fertility status; elemental analysis showed that differences were immaterial regarding biofuel quality. Research also found that the Tilletia maclaganii fungi is the major cause of switchgrass declining yields, and ten new potentially pathogenic fungi were discovered.	Recommendation is to rotate currently infected fields to another crop or forage grass for minimum of three years, and establish cultivar trial at an infested location. Additional disease research, as well as continued fertility and variety trials research will be continued until 2004.
Ash	After analyzing samples of fly ash, researchers found that the cofired ash met the Class C chemical requirements of the ASTM C618 standard. It is still unclear whether the cofired ash can meet the standard's requirements for fineness, strength, soundness, and uniformity.	Currently the ASTM C618 standard precludes the sale of commingled coal/switchgrass fly ash as a cement admixture; until this standard is changed, a comparable market is found, or the state DOT approves/certifies the cofired ash as a cement admixture, this issue will remain important to the project's economics. Research and testing to gain approval for high-value ash markets is planned.

Exhibit 21


Deliverable 5
SOW Task
SOW Task Description
2001-1
2001-2
2001-3
2001-4
2002-1
2002-2
2002-3
2002-4
2003-1
2003-2
2003-3
2003-4
2004-1
2004-2
2004-3
2004-4
2005-1
2005-2
2005-3
2005-4
Partners
1.0.0 Complete NEPA process
2.9.5 Secure services of EPC contractor(s)
CVRC&D
Techwise
Brayfield Conrad Crow Engineering Services
Alliant
5.2.0 Assess the genetic variability for biofuel traits
5.3.0 Determine the effect of timing of harvest on burning qualities
ISU
5.3.1 Fuel quality analysis
5.6.0 Economic analysis of energy crop production
5.5.1 Farmer adoption of biomass production
ISU
Prairie Lands
5.6.0 Obtain commitments on 4,000 acres
5.6.1 Field coordination and stand maintenance
CVRC&D
Prairie Lands
5.7.0 Biomass cropping systems
5.8.0 Switchgrass disease management
ISU
Prairie Lands
5.9.0 Assessment of biomass potential of cool-season grasslands
ISU
Prairie Lands
5.10.0 Site-specific management for biomass production
ISU
Prairie Lands
6.1.2 Greenhouse gas product development
7.1.0 Environmental management
CVRC&D
8.1.0 GIS analysis
CVRC&D
Iowa DSC
Iowa DNR
8.2.0 Soil quality
8.3.0 Water quality
8.4.0 Wildlife impacts
8.5.0 Carbon sequestration
ISU
Prairie Lands
Iowa DSC
Farm Bureau
8.6.0 Benefit-cost analysis of switchgrass versus coal for electric generation
Univ. Of Iowa
Iowa DNR

6.0 APPLICABLE FEDERAL AND STATE LEGISLATION & INCENTIVES

6.1 Feedstock Production

Although farms are not heavily regulated entities, they are subject to federal pesticide and water regulations. The state of Iowa does not impose any additional environmental compliance regulations on its farms. The federal requirements are outlined below, followed by a discussion of the federal Conservation Reserve Program's role in this project.

6.1.1 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

FIFRA is a federal law regulating pesticides. It requires all pesticides sold or distributed in the U.S. to be registered by the EPA. Unregistered pesticides may be used under certain circumstances. Registration requires EPA to examine the ingredients of the pesticide; the particular site or crop on which it is to be used; the amount, frequency and timing of its use; and the storage and disposal practices. A pesticide also has to be used only according to the directions on the label.

6.1.2 Water Regulations

The federal Clean Water Act authorizes EPA to regulate nonpoint sources of water pollution, such as runoff from agricultural and forestry operations. States are authorized to develop a management program for nonpoint source discharges.

The federal Clean Water Action Plan required states to create Unified Watershed Assessments to identify: watersheds needing restoration, watersheds needing preventive action, or pristine or sensitive watersheds in federal lands needing an extra measure of protection. The Chariton Valley biomass project assisted the state in developing its Action Plan for the Chariton Valley watershed.

EPA's Watershed Protection Approach is a strategy with the premise that many water quality and ecosystem problems are best solved at the watershed level rather than at the individual water body or discharger level. It includes stakeholder involvement, multiple agency input, and monitoring and data gathering. The project received a grant from EPA to provide an assessment of the Rathbun Lake watershed; a draft will be submitted to EPA in early 2002.

6.1.3 Conservation Reserve Program

The Conservation Reserve Program is a voluntary federal program that offers annual rental payments, incentive payments for certain activities, and cost-share assistance to establish approved cover on eligible cropland. The program encourages farmers to plant long-term resource-conserving covers to improve soil, water, and wildlife resources. Assistance is available in an amount equal to a maximum of 50% of the participant's costs in establishing approved practices. (USDA/Farm Service Agency, October 1999)

In the year 2000, the federal government authorized the CRP to conduct pilot projects where biomass would be harvested on CRP land and used for energy production. The terms of the project specify harvesting frequency and size, and stipulate that the biomass cannot be used for any commercial purposes other than energy production. The Chariton Valley biomass project is one of these pilot efforts. Under this pilot effort, the farmers still have an incentive to keep the land in the CRP program, but they also have the opportunity to use it to produce a revenue-generating crop. In exchange, they will receive 10% less than the annual rental payment during the year the acreage is harvested. (USDA/Farm Service Agency, November 2000)

6.2 Electricity Generation

6.2.1 Limitations on All Emissions Points at OGS

The following limitations and supporting regulations apply to all emission points at OGS:

Pollutant	Requirement	Authority/Citation
Opacity (visible emissions)	40% opacity	567 IAC 23.3(2)"d"
Sulfur Dioxide	500 ppm	567 IAC 23.3(3)"e"
Particulate Matter	0.1 grain per dry SCF of exhaust gas, except as provided in 567 IAC 21.2(455B), 23.1(455B), 23.4(455B) and 567 IAC – Chapter 24 (for sources constructed, modified or reconstructed after July 21, 1999)	567 IAC 23.3(2)"a"
Fugitive Dust[3]	Reasonable precautions should be taken to prevent particulate matter in quantities sufficient to create a nuisance, as defined in IAC section 657.1, from becoming airborne. For example, an applicable reasonable precaution includes the installation and use of containment or control equipment, to enclose or otherwise limit the emissions resulting from the handling and transfer of dusty materials, such as but not limited to grain, fertilizers, or limestone.	567 IAC 23.3(2)"c"

6.2.2 Limitations on Individual Emissions Points

The following limitations and supporting regulations currently apply to individual emissions points. Presumably, a similar set of requirements would continue to apply if OGS proceeded to commercial switchgrass cofiring.

Electrostatic Precipitator (the dry-bottom pulverized coal, tangentially fired boiler vents through the ESP):

Opacity (visible emissions):	20%
Authority for requirement:	567 IAC 23.1(2)"a" 40 CFR 60 Subpart D
Continuous Emissions Monitoring (CEM):	in accordance with 40 CFR Part 75
Authority for CEM:	567 IAC 25.1(1) and 567 IAC 25.2

[3] This limitation applies to switchgrass processing emissions and cofired ash handling.

Particulate Matter:	0.1 lb./MMBtu
Authority for requirement:	Iowa DNR Construction Permit 78-A-019S 567 IAC 23.3(2)"b" 40 CFR 60 Subpart D
Sulfur Dioxide:	1.2 lb./MMBtu (Coal) 0.8 lb./MMBtu (Oil) (When different fossil fuels are burned simultaneously then emission limit based on formula from 40 CFR 60.43(b))
Authority for requirement:	Iowa DNR Construction Permit 78-A-019S 567 IAC 23.1(2) 40 CFR 60 Subpart D
Continuous Emissions Monitoring (CEM):	in accordance with 40 CFR Part 75
Authority for CEM:	567 IAC 25.2
Sulfur Dioxide:	Sulfur Dioxide allowances effective Jan. 1, 2000
Authority for requirement:	567 IAC 22.108(7) Phase II Acid Rain Permit (Title IV of 1990 CAA)
Nitrogen Oxides:	Specified in Phase II Acid Rain Permit
Authority for requirement:	567 IAC 22.125(4) Phase II Acid Rain Permit (Title IV of 1990 CAA) 40 CFR 76.5(a)(1)
Continuous Emissions Monitoring (CEM):	in accordance with 40 CFR Part 75
Authority for CEM:	567 IAC 25.2

6.2.3 Ash Management

Prior to any possible change in the ASTM C618 standard, the coal/switchgrass cofired ash will continue to be managed by Alliant and its ash affiliates. In cases where disposal is required, the ash will be managed according to RCRA regulations.

6.2.4 Stormwater

The National Pollution Discharge Elimination System (NPDES) rule affects the following activities at OGS switchgrass cofiring project (OGS has a NPDES permit): construction activities, stormwater pollution prevention plan, and the construction/operational use of the berm around the switchgrass storage/processing area.

6.2.5 Federal Tax Credit for "Closed-loop" Biomass

The Section 45 production tax credit for wind, closed-loop biomass and poultry litter expired December 31, 2001 without being extended by Congress. Various proposals have been introduced to extend and expand this credit. Even if the expiration date is extended, the present definition of eligible projects precludes use of this credit for the Chariton Valley Biomass Project unless the definition of qualifying facilities is expanded to allow energy crops cofired at existing power plants that were built prior to 1992. The value of this 1.8 ¢/kWh credit would translate to a discount on the delivered cost of switchgrass to about $24/ton.

6.2.6 State Regulatory Incentives

Several states have instituted a Renewable Portfolio Standard (RPS), a Systems Benefit Charge (SBC), or a Green Pricing program. All of these efforts are designed to promote the use of renewable energy in a deregulated electricity market. An RPS requires that a certain percentage of a state's electricity generation come from renewable energy sources; Iowa refers to it as an Alternative Energy Law, which is also a renewables set aside. Under this law, the state's investor-owned utilities are required to purchase a total of 105 MW of generation from renewable (photovoltaics, wind, biomass, and waste) and small hydro sources. The state's utilities board allocated the 105 MW across its three investor-owned utilities: Mid-American, IES Utilities, and Interstate Power. According to the Iowa Utilities Board, an alternate energy production facility is defined as one that derives at least 75% of its energy input from renewables; cofiring at a 5% or 10% rate would require a waiver from the Board to be recognized as alternate energy. (DSIRE, November 2001; personal communication, 1/24/02)

In addition, Iowa instituted a mandatory utility green power option that requires all utilities in the state to offer green power options to their customers beginning January 1, 2004. The utilities are also required to offer programs that allow customers to make contributions to support the development of alternative/renewable energy sources in the state. Photovoltaics, wind, biomass, hydro, and waste are eligible technologies. The Iowa Utilities Board has not yet adopted rules for implementing the green power option. Alliant Energy has already begun offering a green power option to its residential customers. Through its "Second Nature" program, customers pay a monthly premium (based on their electricity use) to get 25%, 50%, or 100% of their power from renewable sources. The premiums range from $2.25 for the 25% level at a low monthly electricity use to $17.00 for the 100% level for high monthly electricity use. (DSIRE, November 2001; personal communication 1/24/02; Alliant Energy website, 2/25/02)

6.2.7 GHG and Global Warming

After development of the Kyoto Protocol, the international community began delving into more specific issues related to global warming. One such issue was the role of trees/forests and carbon sequestration. The debate is over whether a company should be given credit for planting trees which absorb CO_2 from the atmosphere, and how much credit should be allocated for the offset. As of the date of this publication, no definitive conclusions have been reached, but it is important to monitor this issue, in case the switchgrass plantations can benefit economically from their ability to sequester carbon.

6.2.8 Chicago Climate Exchange

Chicago and Mexico City are joining the Chicago Climate Exchange (CCX), a voluntary market for trading greenhouse gas (GHG) emissions. The CCX is developing a market-based mechanism for limiting emissions through a voluntary cap. Companies will be able to get credit for such voluntary reductions and they can buy and sell credits in an effort to find the most cost-effective way of achieving reductions. The goal is to reduce participants' GHG emissions by 5% below 1999 levels, similar to the limits adopted under the Kyoto Protocol. Since switchgrass cofiring has been found to reduce CO_2 emissions over a coal-only operation, OGS facility may be allowed to participate in the exchange. (ENS, 11/13/01)

7.0 CONCLUSION

This report provided an overview of the research completed to date on the environmental effects of switchgrass production in Chariton Valley, Iowa for use as biomass to generate electricity. In most cases, the research will continue into the future. The project's goal is to cofire switchgrass with coal at the Ottumwa Generating Station (OGS) in a way that improves the quality of soil, water, and wildlife habitat and reduces the environmental impact of the power plant. Environmental impacts were studied at both the farm and OGS. Specifically, planting switchgrass on the land could:

- reduce erosion
- require less fertilization than anticipated
- reduce sediment delivery and water quality impairment in the Rathbun Lake watershed
- provide habitats for various grassland bird species
- provide relatively high carbon sequestration rates if land in row crops is converted to switchgrass

Environmental benefits were also realized at OGS. Cofiring switchgrass with coal could reduce GHG, SO_2, and NO_X emissions compared to a coal-only operation. However, fugitive dust and ash management issues become more challenging with switchgrass cofiring.

There were also various legislative acts and incentives that could benefit this project: tax credits, state utility incentives for green power, the CRP pilot program, the role of biomass and carbon sequestration in reducing global warming, and the voluntary carbon credit exchange markets. Overall, the conclusion at this point in the research was that converting row crop or idle land to switchgrass production and then cofiring this biomass with coal at OGS could be beneficial to the environment.

REFERENCES

Brummer, E.C., C.L. Burras, M.D. Duffy, and K.J. Moore, 2001, *Switchgrass Production in Iowa: Economic Analysis, Soil Suitability, and Varietal Performance*, August.

Burras, C.L., J.M. McLaughlin, M.L. Braster, J.E. Sellers, Jr., S.A. Wills, B.E. Larabee, "Soil Color: An Inexpensive Yet Effective Method for Documenting Soil Carbon Content."

Burras, Lee and Julie McLaughlin, 2000, "Dynamics of Soil Carbon Sequestration in the Chariton Valley, Iowa," October 1.

Burras, Lee and Julie McLaughlin, 2002, "Soil Organic Carbon in Fields of Switchgrass and Row Crops as Well as Woodlots and Pastures Across the Chariton Valley, Iowa," January 25.

Center for Global and Regional Environmental Research, 1999, *A Comparison of Life Cycle Greenhouse Gas Emissions from Switchgrass and Coal for Electric Generation*, October.

Chariton Valley Resource Conservation & Development: Biomass Power for Rural Development, Quarterly Technical Reports, September 1996 - December 2001.

Database of State Incentives for Renewable Energy (DSIRE), 2001, North Carolina State University (www.ies.ncsu.edu/dsire/library), November.

Environment News Service (ENS), 2001, "Carbon Trading Market Expands to Chicago, Mexico City," (www.ens.lycos.com), November 13.

Iowa Department of Natural Resources, *Improved Switchgrass Biomass Production in Iowa: Cropping System Alternatives*.

Iowa State University, 1999, *Soil Carbon Sequestration Potential in the Chariton River Watershed, Iowa*.

Kost, John, Rick Cruse, John Laflen and John Gilley, 2002, "An Assessment of Potential Agricultural Nonpoint Sources of Water Quality Impairment in the Rathbun Lake Watershed, Chapter 2: Switchgrass for Biomass Effects on Water Quality Within the Lake Rathbun Watershed," February.

Ma, Z., C.W. Wood, and D.I. Bransby, 1999, "Carbon Dynamics Subsequent to Establishment of Switchgrass," *Biomass and Bioenergy* 18 (2000) 93-104, September 15.

Ma, Z., C.W. Wood, and D.I. Bransby, 2001, "Impact of Row Spacing, Nitrogen Rate, and Time on Carbon Partitioning of Switchgrass," *Biomass and Bioenergy* 20 (2000) 413-419, January 15.

Ma, Z., C.W. Wood, and D.I. Bransby, 1999, "Soil Management Impacts on Soil Carbon Sequestration by Switchgrass," *Biomass and Bioenergy* 18 (2000) 469-477, November.

Morrison, T.A., D.I. Bransby, S.E. Sladden, and V.R. Tolbert, 2001, "Soil Improvement Related to Switchgrass as Indicated by Subsequent Crop Yield," (5th International Biomass Conference of the Americas CD).

Murray, Les D., 2002, *Avian Response to Harvesting Switchgrass for Biomass in Southern Iowa*, Iowa State University.

Murray, L.D. and L.B. Best, 2001, "Bird Habitat Benefits of Using Switchgrass for Biomass Fuel in the U.S. Midwest," (5th International Biomass Conference of the Americas CD).

Neppel, J.G., R.M. Cruse, U.S. Tim, T. Jacobsen, M. Braster, 2001, "The Rathbun Lake Project: An Evaluation of the Water Quality Implications of Switchgrass Production for Biomass Using SWAT Modeling and ArcView GIS," (5th International Biomass Conference of the Americas CD).

Neppel, Jerry, Sunday Tim, Rick Cruse, Marty Braster, and Tyler Jacobson, 2001, *Modeling Switchgrass Production Effects on Runoff Water Quality*.

Personal communication with Iowa Utilities Board, January 24, 2002.