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MINNESOTA AGRIPOWER PROJECT

Quarterly Report for the
Period April - June 1997

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The Minnesota Valley Alfalfa Producers (MnVAP) propose to build an alfalfa processing plant integrated with an advanced power plant system at the Granite Falls, Minnesota Industrial Park to provide 75 MW of base load electric power and a competitively priced source of value added alfalfa based products.

This project will utilize air blown fluidized bed gasification technology to process alfalfa stems and another biomass to produce a hot, clean, low heating value gas that will be used in a gas turbine. Exhaust heat from the gas turbine will be used to generate steam to power a steam turbine and provide steam for the processing of the alfalfa leaf into a wide range of products including alfalfa leaf meal, a protein source for livestock. The plant will demonstrate high efficiency and environmentally compatible electric power production, as well as increased economic yield from farm operations in the region.

The initial phase of MAP will be to perform alfalfa feedstock testing, prepare preliminary designs, and develop detailed plans with estimated costs for project implementation. The second phase of MAP will include detailed engineering, construction, and startup. Full commercial operation will start in 2001.

MINNESOTA AGRI-POWER PROJECT
Instrument No.: DE-FC36-96GO10147

PROGRAM STATUS AND ACCOMPLISHMENTS

SECOND QUARTER-1997 REPORT

FOR PERIOD
01 APRIL 1997 THROUGH 30 JUNE 1997

TASK 1 DESIGN PACKAGE

Subtask 1.1 Feedstock Testing

1.1.2 Gasification Test Plan and Testing

The alfalfa stem gasification testing in Finland was completed during April. The testing in the pilot plant was much less than planned. This abbreviated test program was the result of several factors:

- The VTT testing showed that at gasification temperatures above 1382°F the ash would sinter resulting in ash plugging and deposition problems. The IGT testing reported in the 1995 "Alfagas Feasibility Study" indicated that the gasification temperature would be above 1470°F and may be as high as 1600°F. The test plan prepared by Carbona was designed to find the optimum operating temperature would be as close as they could get to 1382°F.

- The gasifier ash and filter ash removal systems malfunctioned throughout the testing. The ball valves used to isolate the lockhoppers jammed. The inability to remove ash restricted the operating during the flexibility to vary capacity and fluidization velocity and the ability to achieve full operating pressure. The problem was compounded by the higher than expected ash content of the alfalfa and the fact that the low mandated gasifier temperature reduced the expected carbon conversion. The ash content of the alfalfa stem was found to be 9.2% on a dry basis versus 5.3% reported in the feasibility study. The University of Minnesota analyzed a sampled of the filter ash from the pilot test and reported the carbon content of the ash was about 40% by weight.

Because of the inability to remove ash during the pilot testing, concerns were raised as to whether the data obtained are representative and adequate to proceed with design. The summary results provided to date indicate that the gasifier operation was stable during the 8 to 12 hour periods being used to establish gasifier performance. Operating pressure does not have a significant influence on the gasifier material balance or gas composition and therefore the data collected at a lower than required operating pressure should still be acceptable.

Another concern which is unrelated to the conduct of the gasification test program, but which has a major impact on the validity of the test conclusions is the unanticipated results regarding alfalfa properties, i.e. low ash sintering temperatures, high ash content, high nitrogen content (2.8% vs. 2.1% reported in the feasibility study) and high sulfur content (0.22% vs. 0.08% reported in the feasibility study). These values should be confirmed.

The consensus of the project team is that the testing was a success in that alfalfa stem was determined to be a suitable feed for the gasifier. Although the alfalfa stem must be gasified at an unexpectedly low temperature, the alfalfa is very reactive. Consequently, even at the low gasification temperature, acceptable carbon conversion is achieved and tar formation is low. The low temperature, the alfalfa is very reactive. Consequently, even a the low gasification temperature, acceptable carbon conversion is achieved and tar formation is low. The low operating temperature results in a high alfagas heating value, greater than 150 BTU/SCF. The gas quality satisfied the gas turbine fuel specification. However, the shortness of the testing added a measure of uncertainty to the results.

Carbona has explained that although the ball valves used in the ash removal systems had previously operated satisfactory, Macawber dome valves would be used today. Dome valves are used in the Varnamo Demonstration plant, the IGT plant in China and in the Sierra Pacific Pinion Pines KRW gasifier.

Detail of Gasification Test Plan and Testing is as follows:

Fuel Analysis and Fuel Testing

Pelletized alfalfa was tested in the 2" diameter atmospheric fluidized bed gasifier of VTT. Test run was executed analyzed with special attention on sintering and tar formation.

VTT's report on fuel pre-testing including fuel analysis, PTG-testing, sintering/strength testing (by Abo-Akademi) and bench scale gasifier testing. VTT report was revised and some details discussed with VTT.

Testing of Alfalfa

Pilot Plant testing started on April 14 at 6:00 am with heating up the plant. First alfalfa gasification test run took place during the week of April 14. Second alfalfa gasification test run was executed during the week of April 21. Testing executed according to the Test Plan and Measuring Program. Pilot Plant cool down and clean up completed on April 30 at 4:00 pm.

Test Data Analysis

Routine organization of test data, data collection from data acquisition system. Test data analysis and the evaluation of test data started, preparation of set point balances, etc.

VTT's Final Report on Measurements was received on June 11.

Evaluation of final measuring data was started.

Attachment 1 is a copy of the Pilot Gasification Tests for NAP-Project, "Quick Report" on GASPI Test Run MAA25(97)/Alfalfa Fuel. The report contains the following:

- Overview of test and project background
- Test run specification
- Pilot plant description
- Preliminary process data
- Comments and conclusions

1.1.5 Alfalfa Leaf Meal Product Tests

Feeding Trials and Analysis - Detailed Summary of Research Progress to Date

Alfalfa leaf meal (ALM) is a critical co-product to the economics of the alfalfa biomass energy system. Research is being conducted to characterize the nutritional value of ALM in dairy, beef and turkey diets and provide an estimate of the economic value of alfalfa leaf meal to livestock producers.

Dairy Research

The value of ALM as a feed supplement in lactating dairy cow diets is being determined in laboratory and animal performance trials.

Determine substitution rate for ALM in lactating cow diets.

As reported earlier, this trial was completed on January 8, 1997. Results indicate that including ALM pellets in diets of early lactation cows at a rate of 8 or 16% of the dry matter (DM) in replacement of good quality hay did not adversely affect milk production. Cows averaged 85.6, 87.3, and 87.1 lb./day of milk on the 0, 8 and 16% ALM diets, respectively. Milk composition (protein and fat) was not affected by ALM feeding. However, on the 16% ALM diet dry matter intake tended to be depressed. Additional data are currently being processed to determine ALM effects on rumen function (rumination time, pH, and volatile fatty acid concentration).

Analyses of digestibility, chewing activity, and rumen parameters showed that feeding ALM pellets did not affect dry matter digestibility, fiber digestibility, or time spent eating, and had no adverse effects on rumen fermentation. However, the time cows spent chewing was decreased when ALM pellets were included at 16% of the diet DM. This suggests that ALM may not have the same stimulatory effect on rumination as has alfalfa hay. Overall, results of this study indicate that ALM pellets of the quality used in this study may replace up to 50% of good quality alfalfa hay in early lactation diets without detrimental effects on production and rumen health.

Laboratory evaluation of methods to enhance protein value of ALM.

This task began in May. Heat treatment of ALM to increase the bypass value of its protein will be the first method evaluated. The evaluation of heat treatment of ALM to increase the bypass value of its protein content is under way, and is to be completed by the end of July 1997. An in situ protein degradability study has been conducted on the raw ALM to determine its rate and potential extent of digestion. These results are being summarized.

Formulation and evaluation of combination products containing ALM.

This study has not yet begun.

Dairy cow lactation trial to determine animal performance.

This feeding trial, which began March 3rd, differs from Task Ia in that ALM is being evaluated as a protein supplement instead of a hay replacement. Also, the form of the ALM was different. In this second feeding trial, meal rather than pellets were used to avoid acceptability problems observed in the first study with pellets. In the second lactation trial, ALM replaced soybean meal in the diets. The ALM supplied 0, 11, 21, or 34% of the total dietary CP by replacing soybean meal protein. Distillers dried grains contributed 15% of dietary CP in all diets. The second feeding trial was completed on May 26, 1997. Data collection for this study has been completed and the data is being processed.

Beef Research

The value of ALM as a feed supplement for beef cattle is being evaluated in both steer and beef cow diets.

Evaluation of different levels of ALM in transition diets for steers coming into a feedlot environment.

The receiving studies in St. Paul and Crookston have been completed. Substituting ALM for 0, 33, 66, or 100% of the soybean meal protein reduced average daily gain at Crookston (1.78, 1.38, 1.56, and 1.42 lb./day, respectively), but had no effect in St. Paul (2.86, 3.25, 3.56, and 3.47 lb./day, respectively). Inclusion of ALM reduced efficiency of gain at Crookston due to higher feed intakes. However, higher feed intake is desirable for newly received steers to enhance survivability. Efficiency data from the St. Paul study are still being processed.

Evaluation of different levels of ALM in diets of finishing steers.

The feeding study was completed in June and the steers were slaughtered. After 128 days on feed, steers fed ALM to substitute for 0, 33, 66, or 100% of soybean meal protein gained 3.71, 3.78, 3.74, and 3.86 lb./day, respectively. Efficiencies of gain were similar among diets.

Preliminary results based on dry matter intake, average daily gain, feed to gain ratio, and carcass data indicate that ALM may effectively replace soybean meal in diets of finishing steers.

Evaluation of different levels of ALM in beef cow diets.

The last cows calved the weekend of May 21-22. Cows fed diets containing ALM gained more weight during the winter (1.45 vs. 0.94 lb./day) than those fed soybean meal. Preliminary results based on dry matter intake, average daily gain, and feed to gain ratio indicate that ALM may effectively replace soybean meal in diets of dry beef cows.

Turkey Research

The value of ALM as a feed supplement in turkey diets is being evaluated in laboratory and animal performance trials. The suitability of ALM as a protein source in growing turkey diets and the ability of ALM to provide unidentified hatchability factors for breeding hens is being assessed.

Determination of metabolizable energy and amino acid availability.

Samples have been analyzed. Final calculations of metabolizable energy must still be made. Preliminary calculations indicate greater variability among birds than anticipated. Because of the importance of an accurate metabolizable energy estimate it was suggested that the funds earmarked for amino acid analysis be re-directed toward repeating the metabolizable energy study.

Variability of true metabolizable energy values of the alfalfa leaf meal were found to exceed the acceptable level of 10%. At the June meeting, permission was granted to redo the TME assay using funds set aside for the amino acid analyses. Facilities will be available in mid-August to rerun the trial.

Effect of inclusion of different levels of ALM in market turkey diets.

Body weights: At 2, 4, and 8 weeks of age, weights of tom turkeys were increased by inclusion of 2.5% ALM over that of the control ($P < .05$). At 12 and 16 wks, 2.5% ALM treatment continued to be the heaviest. In comparison to the control no growth depressing effects were noted when ALM was included to 7.5% of the diet.

Body weight gain: During brooding (0-4wks) rate of gain was increased by inclusion of 2.5% ALM over that of the control. After 8 weeks, rate of gain tended to be greater than that of the control. After 12 weeks of age, the lower level of metabolizable energy in the ALM diets was probably starting to limit the gain response.

Feed intake: Feed intake was increased by ALM feeding. During 0-4 wks inclusion of 2.5% ALM increased feed intake over that of the control. After 4 weeks of age, feed intake was greater with ALM inclusion. Feed intake was similar at the inclusion levels of 2.5 and 5% levels. Increasing the ALM to 7.5% ALM level resulted in even more feed intake. This resulted in greater feed intake for the entire 16 weeks which was significant for the 7.5% ALM treatment group in comparison with that of the control.

Feed efficiency (feed/gain): Feed efficiency (g:g) was significantly affected by ALM inclusion during 4-8 and 8-12 wks of age when feed efficiency was somewhat poorer in the 7.5% ALM group. As a result this group also tended to have poorer feed efficiency for the 0-16 wk trial period.

Mortality rate: Inclusion of ALM had no effect on mortality rate or cull rate. Total livability for the flock was 95% which is an excellent level of performance.

The data indicate that ALM could be included to 7.5% of the diet for market tom turkeys depending on economic and performance considerations. The best performance was obtained by the 2.5% inclusion level as early feed intake and growth rates were increased over that of the control.

Effect of inclusion of different levels of ALM in breeder hen diets.

The last eggs were collected the week of May 25th. The data collection portion of the trial was completed four weeks later when the last batch of eggs hatched. Data analysis is proceeding.

Subtask 1.2 Integrated Plant Design and Cost Estimate

1.2 Integrated Plant Design and Cost Estimate

a) Plant Design Basis

A gasification plant material balance was prepared from the pilot plant test results. Utility requirements for the gasification plant were developed. Since the Westinghouse subcontract has not been executed, they have not confirmed the gas turbine performance and prepared combined cycle plant performance calculations. Stone & Webster asked Carbona to utilize the performance model Tampella developed for the MAP LOI Feasibility Study to prepare preliminary plant performance calculations for plant operation at ambient air temperatures of 30°F, 59°F, and 86°F. Using the Tampella cycle design, the plant full load net output ranges from 70 MW at 86°F to 83 MW at 30°F.

Plant design alternatives were reviewed at a June 4, 1997 project meeting. The following decisions were made:

- The gasification combined cycle power plant should be designed assuming it will not be adjacent to an alfalfa processing facility; i.e. the entire stem feed will be received by truck.
- There will be no supplementary firing of the HRSG.
- There will be no bypass stack for simple cycle operation.
- Gas turbine inlet air cooling will be evaluated in the future.
- Black start capability will not be included at this time.
- The gas turbine will be equipped with a dry, low NOx combustor; there will be no provision for steam or water injection.
- The natural gas pressure at the site boundary will be 380-400 psig.
- NSP will be responsible for the main transformer(s).

Battery limits for the gasification plant were also established at the June 4th meeting.

B) Power Plant and Balance of Plant Design

Two alternative preliminary IGCC plant layouts were prepared and superimposed on the Granite Falls Industrial Park site map. The layouts were presented at the Granite Falls Task force meeting on June 5, 1997.

Flow diagrams and piping and instrumentation diagrams have been drafted for all the major combined cycle power plant system and for most of the balance of plant systems.

A meeting was held on June 5 with the Granite Falls City Engineer and the Water Treatment Supervisor to discuss the possibility of using the Minnesota River intake structure at the water treatment plant to provide service water for the MAP plant. The City no longer uses the intake structure, since all the city water is obtained from wells. The intake structure is connected to a pumphouse which feeds the water treatment plant. The collection pipe from the wells is presently connected to the pumphouse, but there appears to be sufficient pressure from the wells to directly feed the water treatment plant, i.e. no need for the pumphouse. Therefore, the intake structure and the pumphouse could be made available for the MAP Plant subject to approval by the City government. River water quality data is being obtained to determine if any treatment is required to utilize it for plant service water.

TASK 2 REVIEW AND CONFIRM FEEDSTOCK SUPPLY PLAN

The following is a summary of Review and confirm feedstock supply plan

Alfalfa Supply System

Task 2 research is designed to improve the efficiency and productivity of the alfalfa supply system.

Rapid Analysis of Hay Attributes Using NIRS

The goal of this research area is to establish a commercial quality control system for alfalfa feedstock and alfalfa product evaluation.

Establish Quality Control Systems and Procedures.

Data analysis continues as planned. Quality evaluations will be recalculated for the leaf stem samples based on newly developed prediction equations.

Determined research protocols for the Spiked Hay and Leaf-Stem Separation experiments. In the spiked hay experiment, a liquid fertilizer will be poured on bales to increase CP and then the samples from the bales will be analyzed to determine if the NIR can detect the spiking. In the leaf-stem separation experiment, cores of hay will be separated into leaf:stem fractions to create a field leaf-stem equation which will augment the research equation.

A sampling scheme was used, in cooperation with MnVAP personnel and a consultant, to measure protein and moisture changes during processing of alfalfa and grass hay bales from the grinding through the drying, mixing and pelletizing. Findings determined: 1) mixing of hay types (legume and grass) was not as uniform as hoped; 2) shrink was measured at two to three percent; 3) drying drum removes three to six percent moisture; 4) pellets were produced at standardized nine percent moisture level; and 5) the moisture meter used in the MnVAP plant processing needs replacing (microwave procedure was suggested). The next steps for in-line processing evaluation is to design a rotating in-process tissue sampling device.

Activities to establish and improve quality control systems and procedures continue.

Evaluate Alfalfa by Variety and Management System.

Alfalfa stored under various conditions was sampled, the samples ground, and ran through the NIR for analysis of crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), total dry matter (DM) and density. Sent report to Gary Fauske comparing NIR and conventional chemistry for bale stacking study samples. Analysis summaries were also sent for statistical analysis as part of the on-going sample analysis. Stem samples were split and provided for mineral analysis.

Tables showing quality and yield of selected samples are being compiled. Data analysis is moving along as expected. Quality evaluations will be recalculated for the leaf stem samples based on new predictions.

In June, additional samples were taken from the alfalfa storage study (BS-97) at West Central Experiment Station (WCES), Morris, MN. Each stack was torn down and each individual bale was weighed. The stacks were cored for quality with up to 5 composited samples per stack. The samples were split; 1/4 for whole plant NIR analysis and 3/4 for leaf-stem separation.

The whole plant samples were ground and analyzed on the NIR. The predicted values were sent to Greg Cuomo, WCES for presentation at the WCES MAP Research Day. Leaf-stem samples were separated by airflow and screen at MnVAP processing plant and then a chemical analysis was run at the University's St. Paul Campus NIR lab.

Alfalfa whole plant samples were collected at St. Paul, dried in a microwave and separated into leaf and stem fractions. Leaf samples from the alfalfa separated in St. Paul and at the MnVAP processing plant was sent to Servi-Tech labs for carotene analysis (Vitamin A). The results from Servi-Tech confirms that carotene breaks down quickly in harvested alfalfa. Only the fresh samples from St. Paul had a significant amount of carotene. Older samples had very little if any carotene.

Alfalfa Varieties for Biomass Production

The goal of this research is to develop new biomass-type alfalfa varieties.

Development of New Biomass-Type Alfalfa Varieties.

Experimental alfalfa sources with large stems, strain crosses between large-stemmed experimental and modern adapted germplasms, selections for high lignin and high cellulose, and new Flemish sources are currently being evaluated and selected for large, thick, solid, non-lodging stems, time of flowering, percentage of leaves at harvest, and incidence of foliar disease. Plants were established with equal spacing (6 in) between and within rows. Plants have been maintained under a two cut management system for two years before evaluation to assure selection for winter hardy plants.

Experimental populations differed in lodging resistance. Sources that were at least 75% Flemish did not lodge at late flower to green pod stages of maturity. Populations and strain crosses that were 50% Flemish were not lodged at late bud to early flower but were lodged by full flower.

Experimental alfalfa biomass germplasms that have undergone two cycles of selection for stem traits and winter hardiness and have been screened for root and crown disease resistance. Most of these sources appear to be highly susceptible to Phytophthora root rot. Cycles of selection for disease resistance will be necessary to produce adapted biomass alfalfa.

Establish Alfalfa Variety Trials for Biomass Energy Production.

We have competed laboratory analysis of forage quality of varieties from trials harvested in 1996. For 5 of the 15 entries in the trial, we separated leaf from stem fractions and on these fractions conducted forage quality analysis. Results for these entries at Morris, Lamberton, and Rosemount show the effect of cutting or harvest treatments as well as entries (varieties). Attachment 2 is a detailed report entitled "Alfalfa Varieties for Biomass Production".

The results generally show that forage yield is not consistently different for the late flower and early flower cutting treatments at Lamberton and Morris in western Minnesota. At Rosemount in eastern Minnesota, yields were greatest for the early flower cutting treatment and least for the early bud treatment. At all locations, forage leaf percentage and crude protein (CP) concentration were higher and acid detergent fiber concentration lower for harvests at early maturity (early flower) than at later maturity (late flower). Alfalfa entries did not consistently differ in whole plant forage yield but did differ in leaf percentage as well as forage quality. We are completing forage quality analysis of the remaining entries in the trial.

We are initiating another year of forage yield and quality sampling on the alfalfa variety plots sampled in 1996. We have also initiated variety trials at two new locations to provide additional data.

The SEAE study, designed to study the effect of plant spacing on yield and quality of selected alfalfa germplasms, at Rosemount was replanted in June due to severe winter damage. The first harvests of the biomass early bud (Rosemount) and early flower treatments (Rosemount, Morris, and Lamberton) was taken. Plots were sprayed for leafhopper as needed.

Determine Leaf and Stem Yield of Experimental Alfalfas.

Trials were established at two locations in summer 1996 to evaluate the influence of maturity and stand density on leaf disease and leaf and stem yield and quality of experimental alfalfa (from the USDA-ARS biomass breeding program at MN) and commercial sources. Alfalfa is being sampled at bud and flower stages in 1997.

CP, NDF and ADF of the leaf/stem samples was predicted with a leaf equation to determine if a better prediction was available. The new predictions were used, and adjusted for bias using NIR results. Tables showing yield of selected samples are being compiled.

Leaf/stem samples from alfalfa harvested in the early bud and early flower treatments were dried, separated and weighed. Dry matter samples were dried and weighed.

Efficiency of Harvest and Storage Systems

Research in this area will compare the efficiencies of different harvest and storage systems.

Compare the Profitability of Various Harvest Systems.

The economical and biological efficiency of alternative hay mowing, packaging, and handling systems is being determined in field tests in July of 1997. Forage quality and leaf and stem yield will be determined as well as cost effectiveness.

A baling equipment demonstration will be conducted at the July 1, 1997 MAP Research Day at the West Central Experiment Station.

Compare the Profitability of Various Storage Systems.

An alfalfa hay storage study was conducted at WCES to evaluate the effects of bale type and storage method on alfalfa hay dry matter and quality losses. Few differences were found in dry matter losses between 5 x 6 foot round bales and mid-sized (3 x 4 x 8 foot) rectangular bales. However, storage method had a large effect on dry matter storage losses. Alfalfa hay stored in a barn lost 2.3% of its dry matter between September and mid-June. Alfalfa hay stored on gravel and covered with tarps lost 4.8 % of its dry matter. Hay stored on gravel without cover and hay stored on the ground lost 10.9 and 11.2% of its dry matter, respectively.

The economics of hay storage were striking. MnVAP offered $45.00/ton for hay stored on the ground and hay stored on gravel but not covered and $75.00/ton for hay stored in the barn and on gravel, covered with tarps. For 200 tons of hay, this translates into $9,000 for hay stored uncovered and $15,000 for hay stored covered or in a barn.

<u>On-Farm Demonstrations</u>

MnVAP cooperator farms are being developed to provide on-farm demonstration sites and hands-on educational program opportunities.

<u>Water Consumption and N Response following Alfalfa</u>

Identify sites, establish and monitor treatments for crop response

Tosel farm, Appleton, MN	Nitrogen response	To be scheduled
Farmfest, Redwood County, MN	Water consumption	Aug 5-7, 1997

<u>Alfalfa Varieties</u>

Identify sites and establish treatments and Characterize varietal differences in stems and leaves

Scanlan Farm, Danube, MN	Alfalfa varieties	August 6, 1997
Scanlan Farm, Danube, MN	Alfalfa leafhopper	To be scheduled

Biomass Packaging and Storage Systems

Identify sites and establish treatments and characterize packaging and storage system effects on biomass quality and quantity

W Central Experiment Station, Morris, MN	Balers & preservatives	July 1, 1997
W Central Experiment Station, Morris, MN	Packaging & storage	To be scheduled

TASK 3 PERFORMANCE GUARANTEES AND WARRANTIES

MnVAP has requested that Kvaerner, Stone & Webster, and Westinghouse each provide written comment on the results of gasification testing. These comments are expected to be indicative of the level of confidence achieved by the testing protocol for the gasification technology.

TASK 4 SALES CONTRACTS

Northern States Power Company (NSP) remains committed to execution of the power purchase agreement.

MAP project information provided to NSP by MnVAP on June 20, 1997 and was submitted under separate cover.

TASK 5 SITE PLAN CONSTRUCTION AND ENVIRONMENTAL PERMITS REPORT

Activities

Stone & Webster continued to prepare detailed Task Descriptions for additional Phase 1 Tasks in anticipation of sending final request forms. Staffing plans and schedules were also initiated. A detailed cost estimate for each task was prepared to be provided with the task descriptions.

We continued developing the plan for developing the water supply system for the Chippewa County site. B.A. Liesch Associates have been contacted and a determination has been made that they can assist with field work on the site for performing geotechnical investigations. An estimate for performing certain tasks on the site was prepared by Liesch Associates, and is being reviewed.

As part of our effort to develop a water supply plan, we made a trip to Granite Falls and met with various officials to explore sources of information that would assist with the development of the water supply plan and other aspects of the Project.

Part of our area visit was with the Granite Falls Water Department, where we reviewed the status of the existing intake structure, and looked at data from the Water Departments monitoring program. One of our data needs is water quality information for the Minnesota River. Another source of information we discovered on the visit was a Granite Fall hydroelectric facility FERC Application which may contain water quality information.

Another aspect of the area visit was to reconalternate power plant sites in Yellow Medicine County. Several sites were explored during a review by County Officials. This preliminary review could be made part of the alternatives analysis.

Agency Contacts

We are maintaining contact with the Environmental Quality Board staff. Recent discussions have been about implementing a joint process with DOE for reviewing the project. Preliminary discussions were also held about the content of the alternative power plant siting analysis. No significant issues have been raised to date. A conversation was held with DOE on April 4, 1997 which confirmed the plan for DOE and EQB to hold a joint proceeding.

We received responses during this quarter to our contacts with the Mn Natural Heritage Program and Chippewa and Yellow Medicine Conservation Districts to obtain the latest mapped wetland and threatened and endangered species habitat areas that may be available. This information will become part of the resource information base for our alternate analysis and Project impact assessment.

Minnesota PCA also has water quality data for the Minnesota River and we are pursuing this source of information.

We contacted the Chippewa County Watershed District to obtain soils and wetland resource information.

Issues and Comments

The conversation with DOE on April 4, 1997 clarified their position as well as Dames & Moore's position with regards to Project review. Our interpretation is that DOE is playing a more traditional role as a reviewer under NEPA requirement, and all assessments and analyses are the responsibility of the Project.

In May we responded to DOE's comments on our preliminary task descriptions and finalizing those descriptions for submittal.

The important issue, at this point in time, is to receive approval of the additional funding request so that required data gathering and permit application development can continue on schedule.

<u>TASK 6 ENVIRONMENTAL MONITORING PLAN</u>

One of the major potential attributes of biomass energy production systems is the ability to create large-scale environmental improvements. This research will document the alfalfa biomass production system's potential impact on the Minnesota River watershed, the environmental liability and/or economic value of the ash generated from the gasification process, and will quantify wildlife diversity and abundance in controlled harvest demonstrations.

<u>Ash</u>

Research will determine the environmental liability and/or the economic value of the ash generated from the gasification process.

A detailed "Ash Characterization Progress Report" is attached.

Water Quality

Research measures the impact of alfalfa production on ground and surface water quality.

Runoff hydrographs of the record snow-melt event during the spring of 1997 at WCES, Morris, MN show that fields with alfalfa tended to yield more runoff than corn-soybean fields. This is attributed to higher amounts of snow trapped by alfalfa stubble. By water balance, alfalfa fields also infiltrated more water.

Chemographs relating the load of a suite of pollutants with runoff amounts indicated that alfalfa fields tend to yield more ammonium while the corn fields yielded more sediments, nitrates, DMRP, bio-available P, and total P. There was no appreciable trend in the distribution of BOD and COD. Statistically, the corn fields produced significantly higher amounts of sediments and total phosphorus of which the latter, at this stage of preliminary observation, could not be attributed to crop rotation effects. The runoff amounts and other water quality constituents between the corn-soybean and alfalfa fields were not significantly different for the Spring 1997 runoff event.

Simulated rainfall-runoff experiments were also conducted on existing crop rotation - input management study plots at Lamberton. In general, soybean fields under four-year (corn-soybean-oat-alfalfa) rotation with organic management had higher infiltration capacity than alfalfa fields following oat and with low purchased input management. Regardless of management, alfalfa fields yielded lower sediments in runoff water than the soybean fields.

A detailed report "Impact of Alfalfa on Water Quality" is attached.

Wildlife

Research will quantify wildlife diversity and abundance in controlled harvest demonstrations.

Finalize study and sampling design

Wildlife demonstration plots on cooperating farms will be monitored to quantify wildlife diversity and abundance.

Use aerial photos and ground reconnaissance to develop a geographic information database

Aerial photos and ground reconnaissance will be utilized in development of a geographic information database which will be used to determine biodiversity on each site before and after the research. The Wildlife Task will be seeking a no cost extension to September 1998.

Economic Analysis

University agricultural economists are supporting all economic evaluation aspects of MAP project development.

Optimize Feedstock Transportation System

Work in this area is focused on optimizing the feedstock transportation system.

Select, Obtain and Create Operational Software Programming to Track Feedstock Inventory.

Software was reviewed and capabilities identified, summarized results of software review to date, and presented results to MnVAP personnel in March and May 1997. Software used by grain marketing and ethanol production cooperatives was studied to help determine specification for MnVAP software.

Preparing a final report detailing recommendations on feedstock inventory software

Record Location of Current Feedstock Production.

Several mapping and routing software packages were tested to find solutions to MnVAP's transportation allowance and plant siting concerns. Software adequate to calculate route miles from field locations has been tested.

Continuing to record the location of feedstock production and working on transportation analysis for current MnVAP members.

Analyze Various Transportation and Storage Models.

Awaiting the final storage data. The returns to storage for MnVAP producers under different storage conditions will be calculated upon completion of data analysis for the storage study.

Optimize Feedstock Transportation System.

This Task continues as production sites are stored on GIS software. The software and stored site information may be used to determine processing site locations and to minimize transportation for different streams of alfalfa products.

Waiting for additional data needed from tasks prior to completion.

Analyze Market Potential for New Alfalfa Products

University agricultural economists will use research results from Task I to predict market potential of new alfalfa products.

Evaluate Domestic Market Opportunities.

Personnel attended a meeting sponsored by the Agricultural Utilization Research Institute regarding potential alfalfa research and business opportunities.

University of Wisconsin staff presented their project involving extraction of phytase from alfalfa at a May meeting attended by Task IV personnel. Phytase extracted from alfalfa could greatly enhance the phosphorus extraction from feeds fed to monogastric animals, reducing the pollution potential of their manure. We shall continue to work with animal scientists as they further define market segments that can benefit from alfalfa leaf meal.

Preliminary findings from the Task I animal feeding trials revealed comparable animal performance in animals feed ALM versus soybean meal. When the final data is available additional market opportunities will be identified.

Evaluate International Market Opportunities

Awaiting additional data from the animal feeding trials.

Total Systems Analysis

Agricultural economists will complete an analysis of the total alfalfa production, storage and processing system.

Sensitivity Analysis on Total System Performance.

A preliminary analysis measuring the competitiveness of alfalfa rotations to other rotations across various price scenarios has been completed.

Production Task Analysis on Total System Performance

Will complete the analysis when the other economic analysis tasks are finished.

Community Education

Educational support for the MAP project is provided under this task.

Demonstrate Alfalfa Biomass Crop Production Systems

This sub-task provides education and information to the local community on alfalfa biomass crop production systems through on-farm and experiment station demonstrations

Organize and Conduct Educational Programs at Four (4) On-Farm Research Demonstrations.

July 1, 1997	Balers and preservatives	West Central Experiment Station, Morris, MN
Aug 5-7, 1997	Water consumption	Farmfest, Redwood County, MN
August 6, 1997	Varieties, Animal Trials	Scanlan farm, Danube, MN
To be scheduled	Irrigation, Economics	Tosel farm, Appleton, MN
To be scheduled	Varieties and Storage	

Communicate with Rural Stakeholders

To inform the community and growers about MAP and to get input regarding various aspects of MAP.

Sponsor Ten (10) Community Meetings.

The following meetings have been held or scheduled.

February 5&6, 1997	Alfalfa-A Burning Issue & More	22nd Annual MN Forage Conf.

March 4, 1997	Alfalfa Clinics	Tracy, MN
March 7-9, 1997	New Ulm Farm Show	New Ulm, MN
April 23, 1997	Minnesota Agri-Power&Minnesota River Project Research Update	W Central Experiment Station Morris, MN.
May 9, 1997	Meeting with Community Leaders	Granite Falls, MN
May 9, 1997	Meeting with Kiwanis	Granite Falls, MN
May 15, 1997	Alfalfa Winter Injury Field Day	W Central Experiment Station
July 1, 1997	MAP Research Field Day	W Central Experiment Station
July 31-Aug 1, 1997	Minnesota River Basin Conference	St. Peter, MN
August 5-7, 1997	Farmfest	Redwood Falls, MN
August 13-14, 1997	Forage Expo	Little Falls, MN
August 26, 1997	MnVAP Processing Open House	Priam, MN

Respond to Community Issues and Concerns.

The "Alfalfa Winter Injury Trials Field Day", was held May 15, 1997 at the West Central Experiment Station, Morris, MN, for seed companies, Extension Educators, MnVAP and other alfalfa producers, and the community.

Provided article on MnVAP to Granite Falls Chamber of Commerce for use in their newsletter.

Continuing planning and attending numerous local meetings.

Educate Rural Stakeholders Through the Publication of Written Materials

University researchers will design and publish written materials to be used to educate rural stakeholders.

Publish a Series of Fact Sheets on Biomass Energy Production.

Two fact sheets, "Establishment of Alfalfa" and "Winter Injury" are completed. Final drafts of two additional fact sheets, "Production-Soils and Fertility" and "Production-Pests", are completed.

These fact sheets and other MAP information will be made available on the World Wide Web.

Distribute Quarterly News Releases to Local Media.

The first news release based on the flood report for the MnVAP area and environmental consequences related to extensive flooding and discussing the opportunity to utilize alfalfa to change the agricultural landscape to benefit the region was released in April.

News releases were also distributed to publicize the July 1, 1997 MAP Research Day and the Forage Expo.

TASK 7 FINAL REPORT

A quarterly technical report was submitted for the January-March, 1997 quarter. Monthly progress reports were submitted for April, May, and June,, 1997.

TASK 8 PROJECT MANAGEMENT, ENGINEERING AND ADMINISTRATIONS

Stone & Webster issued a project manual to Stone & Webster project team members.

Work continued on the Phase I Extension proposal. Work scopes have been written to cover engineering and licensing activities not covered by the current Phase I contract. These activities include alternative sites assessments, preparation of the major permit applications, development of the water supply, back up fuels evaluation, ash disposal options, alfalfa variability characterization, special analyses of pilot plant samples for air toxics, and a gasification plant inert gas (nitrogen) supply study. The extension proposal will also cover extensions of activities related to development of the feedstock supply systems such as additional leaf meal product testing, design and siting of processing plants, development of improved alfalfa strains, determining the benefits of growing alfalfa, farmer and community education program.

Members from UPA, MnVAP, Kvaerner, S&W and DOE attended the gasification tests at the Kvaerner/Carbona Test Facility in Finland. The results of the Alfalfa Steam Gasification Test Program and the University of Minnesota activities were presented at the June 4th project meeting.

A visit to Granite Falls to establish specific power footprints on the industrial park site and the Yellow Medicine County site occurred on June 5th. In addition attended a meeting with the Granite Falls water supply plant supervisor and the City Engineer to discuss the possibility of utilizing the no longer used Minnesota River water intake. Also reviewed information available concern river quantity (flows) and water quality.

Presented two alternative plant layouts and preferred location in the industrial park to the Granite Falls Task force, and also visited potential sites in Yellow Medicine County with County Engineer.

After a corporate review of priorities Westinghouse management reaffirmed their participation in the MAP project. However, Westinghouse contract was prepared and submitted to MnVAP for review and approval.

A meeting was held between Stone & Webster and Kvaerner to discuss issues related to the Phase II EPC contact and teaming agreement.

University of Minnesota - Task VI Project Coordinator

The MAP Project Coordinator and staff developed a proposal which was submitted to a USDA program "The Fund for Rural America" to develop ongoing USDA participation in the USDOE/USDA Biomass Power for Rural Development program. USDA support for the biomass energy program must be accessed through existing USDA programs such as the Fund for Rural America. The MAP project proposal to the Fund for Rural America highlighted agricultural opportunities for dairy farmers and the environmental and economic benefits of the renewable, alfalfa-based energy production system. Notification of selection under this program is anticipated in August 1997.

The Project Coordinator participated in several business meetings with MnVAP staff to coordinate and implement overall policy objectives for the MAP project including: MAP project meetings with

UPA staff; Experiment Station Field Days; and other informational and project development meetings.

The Project Coordinator is working with the University of Minnesota news service and with the Agricultural Education Department to develop educational materials for MAP.

Project Coordinator worked with MnVAP staff and University personnel to develop the MAP Fuel Supply Plan and supporting proforma calculations.

University of Minnesota - Task VII Research Coordination

Performed monthly accounting, reporting, and research coordinating tasks under MnVAP's Cooperative Research Agreement with the University of Minnesota. Coordinated team meetings; revised budgets and prepared and submitted monthly expense and progress reports for March, April and May 1997; reconciled research accounts and verified University expenses; and prepared and submitted revised scope of work and budget; prepared and submitted 1st Quarter 1997 Report; prepared University report for MAP Research Team meeting on June 3rd; and assisted with preparation of Fuel Supply Plan.

Staff also provides support for the Project Coordinator activities.

ATTACHMENT 1

PILOT GASIFICATION TESTS FOR MAP-PROJECT

"QUICK REPORT"
ON
GASPI TEST RUN MAA25(97)/ALFALFA FUEL

cycled separately as DOE/GO/10147--T2-Pt.2

M98020216

ATTACHMENT 2

ALFALFA VARIETIES FOR BIOMASS PRODUCTION

UNIVERSITY OF MINNESOTA

Alfalfa Varieties for Biomass Production

University of Minnesota Task IId

Minnesota Agri-Power

Preliminary Research Report to MnVAP

June 30, 1997

by Craig Sheaffer, Greg Cuomo, Jim Halgerson, Mary Joyce,
Jo Ann Lamb, Neal Martin, and Steve Quering
University of Minnesota

Alfalfa Varieties for Biomass Production

Task IId

Objective

To determine the total biomass yield; leaf and stem biomass yield; and leaf and stem composition of alfalfa varieties and experimental germplasms subject to diverse harvest regimes. Harvest regimes ranged from conventional strategies based on harvests at first flower to unorthodox harvests at late flower to pod stage.

Plant Materials and Establishment

Field experiments were conducted at three locations in 1996. The fifteen alfalfa entries subjected to harvest management in 1996 were planted at Rosemount, MN on 12 May 1995, and at Lamberton and Morris, MN on 18 May 1995. The entries included 9 commercial varieties; Key, Vernal, WL 252HQ, Wintergreen, MP 2000, Pioneer 5444, Pioneer 5262, DK 133, and Paramount, and 6 experimental germplasms: ABI 9127, ABI 9239, Orca, Northland, DS 9506, and CW 9545. Of the 15 entries, 6 were selected for detailed leaf and stem analysis. These were WL 252HQ, MP2000, ABI 9239, 5262, 5444, and Orca. Orca and 5444 are entries containing a significant amount of European characteristics such as increased lodging resistance and a greater proportion of stems. The Orca in these trials has been selected by the USDA-ARS (Dr. Joanne Lamb) and is technically designated Orca-TWS.

The soil at Rosemount was a Tallula silt loam (course-silty, mixed, mesic Typic Hapludoll) with a pH of 7.0 and P and exchangeable K in excess of 34 and 200 ppm.; at Lamberton a Normania loam (fine-loamy, mixed, mesic Aquic Hapludoll) with a pH of 6.1, and exchangeable P and K in excess of 24 and 187 ppm; at Morris a McIntosh silt loam (fine-silty, frigid Aeric Calciaquoll) with a pH of 7.8 and P and K in excess of 24 and 224. Plots were 6 ' x 20'. All plots were seeded at a rate of 15 lb/acre. Weed control at establishment consisted of a preplant application of 0.5 lb/acre of Trifluralin (*alpha*, *alpha*, *alpha*-Trifluoro-2,6-Dinitro-N, N-Dipropyl 1-p-Toluidine) preplant. Plots were sprayed when needed with Permethrin [(3-phenoxyphenyl methyl)±*cis*, *trans*-3-(2,2-dichloroethenyl)-2,2-dimethlycyclopropanecarboxylate] for potato leafhopper (*Empoasca fabae*, Harris) control.

Harvest Regime and Sampling Methods

Three harvest regimes, based on a visual evaluation of maturity, were used at Rosemount and two were used at the other locations. Plots were harvested at the early to mid bud stage (1 - 65 % of stems with 1 or more buds) at Rosemount and early to mid flower (1 - 65% of stems having 1 of more flowers), and late flower - early pod (> 66 % stems with 1 or more flowers to pods present) at all locations. Yield was determined from 3' x 16 ' yield strips at Rosemount, and 3' x 17' strips at Lamberton and Morris. Random subsamples of the standing forage were taken for leaf and stem composition of selected entries (about 100g) and for whole plant quality of all entries (about 500g). Fresh weight was taken of the whole plant samples. Subsamples were then dried at 140° F for 72 hours. Leaf and stem subsamples were divided into leaf and stem fractions, then weighed to determine percent leaf. Dried whole plant samples were weighed to determine dry matter percentage. All subsamples were ground to pass a 1mm screen and stored for quality analysis.

Quality Analysis

Quality of leaf and stem fractions as well as whole plant samples was determined using near infrared reflectance spectra (NIRS) analysis (NIRSystems Inc. , model 6500, Silver Springs MD). Leaf and stem samples were predicted using a Minnesota leaf and stem equation with calibration statistics as follows. For CP, SEC=0.38 g kg^{-1}, R^2=1.0; for ADF, SEC=0.85 g kg^{-1}, R^2=1.0; for NDF, SEC=1.01g kg^{-1}, R^2=1.0. Whole plant samples were predicted using a vegetative whole alfalfa research equation with the following statistics; CP, SEC=0.59 g kg^{-1}, R^2=0.96; ADF SEC=0.81 g kg^{-1}, R^2=0.98; NDF SEC=0.98 g kg^{-1}, R^2=0.98. A random subset of 10 samples was chosen from both the leaf and stem and whole plant samples and used as monitoring sets. Conventional analysis (wet chemistry) for crude protein, acid detergent fiber, and neutral detergent fiber was run on the monitoring subsets. Stem monitoring set CP SEP=0.39 g kg^{-1}, R^2=0.98; ADF SEP=0.78 g kg^{-1}, R^2=0.95; and NDF SEP=0.62 g kg^{-1}, R^2=0.89. Leaf monitoring set CP SEP=0.59 g kg^{-1}, R^2=0.94; ADF SEP=0.82 g kg^{-1}, R^2=0.83; and NDF SEP=0.60 g kg^{-1}, R^2=0.96. Whole plant monitoring set CP SEP=0.96 g kg^{-1}, R^2=0.96; ADF SEP=0.62 g kg^{-1}, R^2=0.95; and NDF SEP=0.77 g kg^{-1}, R^2=0.96. Predicted values were adjusted for bias.

Experimental Design and Statistical Analysis

The experimental design was a randomized complete block with treatments in a split-plot arrangement with four replications. Whole plot treatments were harvest regimes and split-plot treatments were alfalfa entries. Three harvest regimes were used at Rosemount and two at the other locations. For all variables, an analysis of variance (ANOVA) was conducted on seasonal average values (SAS Institute, 1989-1996). This analysis was used because of unequal numbers of individual harvests for the different harvest regimes. When significant differences (P=0.05) were found for treatment variables, means were separated by Fisher's LSD (0.05).

Results and Discussion

Results from the three locations are presented in Tables 1-9. There were often significant differences between harvest regimes and among alfalfa entries; however, the harvest regime x entry interaction was often not statistically significant. A significant harvest regime x entry interaction indicates that entry ranking was not similar for all harvest regimes. Because of the contrasting environments, responses to treatments sometimes differed in magnitude among locations.

Harvest regime had the most consistent and greatest effect on the variables studied. Harvest regimes at earlier maturity (early bud to early flower) frequently resulted in forage which was leafier and of higher quality (more crude protein and lower fiber) than a harvest regime at late flower. Alfalfa entry differences were less consistent.

The 1996 growing season was characterized by a cool spring followed by a moisture deficit in August (Tables 10 -12) These conditions resulted in three harvests for the early flower-early bud harvest regimes and two harvests for the late flower harvest regimes. Data presented in Tables 1-9 is a seasonal average for forage quality variables and leaf concentration, and a seasonal total for yield variables.

Following is a description of specific treatment effects:

<u>Leaf concentration</u>

- Leaf concentration was affected by harvest regime and entry at each location.
- The early bud stage harvest regime resulted in leaf concentration ranging from 57.1% for ABI 9239 to 52.6% for Pioneer 5262 at Rosemount (Table 7).
- For the early flower harvest regime, leaf concentration ranged from 59.4% for WL 252HQ to 56.6% for Orca at Morris (Table 1), 52.1% (MP2000) to 49.9% (Pioneer 5444) at Lamberton (Table 4), and from 52.4% (MP2000) to 48.3% (Pioneer 5444) at Rosemount (Table 7).
- For the late flower/early pod harvest regime, leaf concentration ranged from

53.6% for WL 252HQ to 48.7% for Orca at Morris (Table 1), 50.5% (Pioneer 5444) to 47.1% (Pioneer 5262) at Lamberton (Table 4), and from 46.9% (ABI 9239) to 44.8% (MP2000) at Rosemount (Table 7).

Yield of leaves, stems, and whole plants

Leaf yield

- Leaf yield was significant for entries at all locations and for harvest regime at the Morris and Rosemount locations.
- At early bud stage at Rosemount leaf yield ranged from 2.01 ton/acre for WL 252HQ to 1.88 ton/acre for Pioneer 5262 (Table 7).
- At early flower, leaf yield ranged from 1.91 (WL 252HQ) to 1.75 (MP2000) ton/acre at Morris (Table 1), from 1.74 (ABI 9239) to 1.23 (Pioneer 5444) ton/acre at Lamberton (Table 4), and 2.41 (ABI 9239) to 2.09 (Pioneer 5262) ton/acre at Rosemount (Table 7).
- At late flower, leaf yield ranged from 1.80 (MP2000) to 1.51 (Orca) at Morris Table 1), 1.62 (MP2000) to 1.41 (Pioneer 5444) ton/acre at Lamberton (Table 4), and from 1.88 (ABI 9239) to 1.50 (Pioneer 5444) ton/acre at Rosemount (Table 7).

Stem yield

- Stem yield was affected by alfalfa entry at all locations and by harvest regime at Rosemount.
- At early bud, stem yield ranged from 1.48 (ABI 9239) to 1.67 (Pioneer 5262) ton/acre at Rosemount (Table 7).
- At early flower, stem yield ranged from 1.23 (MP2000 and ABI 9239) to 1.41 (Pioneer 5262 and Orca) ton/acre at Morris (Table 1), from 1.29 (Pioneer 5444) to 1.63 (WL 252HQ and ABI 9239) ton/acre at Lamberton (Table 4), and 1.96 (MP2000) to 2.39 (ABI 9239) ton/acre at Rosemount (Table 7).
- At late flower, stem yield ranged from 1.51 (ABI 9239) to 1.65 (Pioneer 5444) ton/acre at Morris (Table 1), from 1.47 (MP2000) to 1.73 (Pioneer 5262) ton/acre at Lamberton (Table 4), and from 1.79 (Pioneer 5444) to 2.15 (ABI 9239) at Rosemount (Table 7).

Whole plant yield

- Whole plant yield was affected by entry, and the harvest regime by entry interaction was significant at Morris and Rosemount. Whole plant yield was not affected by entry, harvest stage or harvest stage by entry interaction at Lamberton.
- At early bud (Rosemount), whole plant yield was similar for the entries and averaged 3.5 ton/acre (Table 7).

- At early flower, whole plant yield ranged from 3.26 (Orca) to 2.98 (MP2000) ton/acre at Morris (Table 1), from 3.37 (ABI 9239) to 2.52 (Pioneer 5444) ton/acre at Lamberton (Table 4), and from 3.60 (WL 252HQ) to 3.45 (ABI 9239) ton/acre at Rosemount (Table 7).
- At late flower, whole plant yield ranged from 3.36 (MP2000) to 3.07 (Orca) at Morris (Table 1), 3.26 (Pioneer 5262) to 2.90 (Pioneer 5444) at Lamberton (Table 4), and from 4.03 (ABI 9239) 3.29 to (Pioneer 5444) at Rosemount (Table 7).

Whole plant, leaf and stem crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentration.

Whole plant quality

- Whole plant quality was affected by harvest stage and entry at Rosemount, and by harvest stage at Morris and Lamberton. At Morris and Lamberton, the harvest stage X entry interaction was significant.
- In comparing harvest regimes, forage from the early flower regime was significantly higher in CP concentration than forage from the late flower regime (21.3% vs. 16.8% at Morris; 20.9% vs. 17.5% at Lamberton; and 21.1% vs. 18.9% at Rosemount) and lower in ADF than forage from late flower regime (33.6% vs. 40.8% at Morris; 33.5% vs. 40.0% at Lamberton; and 58.2% vs. 62.2 % at Rosemount) and lower in NDF than forage from the late flower regime (38.7% vs. 47.7% at Morris; 39.6% vs. 47.3% at Lamberton; and 42.5 % vs. 46.2% at Rosemount) at all locations (Tables 2, 5, and 8) and the early bud regime resulted in forage with even higher CP (23.3% vs. 21.1%), and lower ADF (31.3 vs. 36.1%) and NDF (36.6% vs. 42.5%) the early flower regime at Rosemount (Table 8).
- For the early flower harvest regime at Morris, WL 252HQ (22.4%) had the highest whole plant CP, with Orca (20.45%) and Pioneer 5444 (20.3%) having the lowest CP (Table 2). At Lamberton, WL 252HQ (21.5%) again had the highest CP concentration with MP2000 (20.1%) having the lowest CP concentration (Table 5).
- For the late flower regime at Morris, WL 252HQ (17.5%) was again the highest in CP concentration with Pioneer 5444 (16.2%) and Pioneer 5262 (16.3%) being the lowest at Morris (Table 2). At Lamberton, WL 252HQ (18.4%) was the highest and Pioneer 5444 (16.7%) was the lowest in CP (Table 5).
- For entry across harvest regimes, ABI 9239 (21.8%) and WL 252HQ and MP2000 (both at 21.7%) were significantly higher in CP, and MP2000 (34.3% and 40.4%) and ABI 9239 (34.7% and 40.8%) were lowest in ADF and NDF respectively at Rosemount (Table 8).

Leaf quality

- Leaf fraction quality (CP, ADF and NDF concentration) was affected by harvest regimes at all locations. Quality was consistently higher for the early flower regime than the late flower regime.
- Alfalfa entry effect on leaf quality was less consistent: alfalfa entries differed in leaf CP, NDF, and ADF concentration at Morris and for crude protein at Rosemount and Lamberton; however, these differences were biologically small.

Stem quality

- Stem forage quality (CP, NDF, ADF) was significantly affected by harvest regime at all locations and by entry at Morris. Stem quality was consistently greater for the harvest regime with harvests of least mature forage.
- Alfalfa entries differed in stem CP, ADF, and NDF concentration at Rosemount and Morris but at Lamberton only differed in CP concentration. The entry x harvest regime interaction was not consistently different for any variables. At Morris and Rosemount, entry effects on stem quality were primarily due to Orca having greater stem ADF and NDF than the other entries and lower CP than other entries especially WL 252HQ.

Summary

Both harvest regime and alfalfa entry impacted the biomass yield and forage quality. Alfalfa entry response was often similar for diverse harvest managements within a location. The forage characteristics of modern alfalfa varieties were similar; however, Orca and 5444 varieties with a European genetic background tended to have more stems and be lower in quality than other entries.

The response to harvest regime was often greater than that observed due to entry which implies that producers can have the greatest impact on yield and quality by harvest management than by entry selection.

Harvests regimes with alfalfa at late flower stage of maturity resulted in forage with more stem production, less leaves, and lower forage quality than regimes with harvests at less mature stages

Table 1. Average leaf concentration and crude protein (CP) for leaf and stem fractions, and total seasonal yield of alfalfa harvested at early flower and late flower stages of growth at Morris, MN in 1996.

Harvest Maturity	Entry	Leaf Conc.	CP YIELD Leaf	CP YIELD Stem	Total Yield Leaf	Total Yield Stem	Total Yield Whole Plant
		-----%-----	----	----	Ton/Acre	----	----
Early Flower	WL 252HQ	59.4	0.62	0.15	1.91	1.29	3.20
	MP2000	58.9	0.55	0.14	1.75	1.23	2.98
	5444	58.5	0.57	0.14	1.88	1.33	3.21
	5262	56.5	0.58	0.16	1.83	1.41	3.24
	ABI 9239	59.0	0.55	0.14	1.77	1.23	3.00
	Orca	56.6	0.57	0.15	1.85	1.41	3.26
	Mean	58.2	0.57	0.15	1.83	1.32	3.15
Late Flower	WL 252HQ	53.6	0.50	0.14	1.77	1.52	3.29
	MP2000	53.4	0.49	0.14	1.80	1.56	3.36
	5444	50.6	0.45	0.14	1.69	1.65	3.34
	5262	48.8	0.43	0.15	1.56	1.62	3.18
	ABI 9239	51.5	0.45	0.14	1.60	1.51	3.11
	Orca	48.7	0.41	0.14	1.51	1.56	3.07
	Mean	51.1	0.46	0.14	1.66	1.57	3.23
Entry Mean	WL 252HQ	56.5	0.56	0.15	1.84	1.41	3.25
	MP2000	56.2	0.52	0.14	1.78	1.40	3.17
	5444	54.6	0.51	0.14	1.79	1.49	3.28
	5262	52.7	0.51	0.16	1.70	1.52	3.21
	ABI 9239	55.3	0.50	0.14	1.69	1.37	3.06
	Orca	52.7	0.49	0.15	1.68	1.49	3.17
LSD $_{0.05}$	Harvest Stage (HS)	3.8	0.03	ns	0.04	ns	ns
	Entry	2.1	0.04	ns	0.14	0.14	0.10
	HS X Entry	ns	ns	ns	ns	ns	0.10

†Harvest stage LSD $_{0.05}$ values are for comparing means between harvest regimes, and entry LSD $_{0.05}$ is for comparing values between entry means. ‡Plots were harvested for early flower on 18 June, 19 July, and 27 August, and late flower on 28 June, and 14 August.

Table 2. Average seasonal crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentrations for alfalfa leaf (L) and stem (S) fractions and whole plant (W) samples harvested at early flower and late flower stages at Morris, MN in 1996.

	Entry	CPL	CPS	CPW	ADFL	ADFS	ADFW	NDFL	NDFS	NDFW
		%								
						Early Flower				
	WL 252HQ	32.3	11.6	22.4	15.6	51.7	32.8	19.1	60.8	37.6
	MP2000	31.3	11.3	21.7	16.0	51.9	32.7	19.4	61.0	37.7
	5444	30.1	10.9	20.3	16.2	52.0	33.7	19.7	60.9	39.2
	5262	31.9	11.3	21.2	15.6	52.6	33.7	19.1	61.6	38.9
	ABI 9239	31.2	11.3	21.7	16.0	51.7	33.3	19.6	60.4	38.3
	Orca	30.8	10.7	20.4	16.0	53.8	35.2	19.3	62.7	40.6
	Mean	31.3	11.2	21.3	15.9	52.3	33.6	19.3	61.2	38.7
						Late Flower				
	WL 252HQ	28.3	9.0	17.6	18.5	59.1	40.1	22.3	68.7	46.6
	MP2000	27.1	8.7	17.2	19.0	59.4	40.2	22.9	69.4	46.9
	5444	26.8	8.5	16.2	18.9	59.7	41.3	22.8	69.7	48.3
	5262	27.4	9.1	16.3	18.1	58.7	41.1	21.9	68.7	48.3
	ABI 9239	28.2	9.1	17.0	18.4	58.7	40.4	22.2	68.6	47.2
	Orca	27.3	8.8	16.7	18.6	59.6	41.5	22.2	69.8	48.6
	Mean	27.5	8.8	16.8	18.6	59.2	40.8	22.4	69.1	47.7
						Entry Mean				
	WL 252HQ	30.3	10.4	20.0	17.1	55.4	36.5	20.7	64.7	42.1
	MP2000	29.2	10.0	19.4	17.5	55.7	36.4	21.1	65.2	42.3
	5444	28.4	9.7	18.2	17.6	55.8	37.5	21.2	65.3	43.8
	5262	29.7	10.2	18.7	16.9	55.6	37.4	20.5	65.4	43.6
	ABI 9239	29.7	10.2	19.4	17.2	55.2	36.9	20.9	64.5	42.8
	Orca	29.0	9.8	18.5	17.3	56.8	38.3	20.8	66.3	44.6
LSD $_{0.05}$[†]	Harvest Stage (HS)	1.9	0.4	0.8	1.1	0.6	1.3	1.5	1.2	1.7
	Entry	0.6	0.5	ns	0.5	1.0	ns	0.6	1.2	ns
	HS X Entry	ns	ns	0.1	ns	ns	0.2	ns	ns	0.3

[†]Harvest stage LSD $_{0.05}$ values are for comparing means between harvest regimes, and entry LSD $_{0.05}$ is for comparing values between entry means. The harvest stage by entry interaction was nonsignificant (P> 0.05) for leaf and stem fractions. [‡] Plots were harvested for early flower on 18 June, 19 July, and 27 August, and late flower on 28 June, and 14 August.

Table 3. Average crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF) concentrations for alfalfa harvested at early bud, early flower and late flower stages of growth at Morris, MN in 1996.

Entry	CP	ADF	NDF	YIELD
	----------	%	----------	Ton/Acre
		Early Flower		
WL 252HQ	22.4	32.8	37.6	3.20
MP2000	21.7	32.7	37.7	2.98
5444	20.3	33.7	39.2	3.21
5262	21.2	33.7	38.9	3.24
ABI 9239	21.7	33.3	38.3	3.00
Orca	20.4	35.2	40.6	3.26
Key	21.0	34.3	39.5	3.09
Vernal	20.9	34.2	39.8	2.99
Wintergreen	21.2	34.4	39.6	3.45
DK133	21.5	33.8	38.8	3.05
Paramount	20.2	34.9	40.4	3.36
ABI 9127	21.6	33.8	39.0	3.24
Northland	20.1	35.2	40.7	3.29
DS 9506	21.1	33.9	39.1	3.23
CW 9545	21.8	33.5	38.5	3.02
Mean	21.1	34.0	39.2	3.17
		Late Flower		
WL 252HQ	17.6	40.1	46.6	3.29
MP2000	17.2	40.2	46.9	3.36
5444	16.2	41.3	48.3	3.34
5262	16.3	41.1	48.3	3.17
ABI 9239	17.0	40.4	47.2	3.11
Orca	16.7	41.5	48.6	3.07
Key	17.2	40.6	47.2	3.06
Vernal	16.8	41.2	48.4	3.04
Wintergreen	17.1	41.0	48.0	3.27
DK133	16.9	40.9	47.7	3.33
Paramount	16.0	42.4	49.6	3.56
ABI 9127	17.6	39.2	45.8	3.42
Northland	15.9	41.8	48.9	3.15
DS 9506	17.1	40.4	47.1	3.26
CW 9545	17.5	39.3	45.8	3.24
Mean	16.9	40.8	47.6	3.24

Table 3 (continued). Average crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF) concentrations for alfalfa harvested at early bud, early flower and late flower stages of growth at Morris, MN in 1996.

	Entry	CP	ADF	NDF	YIELD
		-----	----- % -----	-----	Ton/Acre
			Entry Mean		
	WL 252HQ	20.0	36.5	42.1	3.25
	MP2000	19.4	36.4	42.3	3.17
	5444	18.2	37.5	43.8	3.28
	5262	18.7	37.4	43.6	3.21
	ABI 9239	19.4	36.9	42.8	3.06
	Orca	18.5	38.3	44.6	3.17
	Key	19.1	37.4	43.4	3.08
	Vernal	18.9	37.7	44.1	3.02
	Wintergreen	19.2	37.7	43.8	3.36
	DK133	19.2	37.4	43.3	3.19
	Paramount	18.1	38.7	45.0	3.46
	ABI 9127	19.6	36.5	42.4	3.33
	Northland	18.0	38.5	44.8	3.22
	DS 9506	19.1	37.2	43.1	3.25
	CW 9545	19.6	36.4	42.1	3.13
LSD $_{0.05}$[†]	Harvest Stage (HS)	0.8	1.3	1.7	0.34
	Entry	0.1	0.2	0.3	0.25
	HS X Entry	ns	ns	ns	ns

[†]Harvest stage LSD $_{0.05}$ values are for comparing means between harvest regimes, and entry LSD $_{0.05}$ is for comparing values between entry means. The harvest stage by entry interaction was nonsignificant ($P > 0.05$).

[‡]Plots were harvested for early flower on 18 June, 19 July, and 27 August, and late flower on 28 June, and 14 August.

Table 4. Average leaf concentration and crude protein (CP) for leaf and stem fractions, and total seasonal yield of alfalfa harvested at early flower and late flower stages of growth at Lamberton, MN in 1996.

Harvest Maturity	Entry	Leaf Conc.	CP YIELD Leaf	CP YIELD Stem	Total Yield Leaf	Total Yield Stem	Total Yield Whole Plant
		------%------	----------	----------	Ton/Acre	----------	----------
Early Flower	WL 252HQ	51.2	0.53	0.18	1.72	1.63	3.35
	MP2000	52.1	0.50	0.17	1.66	1.54	3.20
	5444	49.9	0.38	0.14	1.23	1.29	2.52
	5262	50.9	0.51	0.18	1.67	1.61	3.28
	ABI 9239	51.7	0.53	0.18	1.74	1.63	3.37
	Mean	51.2	0.49	0.17	1.60	1.54	3.14
Late Flower	WL 252HQ	48.7	0.45	0.15	1.47	1.55	3.02
	MP2000	49.2	0.47	0.16	1.62	1.47	3.09
	5444	50.5	0.39	0.12	1.41	1.49	2.90
	5262	47.1	0.43	0.15	1.53	1.73	3.26
	ABI 9239	49.1	0.43	0.14	1.48	1.56	3.04
	Mean	48.9	0.43	0.14	1.50	1.56	3.06
Entry Mean	WL 252HQ	50.0	0.49	0.17	1.60	1.59	3.19
	MP2000	50.7	0.49	0.17	1.64	1.51	3.15
	5444	50.2	0.39	0.13	1.32	1.39	2.71
	5262	49.0	0.47	0.17	1.60	1.67	3.27
	ABI 9239	50.4	0.48	0.16	1.61	1.60	3.21
LSD $_{0.05}$	Harvest Stage (HS)	4.0	ns	ns	ns	ns	ns
	Entry	2.9	0.06	0.02	0.19	0.26	ns
	HS X Entry	ns	ns	ns	ns	ns	ns

†Harvest stage LSD $_{0.05}$ values are for comparing means between harvest regimes, and entry LSD $_{0.05}$ is for comparing values between entry means.

‡Plots were harvested for early flower on 14 June, 12 July, and 22 August, and late flower on 1 July, and 6 August.

Table 5. Average crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentrations for alfalfa leaf (L) and stem fractions (S), and whole plant (W) samples harvested at early flower and late flower stages at Lamberton, MN in 1996.

	Entry	CPL	CPS	CPW	ADFL	ADFS	ADFW	NDFL	NDFS	NDFW
						%				
						Early Flower				
	WL 252HQ	30.9	11.2	21.5	17.3	51.9	33.3	21.0	60.8	39.1
	MP2000	29.8	11.1	20.1	18.0	52.1	33.9	21.9	61.1	40.1
	5444	29.8	11.3	20.6	17.2	51.4	32.9	21.1	60.3	39.1
	5262	30.8	11.0	21.2	17.0	52.2	33.5	21.0	61.2	39.6
	ABI 9239	30.6	11.3	20.9	17.4	51.9	33.7	21.2	61.0	39.9
	Mean	30.4	11.2	20.9	17.4	51.9	33.5	21.3	60.9	39.6
						Late Flower				
	WL 252HQ	30.3	9.2	18.4	18.6	57.6	39.0	22.6	66.9	45.9
	MP2000	28.6	9.3	17.6	19.0	57.4	40.7	23.0	66.6	48.0
	5444	27.2	8.1	16.7	19.1	58.8	39.7	23.1	68.6	47.2
	5262	28.0	8.7	17.4	19.1	58.3	40.7	23.1	67.7	48.1
	ABI 9239	28.6	9.0	17.6	19.4	60.0	40.1	23.6	67.5	47.3
	Mean	28.5	8.9	17.5	19.1	58.4	40.0	23.1	67.5	47.3
						Entry Mean				
	WL 252HQ	30.6	10.2	19.9	18.0	54.7	36.1	21.8	63.9	42.5
	MP2000	29.2	10.2	18.8	18.5	54.8	37.3	22.5	63.9	44.0
	5444	28.5	9.7	18.6	18.1	55.1	36.3	22.1	64.5	43.2
	5262	29.4	9.8	19.3	18.1	55.3	37.1	22.1	64.4	43.9
	ABI 9239	29.6	10.2	19.3	18.4	54.9	36.9	22.4	64.3	43.6
LSD $_{0.05}$[†]	Harvest Stage (HS)	1.8	1.0	0.8	0.7	1.5	2.3	0.3	2.1	2.4
	Entry	0.7	0.5	ns	ns	ns	ns	ns	ns	ns
	HS X Entry	0.3	0.2	0.2	ns	ns	0.3	ns	ns	0.4

[†]Harvest stage LSD $_{0.05}$ values are for comparing means between harvest regimes, and entry LSD $_{0.05}$ is for comparing values between entry means. Entry was insignificant for ADF and NDF, and harvest stage by entry interaction was nonsignificant ($P > 0.05$) for leaf and stem ADF and NDF.

[‡]Plots were harvested for early flower on 14 June, 12 July, and 22 August, and late flower on 1 July, and 6 August.

Table 6. Average crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF) concentrations for alfalfa harvested at early bud, early flower and late flower stages of growth at Lamberton, MN in 1996.

Entry	CP	ADF	NDF	YIELD
	-----------------	%	-----------------	Ton/Acre
		Early Flower		
WL252HQ	21.5	33.3	39.1	3.35
MP2000	20.1	33.9	40.1	3.20
5444	20.6	32.9	39.1	2.52
5262	21.2	33.5	39.6	3.29
ABI 9239	20.9	33.7	39.9	3.37
Vernal	20.4	35.8	42.1	3.43
Wintergreen	20.9	33.9	40.1	3.10
DK133	21.0	34.2	40.2	3.11
Paramount	20.0	35.0	41.2	3.16
ABI 9127	21.4	33.5	39.4	3.44
Northland	19.7	35.6	42.0	3.19
DS 9506	19.9	34.1	40.2	3.05
CW 9545	20.9	33.7	39.6	2.82
Mean	20.7	34.1	40.2	3.16
		Late Flower		
WL 252hq	18.4	39.0	45.9	3.02
MP2000	17.6	40.7	48.0	3.08
5444	16.7	39.7	47.2	2.90
5262	17.4	40.7	48.1	3.26
ABI 9239	17.6	40.1	47.3	3.04
Vernal	17.0	41.6	49.0	3.04
Wintergreen	17.6	40.0	47.2	2.79
DK133	18.9	38.9	45.8	3.03
Paramount	17.2	40.3	47.7	2.95
ABI 9127	17.9	39.3	46.6	3.13
Northland	16.9	41.1	48.5	3.37
DS 9506	17.2	40.1	47.2	3.30
CW 9545	18.7	37.1	44.1	2.71
Mean	17.6	39.9	47.1	3.05
		Entry Mean		
WL 252HQ	19.9	36.1	42.5	3.19
MP2000	18.8	37.3	44.0	3.14
5444	18.6	36.3	43.2	2.71
5262	19.3	37.1	43.9	3.28
ABI 9239	19.3	36.9	43.6	3.21
Vernal	18.7	38.7	45.6	3.24
Wintergreen	19.2	36.9	43.6	2.95
DK133	19.9	36.6	43.0	3.07
Paramount	18.6	37.6	44.4	3.06
ABI 9127	19.6	36.4	43.0	3.29
Northland	18.3	38.3	45.2	3.28
DS 9506	18.6	37.1	43.7	3.18
CW 9545	19.8	35.4	41.8	2.77
LSD $_{0.05}$[†] Harvest Stage (HS)	0.8	2.3	2.4	1.20
Entry	0.2	0.3	0.4	0.43
HS X Entry	ns	ns	ns	ns

[†]Harvest stage LSD $_{0.05}$ values are for comparing means between harvest regimes, and entry LSD $_{0.05}$ is for comparing values between entry means. The harvest stage by entry interaction was nonsignificant (P> 0.05).
[‡]Plots were harvested for early flower on 14 June, 12 July, and 22 August, and late flower on 1 July, and 6 August.

Table 7. Average leaf concentration and crude protein (CP) for leaf and stem fractions, and total seasonal yield of alfalfa harvested at early bud, early flower and late flower stages of growth at Rosemount, MN in 1996.

Harvest Maturity	Entry	Leaf Conc.	CP YIELD Leaf	CP YIELD Stem	Total Yield Leaf	Total Yield Stem	Total Yield Whole Plant
		------%------	-----	-----	Ton/Acre	-----	-----
Early Bud	WL 252HQ	56.2	0.65	0.21	2.01	1.59	3.60
	MP2000	56.0	0.65	0.20	2.00	1.59	3.59
	5444	56.2	0.61	0.18	1.95	1.54	3.49
	5262	52.6	0.61	0.22	1.88	1.67	3.55
	ABI 9239	57.1	0.63	0.19	1.97	1.48	3.45
	Orca	54.0	0.61	0.20	1.89	1.59	3.48
	Mean	55.4	0.63	0.20	1.95	1.58	3.53
Early Flower	WL 252HQ	51.3	0.66	0.24	2.13	2.03	4.16
	MP2000	52.4	0.66	0.23	2.16	1.96	4.12
	5444	48.3	0.64	0.28	2.19	2.37	4.56
	5262	49.3	0.63	0.25	2.09	2.14	4.23
	ABI 9239	49.9	0.73	0.28	2.41	2.39	4.80
	Orca	50.7	0.63	0.22	2.15	2.03	4.18
	Mean	50.3	0.66	0.25	2.19	2.15	4.34
Late Flower	WL 252HQ	46.3	0.53	0.21	1.74	2.01	3.75
	MP2000	44.8	0.48	0.19	1.60	1.89	3.49
	5444	45.9	0.42	0.17	1.50	1.79	3.29
	5262	45.7	0.52	0.21	1.75	2.04	3.79
	ABI 9239	46.9	0.55	0.21	1.88	2.15	4.03
	Orca	45.4	0.48	0.20	1.69	2.02	3.71
	Mean	45.8	0.50	0.20	1.69	1.98	3.68
Entry Mean	WL 252HQ	51.3	0.61	0.22	1.96	1.88	3.84
	MP2000	51.1	0.60	0.21	1.92	1.81	3.73
	5444	50.1	0.56	0.21	1.88	1.90	3.78
	5262	49.2	0.59	0.23	1.91	1.95	3.86
	ABI 9239	51.3	0.64	0.23	2.09	2.01	4.09
	Orca	50.0	0.57	0.21	1.91	1.88	3.79
LSD $_{0.05}$	Harvest Stage (HS)	2.4	0.06	0.02	0.20	0.13	0.10
	Entry	2.4	0.05	ns	0.18	0.19	0.20
	HS X Entry	ns	ns	ns	ns	ns	0.20

†Harvest stage $LSD_{0.05}$ values are for comparing means between harvest regimes, and entry $LSD_{0.05}$ is for comparing values between entry means. ‡Plots were harvested for early bud on 6 June, 15 July, and 15 August, for early flower on 20 June, 18 July, and 23 August, and late flower on 3 July, and 12 August.

Table 8. Average seasonal crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentrations for alfalfa leaf (L) and stem (S) fractions, and whole plant (W) samples harvested at early bud, early flower and late flower stages at Rosemount, MN in 1996.

Entry	CPL	CPS	CPW	ADFL	ADFS	ADFW	NDFL	NDFS	NDFW
	%								
					Early Bud				
WL 252HQ	32.7	13.0	23.9	16.1	49.8	30.9	20.1	58.3	35.9
MP2000	32.2	12.6	24.4	16.3	49.2	29.2	20.0	58.1	34.3
5444	31.2	12.0	22.5	16.3	49.5	30.7	20.1	58.1	36.2
5262	32.5	13.1	22.8	16.0	49.5	32.7	20.0	58.0	38.2
ABI 9239	32.2	13.0	23.6	16.3	49.2	31.0	20.4	57.7	36.1
Orca	32.1	12.5	21.9	16.3	50.7	33.4	20.0	59.2	39.0
Mean	32.2	12.7	23.3	16.2	49.7	31.3	20.1	58.2	36.6
					Early Flower				
WL 252HQ	31.0	11.9	22.4	17.3	53.3	35.0	21.3	62.1	41.1
MP2000	30.5	11.6	21.5	17.3	53.5	34.8	21.3	62.5	41.1
5444	29.3	11.6	19.8	17.6	52.2	37.3	21.7	60.8	44.0
5262	30.3	11.8	21.0	17.0	53.0	36.1	21.1	61.8	42.7
ABI 9239	30.5	11.8	21.9	17.3	53.5	35.9	21.4	62.2	42.2
Orca	29.1	11.7	20.3	17.5	55.1	36.9	21.5	64.0	43.3
Mean	30.1	11.7	21.1	17.3	53.4	36.1	21.4	62.2	42.5
					Late Flower				
WL 252HQ	30.3	10.5	18.9	18.7	55.9	40.1	23.2	64.6	47.1
MP2000	30.1	9.7	19.3	18.7	56.5	38.9	22.9	65.7	45.9
5444	28.1	9.3	17.6	18.4	56.1	40.0	22.5	65.3	47.3
5262	29.6	10.2	18.9	18.8	55.3	38.9	23.2	64.5	45.8
ABI 9239	29.5	9.7	19.9	18.6	56.7	37.4	23.1	65.9	44.0
Orca	28.5	10.0	19.1	18.8	56.9	37.9	23.1	65.7	44.9
Mean	29.4	9.9	18.9	18.6	56.2	39.3	23.0	65.3	46.2
					Entry Mean				
WL 252HQ	31.3	11.8	21.7	17.4	53.0	35.4	21.5	61.6	41.4
MP2000	30.9	11.3	21.7	17.4	53.1	34.3	21.4	62.1	40.4
5444	29.6	11.0	20.0	17.4	52.6	36.0	21.4	61.4	42.5
5262	30.8	11.7	20.9	17.3	52.6	35.9	21.4	61.4	42.2
ABI 9239	30.7	11.5	21.8	17.4	53.1	34.7	21.6	61.9	40.8
Orca	29.9	11.2	20.5	17.5	54.2	36.1	21.5	63.0	42.4
LSD $_{0.05}$ †									
Harvest Stage (HS)	0.5	0.3	0.1	0.5	0.6	0.7	0.6	0.9	1.4
Entry	0.5	0.6	0.2	ns	1.1	0.4	ns	1.3	0.4
HS X Entry	ns	ns	ns	ns	ns	ns	ns	ns	ns

†Harvest stage LSD $_{0.05}$ values are for comparing means between harvest regimes, and entry LSD $_{0.05}$ is for comparing values between entry means. The harvest stage by entry interaction was nonsignificant ($P > 0.05$). ‡ Plots were harvested for early bud on 6 June, 15 July, and 15 August, for early flower on 20 June, 18 July, and 23 August, and late flower on 3 July, and 12 August.

Table 9. Average crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF) concentrations for alfalfa at early bud, early flower and late flower stages of growth at Rosemount, MN in 1996.

Entry	CP	ADF	NDF	YIELD
	----------	---------- %	----------	Ton/Acre
		Early Bud		
WL252HQ	23.9	30.9	35.9	3.60
MP2000	24.4	29.2	34.3	3.59
5444	22.5	30.7	36.2	3.49
5262	22.8	32.7	38.2	3.55
ABI 9239	23.6	31.0	36.1	3.45
Orca	21.9	33.4	39.0	3.48
Key	23.9	30.8	35.9	3.71
Vernal	23.5	31.4	37.0	3.71
Wintergreen	23.1	32.0	37.4	3.57
DK133	23.9	30.5	35.7	3.56
Paramount	22.1	32.3	38.0	3.63
ABI 9127	23.5	31.4	36.9	3.52
Northland	22.9	31.4	36.8	3.45
DS 9506	23.3	31.1	36.4	3.59
CW 9545	24.7	30.3	35.1	3.36
Mean	23.3	31.3	36.6	3.55
		Early Flower		
WL252HQ	22.4	35.0	41.1	4.16
MP2000	21.5	34.8	41.1	4.12
5444	19.8	37.3	44.0	4.56
5262	21.0	36.1	42.7	4.23
ABI 9239	21.9	35.9	42.2	4.80
Orca	20.3	36.9	43.3	4.17
Key	21.6	35.1	41.4	4.00
Vernal	20.8	37.2	44.1	4.26
Wintergreen	21.3	36.9	43.3	4.13
DK133	21.4	36.3	42.5	4.24
Paramount	20.3	36.6	43.1	4.06
ABI 9127	21.2	35.2	41.9	4.50
Northland	21.0	36.5	43.0	4.12
DS 9506	20.8	36.2	42.7	4.27
CW 9545	21.8	35.0	41.1	4.16
Mean	21.1	36.1	42.5	4.25
		Late Flower		
WL252HQ	18.9	40.1	47.1	3.75
MP2000	19.3	38.9	45.9	3.50
5444	17.6	40.0	47.3	3.29
5262	18.9	38.9	45.8	3.79
ABI 9239	19.9	37.4	44.0	4.03
Orca	19.1	37.9	44.9	3.71
Key	19.2	39.1	46.1	3.25
Vernal	18.2	41.4	48.9	3.52
Wintergreen	18.7	39.9	47.3	3.87
DK133	19.9	38.3	45.0	3.60
Paramount	18.7	40.2	47.5	3.71
ABI 9127	19.7	38.8	45.8	3.83
Northland	17.0	42.3	49.8	3.58
DS 9506	18.4	38.7	45.8	3.62
CW 9545	19.2	38.1	45.0	3.41
Mean	18.8	39.3	46.4	3.63

Table 9 (continued). Average crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF) concentrations for alfalfa at early bud, early flower and late flower stages of growth at Rosemount, MN in 1996.

	Entry	CP	ADF	NDF	Yield
		------------	%	------------	Ton/Acre
			Entry Mean		
	WL 252HQ	21.7	35.4	41.4	3.84
	MP2000	21.7	34.3	40.4	3.74
	5444	20.0	36.0	42.5	3.78
	5262	20.9	35.9	42.2	3.86
	ABI 9239	21.8	34.7	40.8	4.09
	Orca	20.5	36.1	42.4	3.79
	Key	21.6	35.0	41.1	3.65
	Vernal	20.8	36.7	43.3	3.83
	Wintergreen	21.1	36.3	42.7	3.86
	DK133	21.7	35.0	41.1	3.80
	Paramount	20.4	36.4	42.9	3.80
	ABI 9127	21.5	35.1	41.5	3.95
	Northland	20.3	36.7	43.2	3.72
	DS 9506	20.8	35.3	41.6	3.83
	CW 9545	21.9	34.5	40.4	3.64
LSD $_{0.05}$†	Harvest Stage (HS)	0.1	0.7	1.4	0.25
	Entry	0.2	0.4	0.4	0.32
	HS X Entry	ns	ns	ns	ns

†Harvest stage LSD $_{0.05}$ values are for comparing means between harvest regimes, and entry LSD $_{0.05}$ is for comparing values between entry means. The harvest stage by entry interaction was nonsignificant (P> 0.05).
‡Plots were harvested for early bud on 6 June, 15 July, and 15 August, for early flower on 20 June, 18 July, and 23 August, and late flower on 3 July, and 12 August.

Table 10. Monthly precipitation and temperatures for 1996 and average normal precipitation from 1961 to 1990 at the West Central Agricultural Experiment Station, Morris Mn.

	Total	1996 Temperatures				Average Normals		
	Precip.	Ave Low		Ave High		Precip.	Low	High
Month	(in)	(F)	Low Range	(F)	High Range	(in)	(F)	(F)
Jan	1.90	-8	-29 - +26	11	-15 - +42	0.74	-3	17
Feb	0.39	3	-12 - +28	21	-1 - +46	0.70	3	23
Mar	0.30	12	-14 - +34	28	-1 - +48	1.36	18	35
Apr	0.83	29	+17 - +39	48	+30 - +74	2.23	33	53
May	3.28	44	+28 - +60	63	+47 - +80	2.78	45	68
Jun	2.37	58	+38 - 76	79	+61 - 96	3.73	55	77
Jul	3.33	58	+46 - +68	79	+71 - +90	3.37	59	82
Aug	1.88	58	+47 - +69	80	+72 - +90	3.25	56	80
Sep	2.45	49	+35 - +65	70	+52 - +86	2.39	46	70
Oct	5.40	35	+14 - +50	58	+28 - +82	2.17	34	58
Nov	2.34	13	-15 - +39	27	+6 - +56	1.08	21	38
Dec	0.73	1	-25 - +20	15	-14 - +33	0.70	5	22

Table 11. Monthly precipitation and temperatures for 1996 and average normal precipitation from 1961 to 1990 at the Southwest Agricultural Experiment Station, Lamberton, Mn.

	Total	1996 Temperatures				Average Normals		
Month	Precip. (in)	Ave Low (F)	Low Range	Ave High (F)	High Range	Precip. (in)	Low (F)	High (F)
Jan	1.9	-3	-26 - +29	16	-10 - +46	0.62	1	22
Feb	0.12	9	-5 - +34	28	+5 - +57	0.57	6	27
Mar	1.19	15	-10 - +37	35	+6 - +64	1.52	20	39
Apr	0.35	29	+21 - +40	53	+34 - +75	2.71	34	56
May	4.43	44	+29 - +61	64	+45 - +95	3.12	46	71
Jun	5.76	58	+39 - +79	81	+59 - +98	3.48	56	81
Jul	5.56	57	+45 - +68	82	+73 - +93	3.71	61	84
Aug	4.66	55	+47 - +65	81	+75 - +92	2.79	57	81
Sep	2.23	46	+32 - +63	71	+55 - +85	3.01	48	72
Oct	2.66	34	+14 - +50	63	+31 - +84	2.09	36	61
Nov	4.76	13	-14 - +40	31	+7 - +65	1.15	23	42
Dec	1.28	2	-21 - +23	18	-8 - +34	0.68	7	26

Table 12. Monthly precipitation and temperatures for 1996 and average normal precipitation from 1961 to 1990 at the Rosemount Agricultural Experiment Station, Rosemount, Mn.

	Total	1996 Temperatures				Average Normals		
	Precip.	Ave Low		Ave High		Precip.	Low	High
Month	(in)	(F)	Low Range	(F)	High Range	(in)	(F)	(F)
Jan	2.77	-2	-37 - +21	19	-7 - +41	1.06	1	22
Feb	0.18	9	-8 - +33	26	+13 - +47	0.94	7	28
Mar	2.18	16	-12 - +36	35	+8 - +57	2.13	21	40
Apr	0.78	31	+22 - +50	55	+35 - +69	2.87	34	58
May	3.13	45	+29 - +60	65	+48 - +86	3.92	46	71
Jun	3.89	58	+44 - +75	78	+62 - +95	4.31	55	80
Jul	1.70	59	+49 - +72	80	+72 - +89	4.03	60	85
Aug	4.12	58	+53 - +69	81	+73 - +91	3.97	57	82
Sep	1.67	51	+36 - +66	70	+54 - +83	3.56	49	73
Oct	5.65	38	+15 - +55	62	+33 - +83	2.56	38	61
Nov	5.10	18	-12 - +39	33	+17 - +57	1.84	24	42
Dec	2.11	5	-25 - +28	22	-5 - +34	1.23	9	26

ATTACHMENT 3

BIOMASS ENERGY PRODUCTION EFFECTS ON THE ENVIRONMENT

ASH CHARACTERIZATION PROGRESS REPORT

JULY 7,1997

Biomass Energy Production Effects on the Environment
Ash Characterization Progress Report (7 July 1997)

Carl Rosen and Bruce Cook, Dept. of Soil, Water, and Climate, Univ. of Minnesota

CHEMICAL CHARACTERIZATION OF FILTER ASH

Biomass gasification ash is considered an "industrial solid waste" by the Minnesota Pollution Control Agency (MPCA), and based on initial characterization does not meet the criteria for a "hazardous waste" as defined by the US-EPA and MPCA. The MPCA requires that industrial solid wastes must be thoroughly characterized before disposal or land application is permitted. This involves total compositional analysis of the raw materials and waste product, determination of leaching potential, and other chemical analyses (e.g., pH, toxic organic compounds).

A sample of filter ash from the test burn in Finland was sent to United Power Associates (UPA) in May, and the remaining ash (3 samples of filter ash, and 1 sample of reactor ash) was sent in June. The initial sample that was sent in May was exhaustively analyzed for a wide range of elements and organic compounds that could be present in the ash (Table 2); subsequent samples were submitted for analyses in late June based on the results of the initial filter ash sample.

Compositional analysis of the filter ash reflects the elemental composition of the alfalfa stems (Table 1) and dolomite ($CaMg(CO_3)_2$) that was used in the bed of the gasification reactor. The filter ash is high in K, Ca and Mg (Table 2), and the pH and calcium carbonate equivalent (CCE) measurements suggest some liming potential. Fertilizer value analysis (Table 2) suggested that soil application rates should be based on crop requirements for potassium.

Polyaromatic hydrocarbons (PAHs) were detected at low concentrations in the filter ash (Table 2). These compounds are products of incomplete combustion, and are commonly present in automobile exhaust and smoke from charcoal fires and cigarettes. Some PAHs are human carcinogens, and inhalation or ingestion of the ash by those handling the ash should be avoided. This may involve pelletizing the ash immediately after it exits the hopper. PAH concentrations are low enough that PAHs would not be detectable once the ash is land applied and incorporated (assuming <3 tons/acre for K replacement). PAHs are moderately to strongly adsorbed to particles present in agricultural topsoils, and will undergo biodegradation.

Other than the PAHs, few semivolatile organic compounds were measured in the filter ash (Table 2). Chlorinated benzenes are considered quite toxic, and can be formed from the combustion of wastes and natural materials. However, dioxins, furans, and PCBs were not detected in the initial fly ash sample (Table 2).

Leach tests are used to determine whether elements or compounds in a waste may be mobilized in the water phase. The Toxicity Characteristic Leaching Procedure (TCLP) simulates leaching in a landfill by using an acetic acid solution. No metals, semivolatile organics, or volatile organics of concern were detected in the leachate from the filter ash sample (Table 3). We have also submitted samples for the Synthetic Leach test, which simulates leaching from acid rain.

LAND APPLICATION: PERMITTING AND BENEFICIAL USES

The MPCA is responsible for permitting land application of industrial solid waste. We met with the MPCA in June to discuss the alfalfa gasification ash, and will be preparing a permit request using the ash characterization results and production estimates of 40,000 tons/year.

The initial filter ash sample had an organic carbon content of about 44%, and the material had a distinct charcoal-like appearance. In Japan, "char-ash" from a wood gasification system is being used to replenish nutrients on organic farms. We are currently pursuing contacts with the International Charcoal Cooperate Association in Tokyo, and U.S.-based biomass gasification plants in Hawaii and Vermont to discuss land application experiences. We are also following up on the possibility of registering the ash as an organic fertilizer with the Minnesota Department of Agriculture (MDA) .

Table 1. Chemical characteristics of pelletized and reground alfalfa stems.

Chemical property	Units	Concentration			Analytical method†
		Average (n=5)	Range	CV	
ASH CONTENT	%	9.17	6.79 - 10.9	17%	A
TOTAL ELEMENTS					
C	%	44.1	43.3 - 45.6	2%	B
N	%	2.06	1.66 - 2.58	19%	C
C:N		22.0	16.9 - 26.1	17%	
K	g/kg	26.6	16.5 - 30.7	22%	E
Ca	g/kg	13.1	10.7 - 15.7	18%	E
Cl	g/kg	6.99	5.24 - 9.89	33%	F
Mg	g/kg	2.99	2.53 - 3.61	15%	E
P	g/kg	2.87	2.33 - 3.53	16%	E
S	g/kg	1.89	1.46 - 2.58	25%	D
Si	g/kg	0.455	0.356 - 0.667	26%	E
Na	g/kg	0.451	0.118 - 0.993	81%	E
Fe	mg/kg (ppm)	209	138 - 264	30%	E
Al	mg/kg (ppm)	185	111 - 251	36%	E
Mn	mg/kg (ppm)	36.0	28.3 - 48.7	27%	E
Ba	mg/kg (ppm)	32.7	26.7 - 49.2	28%	E
Sr	mg/kg (ppm)	31.5	23.4 - 41.9	23%	E
B	mg/kg (ppm)	30.1	24.1 - 40.9	21%	E
Zn	mg/kg (ppm)	20.3	16.7 - 24.3	17%	E
Cu	mg/kg (ppm)	9.67	8.24 - 13.1	20%	E
Ti	mg/kg (ppm)	2.30	1.16 - 3.46	47%	E
Ni	mg/kg (ppm)	1.36	0.941 - 2.18	36%	E
Mo	mg/kg (ppm)	0.978	0.520 - 1.82	52%	E
V	μg/kg (ppb)	< 534	< 449 - 681	26%	E
Cr	μg/kg (ppb)	512	350 - 650	26%	E
Co	μg/kg (ppb)	< 360	< 240 - 400	11%	E
Se	μg/kg (ppb)	310	200 - 407	26%	G
Cd	μg/kg (ppb)	197	160 - 280	26%	E
As	μg/kg (ppb)	58	31 - 77	33%	G
Hg	μg/kg (ppb)	3.99	3.18 - 5.83	26%	H
Rb	mg/kg (ppm)	< 66.2	not detected	---	E
Pb	mg/kg (ppm)	< 2.10	not detected	---	E
Li	mg/kg (ppm)	< 0.499	not detected	---	E
Be	mg/kg (ppm)	< 0.050	not detected	---	E

† A. Dry ashed at 485°C for 10-12 hours.
B. Dry combustion and IR detection of CO_2.
C. Kjeldahl procedure with nitrate prereduction.
D. Dry combustion and IR detection of SO_2.
E. Inductively Coupled Plasma (ICP) analysis of microwave digest with conc. HNO_3-H_2O_2.
F. H_2O/Carbon black extract and colorimetric analysis.
G. ICP-Mass Spectrometry (ICP-MS) of HNO_3-perchloric-HCl acid digest.
H. Cold Vapor Atomic Fluorescence Spectrometry (CVAFS) of 70°C digest with conc. HNO_3.

Table 2. **Chemical characteristics of fly ash from alfalfa gasification test burn.**

Chemical property	Result	
pH†	10.2	
Electrical conductivity (EC)‡	91.7	μmho/cm
Calcium carbonate equivalent (CCE)§	32.0	%
Loss on ignition (LOI)¶	47.2	%
TOTAL ELEMENTS#		
Organic carbon (TOC)	42.6	%
Nitrogen (TN)	1.07	%
TOC:TN	39.8	
K	111	g/kg
Ca	83.0	g/kg
Cl	24.4	g/kg
Mg	19.1	g/kg
P	15.5	g/kg
S	3.83	g/kg
Na	2.82	g/kg
Fe	2.26	g/kg
Al	1.87	g/kg
Si	289	mg/kg (ppm)
Sr	250	mg/kg (ppm)
Mn	240	mg/kg (ppm)
Ba	177	mg/kg (ppm)
B	166	mg/kg (ppm)
Ti	106	mg/kg (ppm)
Zn	98.9	mg/kg (ppm)
Cu	41.1	mg/kg (ppm)
Mo	27.2	mg/kg (ppm)
Ni	10.7	mg/kg (ppm)
Li	5.85	mg/kg (ppm)
V	5.69	mg/kg (ppm)
Cr	5.53	mg/kg (ppm)
Rb	< 425	mg/kg (ppm)
Pb	< 13.5	mg/kg (ppm)
Se	< 2.40	mg/kg (ppm)
Co	< 1.92	mg/kg (ppm)
As	< 0.96	mg/kg (ppm)
Cd	< 0.96	mg/kg (ppm)
Be	<0.32	mg/kg (ppm)
EXTRACTABLE NUTRIENTS††		
Nitrate (NO_3)	< 0.1	mg/kg (ppm)
Ammonium (NH_4)	7.36	mg/kg (ppm)
Sulfate (SO_4)	138	mg/kg (ppm)

FERTILIZER VALUE‡‡

N	1.22	%
P_2O_5	2.39	%
K_2O	11.8	%
B	154	mg/kg (ppm)

POLYAROMATIC HYDROCARBONS (PAHs)§§

Naphthalene	20	mg/kg (ppm)
Phenanthrene	3.4	mg/kg (ppm)
Pyrene	3.4	mg/kg (ppm)
Chrysene	2.6	mg/kg (ppm)
Fluoranthene	2.5	mg/kg (ppm)
Acenaphthene	2.3	mg/kg (ppm)
Benzo(a)pyrene	1.3	mg/kg (ppm)
Benzo(a)anthracene	1.2	mg/kg (ppm)
Benzo(b)fluoranthene	0.93	mg/kg (ppm)
Anthracene	0.84	mg/kg (ppm)
Benzo(k)fluoranthene	0.67	mg/kg (ppm)
Indeno(1,2,3-cd)pyrene	0.32	mg/kg (ppm)
Benzo(g,h,i)perylene	0.28	mg/kg (ppm)
Fluorene	< 0.21	mg/kg (ppm)
Acenaphthylene	< 0.18	mg/kg (ppm)
Dibenzo(a,h)anthracene	< 0.18	mg/kg (ppm)

OTHER SEMIVOLATILE COMPOUNDS§§

2-Methylnaphthalene	4.4	mg/kg (ppm)
Bis(2-ethylhexyl)phthalate	1.5	mg/kg (ppm)
Benzoic acid	< 16	mg/kg (ppm)
n-Nitroso-dimethylamine	< 3.0	mg/kg (ppm)
Benzidine	< 3.0	mg/kg (ppm)
1,2,4,5-Tetrachlorobenzene	< 2.8	mg/kg (ppm)
4-Aminobiphenyl	< 2.7	mg/kg (ppm)
3-Nitroaniline	< 2.2	mg/kg (ppm)
4-Nitroaniline	< 2.2	mg/kg (ppm)
3-Methylcholanthrene	< 1.7	mg/kg (ppm)
Phenacetin	< 1.5	mg/kg (ppm)
3,3'-Dichlorobenzidine	< 1.3	mg/kg (ppm)
2-Picoline	< 1.3	mg/kg (ppm)
1-Naphthylamine	< 1.3	mg/kg (ppm)
2-Naphthylamine	< 1.3	mg/kg (ppm)
P-Dimethylaminoazobenzene	< 1.1	mg/kg (ppm)
2-Nitroaniline	< 1.0	mg/kg (ppm)
2,4,5-Trichlorophenol	< 0.95	mg/kg (ppm)
2,3,4,6-Tetrachlorophenol	< 0.95	mg/kg (ppm)
Ethyl methanesulfonate	< 0.90	mg/kg (ppm)
Phenol	< 0.89	mg/kg (ppm)
1-Chloronaphthalene	< 0.89	mg/kg (ppm)
4-Chloroaniline	< 0.83	mg/kg (ppm)
2,3-Dimethylphenol	< 0.76	mg/kg (ppm)
Pentachlorobenzene	< 0.76	mg/kg (ppm)
Pentachloronitrobenzene	< 0.76	mg/kg (ppm)
Pronamide	< 0.76	mg/kg (ppm)
n-Nitroso-di-n-propylamine	< 0.62	mg/kg (ppm)
Hexachlorobutadiene	< 0.62	mg/kg (ppm)
Hexachlorocyclopentadiene	< 0.59	mg/kg (ppm)
4,6-Dinitro-2-methyl phenol	< 0.59	mg/kg (ppm)
Pentachlorophenol	< 0.59	mg/kg (ppm)
Di-n-octyl phthalate	< 0.59	mg/kg (ppm)

Methyl methanesultonate	< 0.57	mg/kg (ppm)
2,4-Dichlorphenol	< 0.55	mg/kg (ppm)
2,4-Dinitrotoluene	< 0.55	mg/kg (ppm)
4-Bromophenyl phenyl ether	< 0.55	mg/kg (ppm)
1,4-Dichlorobenzene	< 0.53	mg/kg (ppm)
Benzyl alcohol	< 0.53	mg/kg (ppm)
Dibenzofuran	< 0.53	mg/kg (ppm)
Diphenylamine	< 0.53	mg/kg (ppm)
1,2,4-Trichlorobenzene	< 0.51	mg/kg (ppm)
4-Chloro-3-methylphenol	< 0.51	mg/kg (ppm)
1,2-Diphenylhydrazine	< 0.51	mg/kg (ppm)
2,6-Dichlorophenol	< 0.51	mg/kg (ppm)
2,4-Dinitrophenol	< 0.49	mg/kg (ppm)
N-Nitrosopiperidine	< 0.46	mg/kg (ppm)
1,2-Dichlorobenzene	< 0.44	mg/kg (ppm)
4-Nitrophenol	< 0.44	mg/kg (ppm)
7,12-Dimethylbenz(a)anthracene	< 0.43	mg/kg (ppm)
2,4,6-Trichlorophenol	< 0.40	mg/kg (ppm)
Hexachlorobenzene	< 0.40	mg/kg (ppm)
1,3-Dichlorobenzene	< 0.38	mg/kg (ppm)
Bis(2-chloroethoxy)methane	< 0.38	mg/kg (ppm)
Dimethyl phthalate	< 0.38	mg/kg (ppm)
2,6-Dinitrotoluene	< 0.38	mg/kg (ppm)
N-Nitroso-dibutylamine	< 0.38	mg/kg (ppm)
Acetophenone	< 0.34	mg/kg (ppm)
Dibenz(a,j)acridine	< 0.34	mg/kg (ppm)
Bis(2-chloroisopropyl)ether	< 0.30	mg/kg (ppm)
Nitrobenzene	< 0.30	mg/kg (ppm)
Di-n-butyl phthalate	< 0.30	mg/kg (ppm)
2-Chlorophenol	< 0.25	mg/kg (ppm)
Hexachloroethane	< 0.25	mg/kg (ppm)
α,α'-Dimethylphenethylamine	< 0.25	mg/kg (ppm)
Isophorone	< 0.23	mg/kg (ppm)
2-Nitrophenol	< 0.23	mg/kg (ppm)
Aniline	< 0.22	mg/kg (ppm)
Butylbenzyl phthalate	< 0.21	mg/kg (ppm)
2-Methyl phenol	< 0.19	mg/kg (ppm)
4-Methyl phenol	< 0.19	mg/kg (ppm)
n-Nitroso-diphenylamine	< 0.17	mg/kg (ppm)
Diethyl phthalate	< 0.12	mg/kg (ppm)
2-Chloronaphthalene	< 0.11	mg/kg (ppm)
Bis(2-chloroethyl)ether	< 0.083	mg/kg (ppm)
4-Chlorophenyl phenyl ether	< 0.083	mg/kg (ppm)
Total polychlorinated biphenyls (PCBs)	< 0.021	mg/kg (ppm)
DIOXINS¶¶		
Total TCDD	< 0.1	µg/kg (ppb)
Total PeCDD	< 0.6	µg/kg (ppb)
Total HxCDD	< 0.3	µg/kg (ppb)
Total HpCDD	< 0.6	µg/kg (ppb)
FURANS¶¶		
Total TCDF	< 0.08	µg/kg (ppb)
Total PeCDF	< 0.4	µg/kg (ppb)
Total HxCDF	< 0.2	µg/kg (ppb)
Total HpCDF	< 0.3	µg/kg (ppb)

† Measured in 1:1 ash:H_2O.
‡ Measured in saturated extract.
§ Measured by acid titration.
¶ Dry ashed at 485°C for 10-12 hours.
# Organic C, sample pretreated with acid and analyzed by dry combustion and IR detection of CO_2; N, Kjeldahl procedure with nitrate prereduction; S, dry combustion and IR detection of SO_2; Cl, H_2O/carbon black extract and colorimetric analysis; other elements, Inductively Coupled Plasma (ICP) analysis of microwave digest with conc. HNO_3-H_2O_2.
†† NO_3,and NH_4, extracted with 2 M KCl and analyzed by colormetric methods; SO_4, 0.008 M calcium phophate extract and colorimetric analysis.
‡‡ N, AOAC 993.13; P, AOAC 960.03; K, AOAC 983.02; B, EPA 6010.
§§ EPA 8270.
¶¶ EPA 8280.

Table 3. **Soluble and leachable elements and organics in fly ash from alfalfa gasification test burn (mg/L).**

Analyte	Saturated water extract†	Toxicity Characteristic Leaching Procedure (TCLP)‡
TOTAL ELEMENTS		
K	66100	
Cl	20200	
S§	1230	
Na	762	
Mg	651	
Ca	90.3	
Rb	48.3	
Si	41.8	
Mo	10.2	
P	9.44	
Fe	4.90	
Al	0.809	
V	0.283	
Sr	0.167	
B	0.137	
Li	1.13	
Ba	0.102	< 0.5
Ti	0.075	
Mn	0.058	
Ag	< 0.24	
As	< 0.133	< 0.12
Be	< 0.007	
Cd	< 0.020	< 0.004
Co	< 0.041	
Cr	< 0.048	< 0.01
Cu	< 0.089	
Pb	< 0.287	< 0.08
Se		< 0.13
Zn	< 0.024	
SEMIVOLATILE ORGANIC COMPOUNDS		
o-Cresol		< 0.0045
m+p-Cresol		< 0.0045
2,4-Dinitrotoluene		< 0.013
Hexachlorobenzene		< 0.0095
Hexachlorobutadiene		< 0.014
Hexachloroethane		< 0.0060
Nitrobenzene		< 0.0070
Pentachlorophenol		< 0.014
2,4,5-Trichlorophenol		< 0.0080
2,4,6-Trichlorophenol		< 0.0095
Pyridine		< 0.0075
VOLATILE ORGANIC COMPOUNDS		
Benzene		< 0.020
Carbon tetrachloride		< 0.034

Chloroform	< 0.020
1,4-Dichlorobenzene	< 0.020
1,2-Dichloroethane	< 0.020
1,1-Dichloroethene	< 0.032
Methyl ethyl ketone	< 0.20
Tetrachloroethene	< 0.16
Trichloroethene	< 0.042
Vinyl chloride	< 0.032

† TCLP Extraction, EPA 1311; Hg, EPA 7470A; Ag, EPA 7760A; other elements, EPA 6010A; semivolatile organic compounds, EPA 8270; volatile organic compounds, EPA 8240.

‡ Cl, measured by ion chromotograph; other elements measured by Inductively Coupled Plasma (ICP)

§ SO_4-S, determined by ion chromotography, accounted for 254 mg/L.

ATTACHMENT 4

BIOMASS ENERGY PRODUCTION EFFECTS ON THE ENVIRONMENT

IMPACT OF ALFALFA ON WATER QUALITY

JUNE 30, 1997

Biomass Energy Production Effects on Environment

Impact of Alfalfa on Water Quality

Research report submitted to
Minnesota Valley Alfalfa Producers

Padam P. Sharma, and John M. Moncrief

Department of Soil, Water and Climate &
West Central Experiment Station
University of Minnesota

June 30, 1997

Table of Contents

Executive Summary

Alfalfa is being promoted in western Minnesota to harvest the leaves for animal feed and stems to generate electricity. Dominance of row crop agriculture in western Minnesota is also identified as a primary, non-point source of sediments and associated pollutants reaching the Minnesota River. As a perennial, leguminous crop grown with minimum inputs, alfalfa has potential to improve both in-situ soil productivity and downstream water quality.

Field study was initiated in 1996 to compare the volume of runoff and pollutants coming from alfalfa and corn-soybean fields in western Minnesota. Two pairs of alfalfa and corn-soybean watersheds were instrumented at Morris in the Fall of 1996 to measure rainfall, runoff, and sample water for sediment load, phosphorus, nitrogen, biochemical oxygen demand, and chemical oxygen demand.

Runoff hydrographs of the record snow-melt event during the spring of 1997 at Morris show alfalfa fields yielding more runoff than corn-soybean fields. The chemographs relating the loading of a suite of pollutants with cumulative runoff show trends of alfalfa fields yielding more ammonium than the corn fields. The corn fields tended to yield more sediment, nitrate, DMRP, bio-available P, and total P. There was no appreciable trend in the distribution of BOD and COD between the corn and alfalfa fields. The analysis of variance showed corn fields yielding significantly higher amounts of sediments and total phosphorus of which the latter, at this stage of preliminary observation, can not be attributed to crop rotation effects. The runoff amounts and other water quality constituents between the corn-soybean and alfalfa fields were not significantly different for the Spring 97 runoff event.

Simulated rainfall-runoff experiments were also conducted on existing crop rotation - input management study plots at Lamberton. In general, soybean fields following corn under four-year (corn-soybean-oat-alfalfa) rotation with organic management had higher infiltration capacity than alfalfa fields following oat with low purchased input management. Regardless of soil and crop management, alfalfa fields yielded lower sediments in runoff water than the soybean fields.

Introduction and Objectives

In justification of the proposed Minnesota Agri-Power Project, Westinghouse Technology Bulletin No. 59 states, "Alfalfa is a renewable resource that provides significant environmental, agricultural and economic benefits. By improving soil and water quality and wildlife habitat, alfalfa production sustains agricultural productivity and environmental quality." The research focus of this project is geared towards quantifying the above statement by measuring how much of the precipitation water enters into the soil (hence, utilized for biomass production) and how much water runs off (and hence, carrier of sediments and pollutants) the field of alfalfa vs. existing corn-soybean fields.

Management of water is the key to environmentally and economically sustainable production of alfalfa. Compared to annual crops of corn and soybean, alfalfa uses higher amounts of water from a deeper root zone. The desirable management objective for the farmers is to maximize utilization of precipitation water in the field and improve the productivity of soil for succeeding crops in the rotation. The desirable land use management objective for the state is to minimize runoff and erosion from lacustrine landscapes and nitrate leaching to ground water from glacial outwash plains in the proposed alfalfa crop expansion area in Western Minnesota. The goal is to improve the surface and ground water quality of the Minnesota River basin and its tributaries. **The specific objectives** of this phase of environmental research program which states, "**Measure the impact of introduction of alfalfa in a corn-soybean rotation on erosive losses of a suite of pollutants**", is in the interest of both the alfalfa farmer and the public at large.

Specific Objectives

Background

Dominance of row crop agriculture contributes to high sediment load in the Minnesota River

The Minnesota River is one of the 20 most polluted waterways in the United States. A significant part of the Minnesota River's water quality problem comes from sediment that enters the river and its tributaries throughout its 4-million-hectare watershed predominantly used for row-crop agriculture. Continuous corn, small grains, and corn-soybean cropping systems dominate the agricultural land use practices in the Minnesota River basin.

As a general rule, soil erosion occurs during early season when the exposed soil surface in a row-cropped field is acted upon by high volume snow-melt runoff and raindrop impact from spring precipitation events. As the season progresses and a crop cover is established, the erosion rates are decreased. Adoption of high residue, conservation tillage practices significantly reduce the soil erosion from the row-cropped agricultural lands. However due to low adoption, the water quality benefits of conservation tillage systems have yet to be realized. Specifically, a full adoption of conservation tillage systems is critical on the highly erodible, gently to steeply rolling, row-cropped landscapes prevalent in the Minnesota River basin.

A general strategy for the management of agricultural lands and reducing the delivery of pollutants to the Minnesota River would involve efforts to (1) improve and sustain soil quality through adoption of conservation and sustainable tillage practices, and (2) improve the efficiency and application of farm inputs, including nutrients and crop protection products. The goal is to improve on-farm productivity and reduce the off-farm delivery of sediment, nutrients, and pesticides due to erosion, runoff, and drainage.

Introduction of alfalfa into row-crop rotation offers promise of judicious soil and water management

Compared to row crop agriculture, an established crop of forage such as alfalfa provides continuous surface cover throughout the growing season. Alfalfa is a perennial crop which following winter dormancy or cutting regrows from the crown. Alfalfa grows under diverse environmental conditions and tolerates extremes in temperature and survives severe moisture deficits. In Minnesota, adapted disease resistant varieties usually maintain productive stands for 4 years following the seeding year. Alfalfa needs a minimum of fertilization and pesticides.

Being a deep rooted leguminous crop, alfalfa enhances soil quality through improvement in fertility and soil structure. Improved soil quality means increased onsite productivity due to increased storage of precipitation water in the root zone and decreased offsite delivery of runoff and pollutants. Available research information on the effect of forage crop such as alfalfa following continuous corn-soybean rotation in the United States and other countries around the World indicate positive improvement in soil structure and fertility over time. Introduction of alfalfa into a row crop rotation shows promise of meeting above mentioned strategies and goals of judicious soil management and improve the water quality of Minnesota River.

Research goals and deliverables

Interpretations of research results conducted in a different physiographic region is subject to variability of climate, soil, landscape characteristics, and management practices specific to that region. To systematically document the perceived "mostly positive" effects of introduction of alfalfa into the corn-soybean cropping system in western Minnesota and assure sustained availability of alfalfa to the proposed power plant in the future, the overall research goal is to evaluate:

Long term research goals

- best management practices for alfalfa and succeeding crops in the cropping sequence
- changes in indicators of soil and water quality over time
- effect of alfalfa based land use on Minnesota River water quality

Deliverables for this phase of research

For this phase of the environmental research, the following deliverables were set:

a) Establishment of small, paired watershed study sites to evaluate the total effect of alfalfa in the rotation on runoff and losses of total P, soluble P, bioavailable P, sediment, ammonium, and nitrate.
b) Instrumentation of the watersheds with rain-gages, flumes, flow sensors, water quality samplers, and data loggers to continuously monitor snow-melt and precipitation-runoff events throughout the year
c) Development of protocol for runoff sample collection, handling, transportation, and determination of soluble P, total P, bioavailable P, sediment, nitrate, ammonium, biochemical oxygen demand, and chemical oxygen demand.
d) Characterization of watersheds and soils with detailed topographic and soil surveys
e) Analysis of data from each runoff event with hydrographs, chemographs, and appropriate statistical tools.

Research Methodology

Paired watershed study at Morris

The physiography and soils

The studies are carried out at the University of Minnesota, West Central Experiment Station located at the east edge of Morris in Stevens County, Minnesota (T. 125N, R. 41W). The soils are primarily formed on calcareous loamy glacial till (Rust and Erickson, 1971). The relief of the area surrounding the station is nearly level to gently and steeply rolling till moraine deposits through which the Pomme de Terre River Valley is carved out. The study area is dominated by gently sloping to hilly, well-drained Buse-Barnes-Forman soil association which are mostly loam or clay loam soils. The dominant soil series at the watershed experiment site include the well drained, gently (2-6%) to moderately sloped (6 - 12% slopes), Barnes - Buse loam and the steeply sloping (12 - 18 % slopes), Buse - Barnes loam (Lewis et. al, 1971).

The paired watersheds

Four field size watersheds laying east-west and draining south were selected on the east ½ of West Central Experiment Station field E-5. Figure 1 shows the general relief of the study area. The fields were under wheat in 1995 and they were chisel plowed in the fall after harvest of the wheat crop. The eastern (0.65 ha with designation Plot-5) and the western (1.78 ha with designation Plot-8) fields were seeded with alfalfa in 1996. The central two watersheds (total of 1.82 ha with designation Plot-6 and Plot-7) were seeded with corn in 1996. The corn was harvested for grain in October and plowed in November 1996 using a coulter chisel plow with 4-inch twisted shovels (Glencoe Soil Shovels). Corn stalks were not chopped. The alfalfa fields were seeded on May 28 with variety MP2000 and harvested on July 17, 1996. Both the fields were inter-seeded with MP2000 on August 8 to reinforce the stand. A second cutting of alfalfa was done on August 29, 1996.

At the lower boundaries of each field, earthen berms were constructed to guide water towards the flumes. A flume is a specially shaped open channel structure which converges the incoming flow, guides through its neck, and diverges the flow as it exits the flume. The flow rate through the flume is a function of liquid level in the flume.

Flumes for runoff measurements

We used two fiberglass constructed flumes in sequence to capture and measure the flow coming out of each watershed. A 6-inch Parshall flume was located at the convergence point of the berms, and water then passed through a 4-inch Palmer Bowlus flume at the down slope end. The two flumes were selected to accommodate both large and small flows expected to occur during runoff events. The Parshall flumes were installed and leveled during the Fall of 1996. The smaller Palmer-Bowlus flumes were installed and leveled during second week of March 1997, just before the beginning of snow-melt event.

WATERSHED STUDY AT MORRIS SURFACE ELEVATION

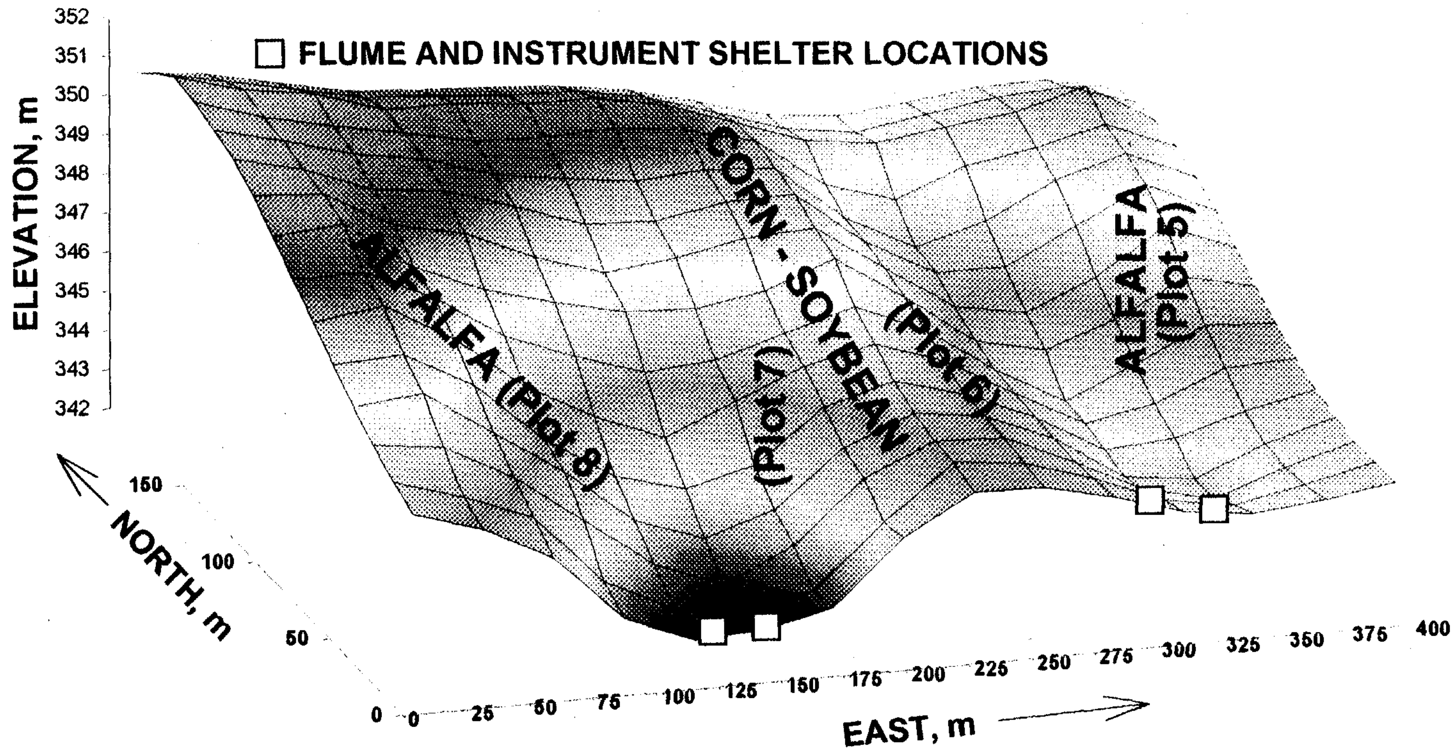

Fig. 1: Approximate surface topography and location of the four watershed plots at the alfalfa water quality study site in Morris.

Data acquisition hardware and sampling protocol

Along the side of the two flumes at each watershed, an instrument shelter was constructed to house a Champbell Scientific 21-X data logger, an ISCO water sampler, a gas cylinder, and batteries for power backup. A 110-V electrical power source was also connected to each instrument shelter. A pressure differential transducer was connected with tygon tubing to a gaging tube at each flume to measure the level of water in the flumes. The tygon tubing carried N-gas at a constant rate. The pressure with which the gas bubbles as it comes out of water is proportional to the height of water in the flume. The pressure difference is measured in voltage with the transducer. Each transducer was individually calibrated to convert volt readings into height of water which was then used to calculate the flow rate passing through the flumes. A recording raingage and three copper-Constantan thermocouples were connected to the data logger to measure rainfall, water, air, and soil/snow temperatures. A 24-bottle ISCO water sampler at each site was individually programmed to sample runoff water during a flow period.

A program was written for the data-logger to sense the instruments every 30 seconds and record cumulative precipitation and flow every five minutes. Whenever there was a minimum depth of flow, the program triggered the ISCO sampler to collect 65-ml of runoff water every five minutes. Twelve sub-samples were composited into a one-liter bottle representing an hour of flow. From the bottles collected during the flow event of the past 24-hour period, representative samples were transported the same day to the University of Minnesota, Soil Water & Climate laboratory at St. Paul for determination of biochemical oxygen demand. Remaining water samples were refrigerated at West Central Experiment Station in Morris. The samples were conveniently transported to St. Paul to determine sediment load, chemical oxygen demand, dissolved phosphorus, bioavailable phosphorus, total phosphorus, ammonium, and nitrate nitrogen.

Simulated rainfall experiments at Lamberton

Long term crop management and rotation study

A Variable Input Crop Management (VICM) study has been underway at Southwest Experiment Station (SWES) at Lamberton since 1989 to evaluate the performance of a two-year corn-soybean rotation vs. four-year corn-soybean-oat-alfalfa rotation under different levels of inputs (Perillo et al., 1996). Among four management treatments included in the VICM study, we selected the Low Purchased Inputs (LPI) and the organic (ORG) plots under a 2-year corn-soybean (CSCS) and a 4-year corn-soybean-oat-alfalfa (CSOA) rotation for measurement of runoff and water quality using simulated rainfall during April 21 - 26, 1996.

Briefly, the LPI management system involved primary tillage with chisel plow following corn, moldboard plow following alfalfa, and no-till following soybean (with secondary tillage before planting). Dependent on crop residue and soil conditions, disc or field cultivators are used for pre-planting secondary tillage. Crops are planted in 30-inch (0.76 m) rows for corn and soybean and oat is drilled with alfalfa undersown. Fertilizers are applied based on soil tests (NPK), previous crop, and a realistic yield goal. Both mechanical and chemical methods are used for weed control.

For organic treatment, primary tillage is done with moldboard plow following corn and alfalfa and with chisel plow following soybean. Disc and field cultivators are used for weed control before planting. The four year rotation receives solid beef manure and the 2-yr rotation receives liquid hog manure at rates based on soil tests. The weeds are controlled only mechanically with rotary hoe and row cultivator.

In cooperation with the Minnesota Department of Agriculture, we applied simulated rain and measured runoff and water quality on eight plots during April 21-26, 1996. The snow had melted during the last month and the soil temperatures were above freezing in the root zone. Four plots had alfalfa residues from year before on a 4-year rotation (CSOA) two each with LPI and ORG management. Four plots had soybean residues from year before: two plots each on 2-year (CSCS) with LPI and 4-year (CSOA) with ORG management.

Rainfall simulator

A Purdue-type sprinkling rainulator was used to rain on 30-inch (0.76 m) by 24-ft (7.31 m) runoff plots prepared with corrugated metal boarders and collection troughs. Water pumped with about 6 lb. in^{-2} (41.4 kPa) pressure is supplied to the simulator nozzles to mimic approximate terminal velocity of natural rainfall. The rainfall intensity was adjusted to 2 $inch.h^{-1}$ (50.8 mm) until steady state runoff measurements were obtained. When plots with high infiltration rates did not yield any runoff for 2 hours of water application, the application rates were increased to 3 $inch.h^{-1}$ (76 mm). After the initiation of runoff, water samples were collected every 5 minutes for determination of runoff volume until steady state runoff rates were observed. The water samples were transported to University of Minnesota, Department of Soil, Water and Climate laboratory for analysis of sediment load, total phosphorus, dissolved phosphorus, and chemical oxygen demand.

Determination of a suite of pollutants

Total Sediments

Sediment in water often leads to impaired habitat for aquatic life, and decreased photosynthetic activity. Sediment load is a major contributor to increased total suspended solids and turbidity of water. Sediment concentration is determined by thoroughly shaking the sample and evaporating a known volume of sub-sample by oven drying at 104 °C (US-EPA, 1971).

Phosphorus

Excessive levels of phosphorus often promote eutrophication, which results in the depletion of oxygen in nutrient rich waters with abundant algal growth. Phosphorus may be transported into water in the adsorbed phase with eroded sediment or organic material, or in soluble inorganic form (orthophosphate) with runoff water.

We tested the water samples for three indicators of phosphorus, namely; Dissolved Molybdate Reactive Phosphorus (DMRP), Bioavailable Phosphorus (BP), and Total Phosphorus (TP). The DMRP measures phosphorus in solution, and the TP indicates both the dissolved and sediment-adsorbed phosphorus. The BP is an estimate of phosphorus (both dissolved and adsorbed) that would be available for growth of aquatic vegetation. After filtration of water samples with glass fiber membrane filter, the DMRP was determined using Mo blue method (US-EPA, 1971). The total phosphorus (TP) was determined by digesting with HNO_3 and $HClO_4$ and neutralization with NaOH (Olson, and Sommers, 1982). The bioavailable phosphorus is determined by mixing thoroughly with NaOH and neutralization with H_2SO_4 (Sharpley, et al., 1992).

Nitrate and Ammonia

Nitrogen is a source of nutrients for biomass production in the aquatic habitat, and excessive nitrates in drinking water is known to cause health problems for infants. Ammonium is determined by gas diffusion-conductivity method by passing alkaline reagent treated sample solution through a gas permeable membrane into an NH_3-absorber solution of known conductivity (Carlson et al., 1990). Nitrate is quantitatively reduced to NH_3 by Cu^{++} activated granular Zn column in the reagent stream. The NO_3 concentration is calculated by subtracting the NH_4 determined without the Zn.

Biochemical (BOD) and Chemical Oxygen Demand (COD)

The biochemical oxygen demand (BOD) is the amount of oxygen required by bacteria to decompose organic material in the water under aerobic conditions. The chemical oxygen demand (COD) is an estimate of the total available carbon and other food source for oxidation by chemical and biochemical reactions. The BOD test reflects the effect of easily decomposed organic materials on oxygen depletion while COD reflects total source of oxidizable substrates.

The COD is determined using a spectrophotometer after oxidization with premixed COD reagents (US-EPA, 1989). For BOD, the water samples collected at the sites are stored at 4 °C and analyzed for oxygen within 24 hours. The samples are diluted 2, 6, and 10 times and incubated for five days. The comparison of oxygen remaining in the samples with its original counterpart is used to calculate the BOD.

Results and Discussion

Runoff and pollutant delivery from paired watersheds at Morris

Precipitation during the winter of 1996-97 at Morris, MN

Table 1 below shows the monthly summary of precipitation and temperatures with deviations from 110-yr averages shown in the parenthesis. Except for February, the winter months of 1996-97 were colder than normal and the station received above normal precipitation and record amounts of snow fall. The unusually high precipitation of ice sleet during November 15-17, 1996 also produced a layer of ice specially on the relatively smooth alfalfa fields.

The four watersheds received various amounts of snowfall and snow drift during the winter of 1996-97. A snow course survey was conducted between December '96 and February '97 to measure the depth and density of snow every 10 meters in a north-south diagonal transect of about 200 meters at each field. Table 2 summarizes the average water equivalent of snowpack at the four plots.

The snow water equivalent data show a progressive increase in snow depth and density during the winter. Due to frequency of dominant north-west blizzards, significant amount of snow drifted from adjoining fields into the western watershed (Plot 8).

Table 1: Monthly summary of average daily temperature (°C) and total precipitation (mm) during November 96 to March 97 at Morris, Minnesota. The numbers in parenthesis denote above (+) or below (-) the 110 year (1886-1996) averages.

Month	Average Maximum Temperature	Average Minimum Temperature	Precipitation	Snow Fall
	(°C)		(mm)	
November-96	-2.8 (-6.8)	-10.8 (-4.4)	59.4 (34.8)	368 (244)
December-96	-9.8 (-5.4)	-17.6 (-3.1)	18.5 (1.5)	267 (97)
January-97	-11.0 (-3.2)	-20.8 (-2.0)	57.2 (40.1)	650 (455)
February-97	-4.4 (0.7)	-15.4 (1.0)	7.9 (-9.1)	130 (-48)
March-97	-0.4 (-2.8)	-10.5 (-2.4)	55.6 (26.9)	577 (373)

Table 2: Average water equivalents and density of snow-pack measured on 200-m long transect at each watershed.

	Alfalfa		Corn		Average Snow
Date	Plot 5	Plot 8	Plot 6	Plot 7	Density
		(mm)			(gm/cm^3)
12/12/96	42	42	39	42	0.215
1/3/97	64	83	56	59	0.267
1/21/97	95	148	76	87	0.309
2/18/97	153	249	127	142	0.434

The snow-melt and runoff events of Spring 1997

Figure 2-a shows the temperature and rainfall distribution during snow-melt periods between March 21 and April 8, and Fig. 2-b shows the runoff hydrographs for the four plots. The spring 1997 snow-melt started on March 21 on the eastern half plots of alfalfa (Plot-5) and corn (Plot-6), but the flow was low during the day and it froze during the night. The western half of the watershed (plots 7 and 8) started yielding water on March 26 when high temperatures during the day stayed above freezing.

From March 26, the flow continued on all plots during the day and slowed down during the nights and early morning hours due to below freezing temperatures. Significant snow-melt occurred between March 31 and April 3 when both day and night temperatures increased above freezing (Fig. 2-a). The snow-melt ended on April 1 on Plot 5, April 3 on Plot 6, April 4 on Plot 7. The snow-melt and sub-surface flow continued to trickle on Plot 8 (which had the deepest depths of snow at lower end of field) until April 14.

Runoff hydrographs

The amount of runoff from each plot depended on amount of snow, the aspect, and surface characteristics determined by the cropping system (Fig. 2-b). Even though of equal area, the south-west facing corn field (Plot 7) yielded more water than the adjacent south-east facing field of corn (Plot 6). Similarly, the smaller south-west facing alfalfa field (Plot 5) yielded more water than the south-west facing larger alfalfa field (Plot 8) even though the latter had more average depth of snow (Table 2). On an average, the alfalfa fields had more runoff than corn fields. This could be attributed to the ice layer formed by the freezing rains on November 15-17, 1996 on the relatively smooth alfalfa fields. The rougher corn fields may have less uniform coverage of ice layer, and hence more infiltration, due to its higher surface storage as a result of high-residue, on-contour, chisel plowing in the fall.

Figure 3 shows the relationship between the cumulative runoff amounts and the load of sediments coming from each plot. At a given amount of runoff, both corn fields yielded more sediments than both the alfalfa fields. The graph clearly manifests the role of alfalfa in protecting the soil surface against the erosive forces of running water and raindrop impact.

Summary of runoff and sediment load data

Table 3 summarizes the amounts of rainfall, snow-melt runoff, rainfall-runoff, sediment load due to snow-melt, and due to rainfall-runoff on the four plots. About 50-mm (2-inch) of rain on April 5 and 6 contributed to about 14% increase in runoff from alfalfa field (Plot 5) and about 19 and 25% of total flow in the two corn fields. The rainfall contribution to sediment load was 25% in the alfalfa field (Plot 5) and about 41 to 48 % on the corn field plots 6 and 7, respectively. On alfalfa Plot 8, due to continuation of snow-melt flow during April 5 and 6, the flow amounts between snow-melt and rainfall-runoff could not be discerned.

While the alfalfa Plot 5 produced higher runoff (Fig. 2-b), the sediment load per unit of runoff was significantly lower than both the corn plots (Fig. 3, Table 3). The sediment load due to rainfall-runoff shows that the raindrop impact doubled and quadrupled the sediment transport capacity of runoff on all plots. Compared to conventional tillage, the high residue, corn plots had about 63% surface cover (see last row on Table 3), and yet, the alfalfa cover protected soil erosion better than the well managed corn plots. While there was no significant difference in the amount of total runoff, analysis of variance showed that corn had significantly higher ($p = 0.025$) average sediment load than alfalfa.

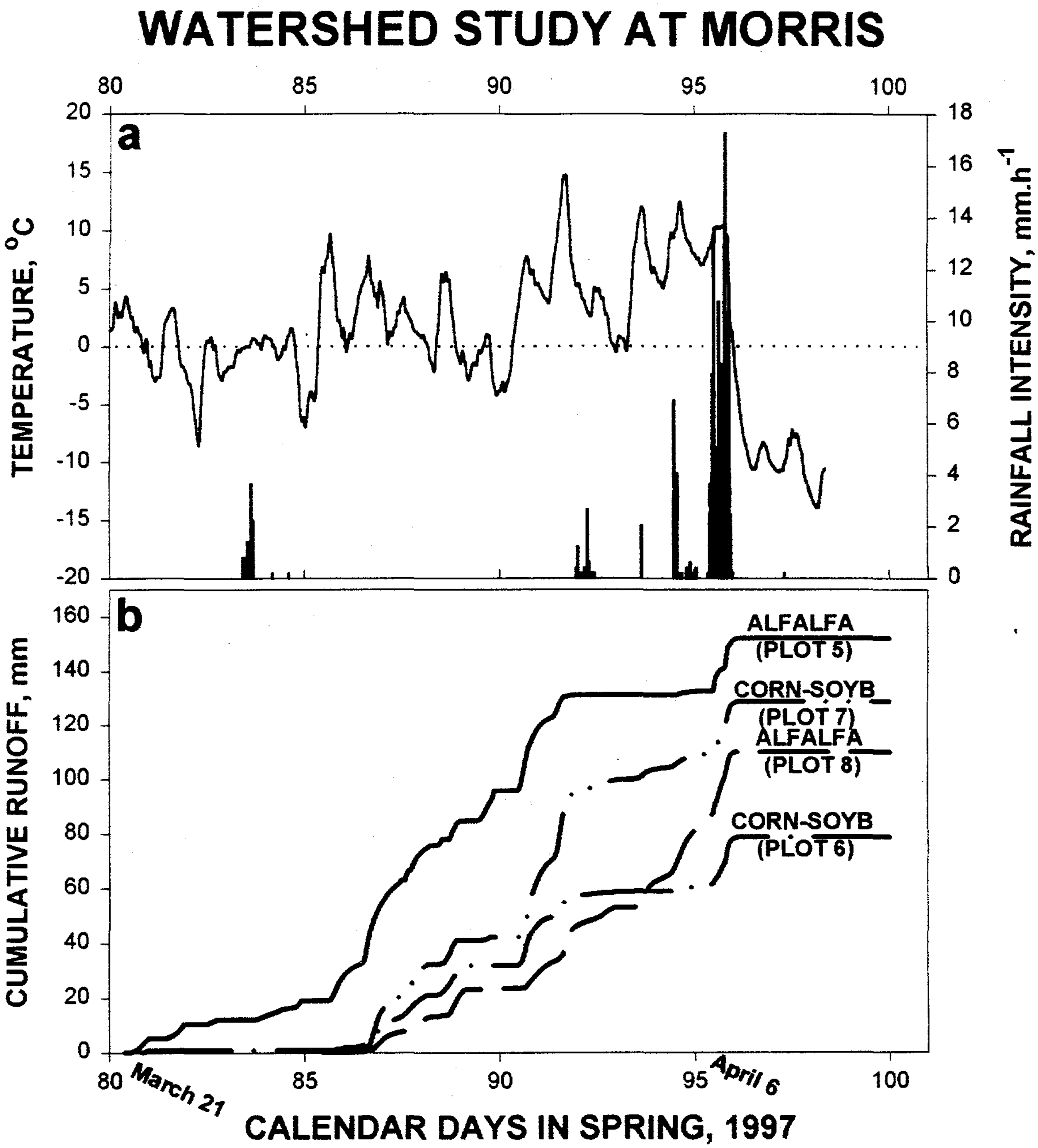

Fig. 2: (a) Distribution of average air temperature and rainfall, and (b) runoff hydrographs of the four watershed plots.

WATERSHED STUDY AT MORRIS

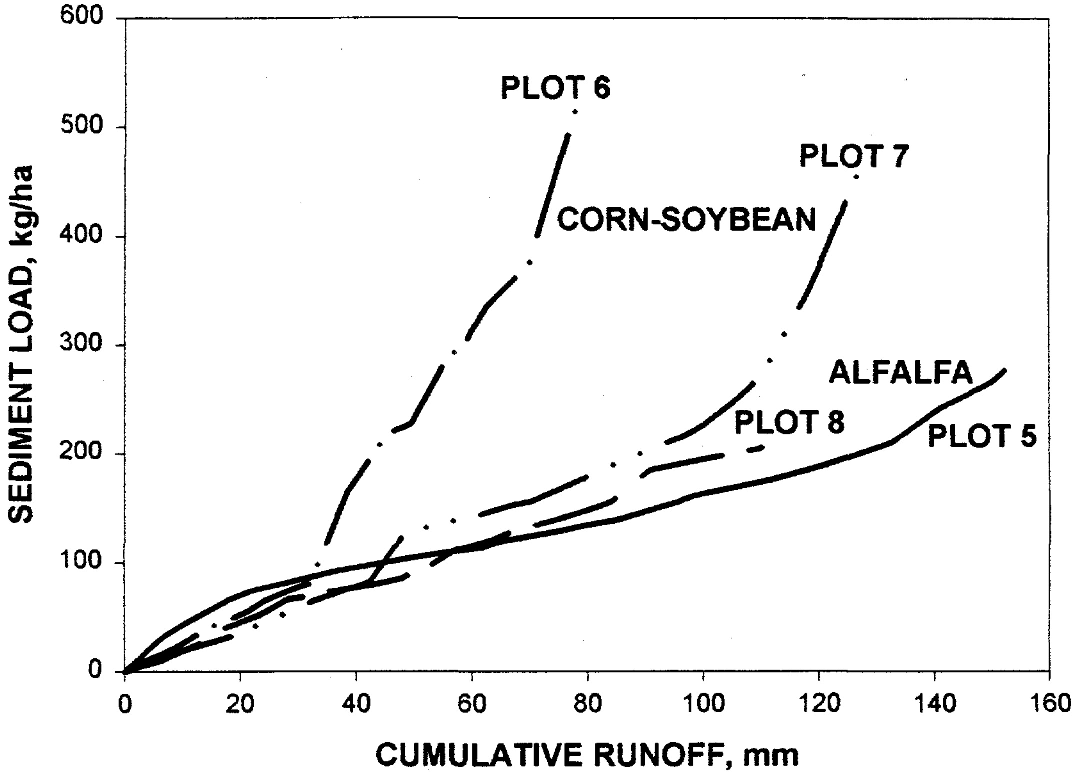

Fig. 3: Sediment load vs. cumulative runoff from the four watershed plots during spring-1997 at Morris.

Fate of other pollutants in runoff water

Figure 4 shows the distribution of different forms of phosphorus in runoff water. Figure 4-a, 4-b, and 4-c show that corn fields in general yielded more DMRP, bioavailable P, and total P than alfalfa. This does not necessarily indicate an effect due to crop rotation. It is suspected that the higher levels of phosphorus in corn plots may be due to residual effect of manuring and fertilization history of the runoff plots.

Figures 5-a and 5-b show the distribution of ammonium and nitrate nitrogen in spring-melt runoff water. In general, the alfalfa fields yielded more ammonium and the corn fields yielded more nitrates. Again, at the state of this preliminary and one-time spring-melt data, it can not be discerned whether these differences are due to crop rotation or due to residual effects of management history of these plots. Compared to sediment load, phosphorus, and nitrogen, no definite trend was observed in loading of BOD (Fig. 6-a) and COD (Fig. 6-b) in the runoff water.

Table 4 summarizes the total load of pollutants coming from each of the four watersheds during the spring runoff event of 1997. Both one way and two-way analysis of variance was performed on the cumulative amounts listed in Table 4. The one way analysis assumed the four fields as two observations each of corn and alfalfa. For two way analysis, we assumed plots with similar aspects as replications. Of the variables listed in Table 4, only total phosphorus (TP) showed a significant difference between alfalfa and corn. As discussed above, this could be an anomaly that needs to be evaluated with continued monitoring residual soil P and runoff P over a period of time.

WATERSHED STUDY AT MORRIS

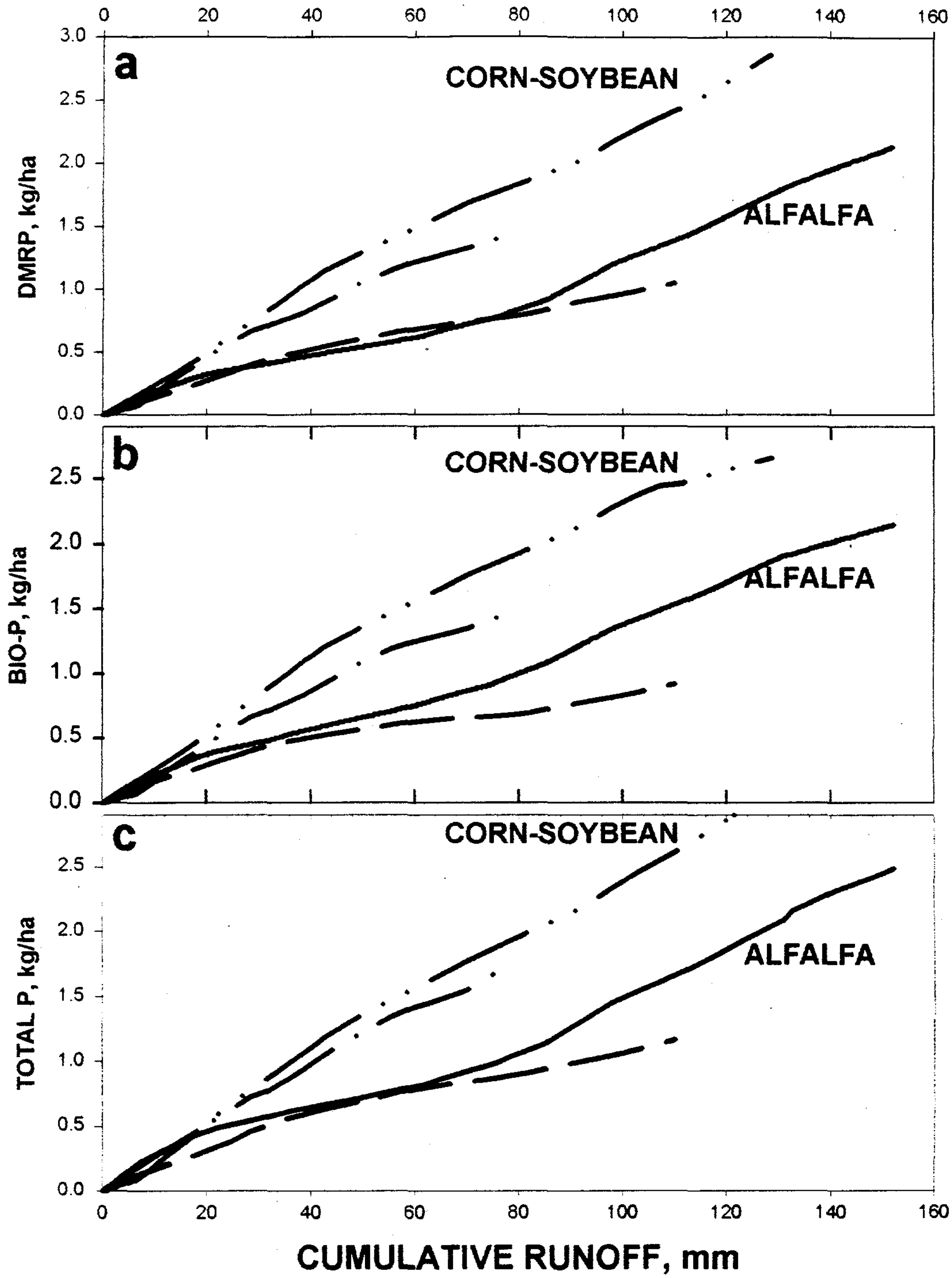

Fig. 4: Loadings of phosphorus vs. cumulative runoff:
(a) DMRP, (b) Bioavailable P, and (c) Total Phosphorus

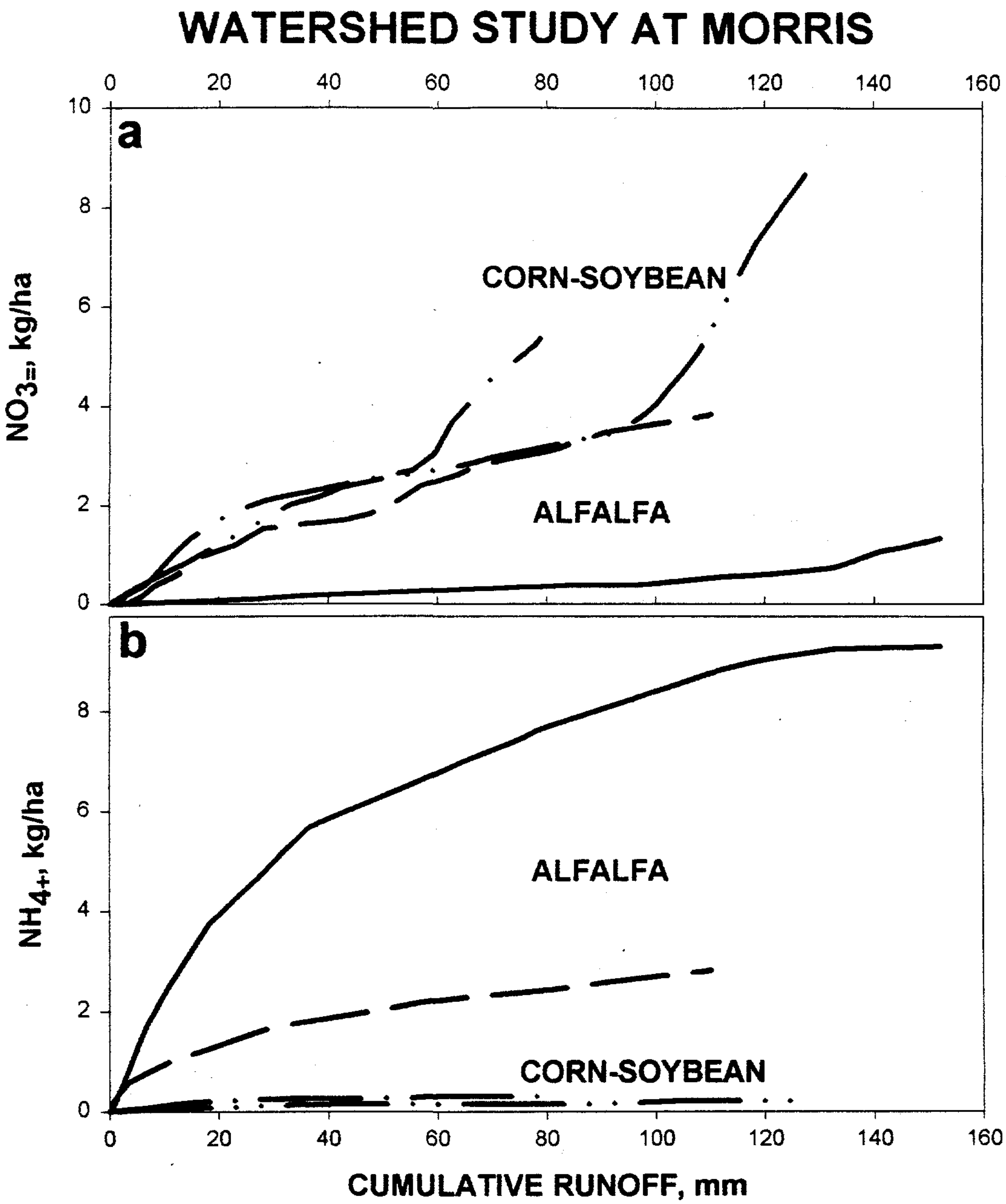

Fig. 5: Loadings of nitrogen vs. cumulative runoff: (a) nitrate, and (b) ammonium.

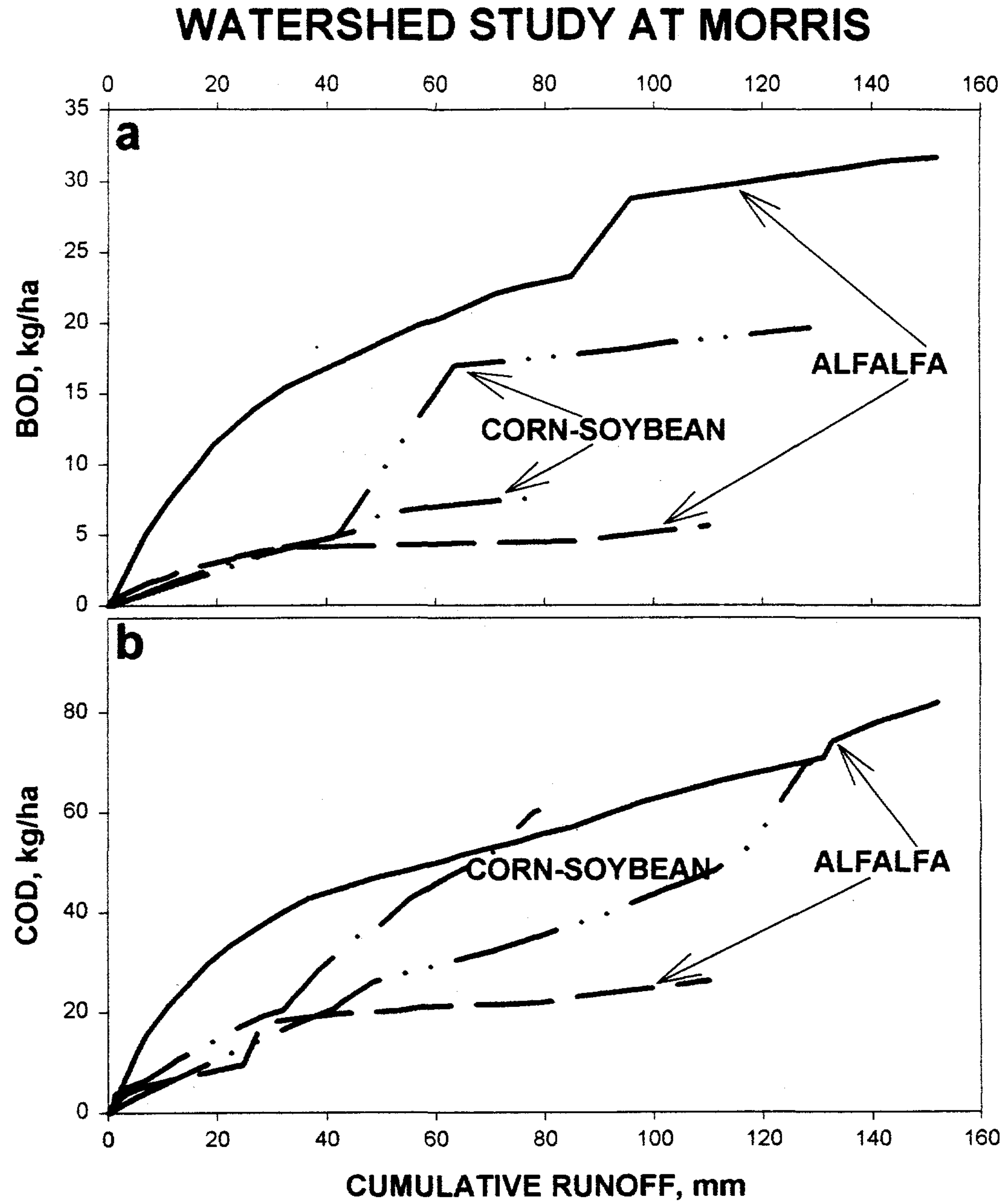

Fig. 6: Loadings of (a) biochemical oxygen demand (BOD) and, (b) chemical oxygen demand (COD).

Table 3: Summary of cumulative rainfall, runoff, sediment load, and sediment transport per unit of runoff due to snow-melt and precipitation during spring of 1997 at Morris.

	Alfalfa			Corn-Soybean		
Source of runoff and sediments	Plot 5	Plot 8†	**Mean**	Plot 6	Plot 7	**Mean**
Snow-melt						
Runoff, mm	131.0			59.0	104.6	
Sediment yield, $kg.ha^{-1}$	207.6			304.3	245.1	
Sediment load in runoff, $kg.\ ha^{-1}.mm^{-1}$	1.58			5.15	2.34	
Rainfall-Runoff						
Rain on April 5-6, mm	47.3	51.1		53.9	51.1	
Runoff, mm	21.2			19.8	23.9	
Sediment yield, $kg.ha^{-1}$	69.7			214.1	229.3	
Sediment load in runoff, $kg\ ha^{-1}.mm^{-1}$	3.29			10.8	9.6	
Total						
Runoff, mm	152.2	110.5	131.4	78.8	128.6	103.7
Sediment yield††, $kg.ha^{-1}$	277.3	208.3	**242.8**	518.5	474.4	**496.4**
Sediment load in runoff, $kg.ha^{-1}.mm^{-1}$	1.82	1.88	1.85	6.58	3.69	5.14
Avg. surface cover after snow-melt, %	74.5	83.0	78.8	61.0	65.5	63.3

† Due to continued snow-melt from Plot 8 on April 5 and 6, the flow volumes due to snow-melt and rainfall-runoff could not be discerned. †† The treatment means of sediment yield denoted by **bold faced** letters are significantly different by one- way ANOVA at p=0.025.

Table 4: Summary of total amounts of pollutants on runoff water from four watersheds during spring of 1997 at Morris.

	Alfalfa			**Corn-Soybean**		
Constituents in Runoff Water	**Plot 5**	**Plot 8**	**Mean**	**Plot 6**	**Plot 7**	**Mean**
Oxygen Demand						
Biochemical (BOD)	31.7	5.6	18.7	7.6	19.7	13.6
Chemical (COD)	82.1	26.3	54.2	60.3	69.8	65.1
Phosphorus						
Dissolved (DMRP)	2.14	1.07	1.61	1.45	2.86	2.16
Bio-available	2.15	0.93	1.54	1.47	2.66	1.57
Total†	2.48	1.17	**1.83**	1.75	3.09	**2.39**
Nitrogen						
Ammonium	9.30	2.82	6.06	0.31	0.22	0.26
Nitrate	1.34	3.90	2.62	5.37	8.92	7.15

† The treatment means of total phosphorus denoted by **bold faced** letters are significantly different by two-way ANOVA at p=0.02.

Effect of management and rotation on runoff and water quality

Rainfall simulation results from Lamberton

Figure 7 shows the relationship between the amount of applied rainfall and the cumulative runoff observed on the eight plots. Input management, sequence of crops in rotation, and the residue cover influenced the amount of rain needed to initiate runoff and the steady state infiltration rates. The runoff started earliest on the four-year (CSOA) alfalfa plots with LPI management. The four-year soybean fields where alfalfa was planted two years ago with the organic management had the highest infiltration rates and needed the most rainfall to initiate runoff. The two year corn-soybean plots with LPI management performed in between the two.

The high infiltration rates of organic, soybean plots in the four-crop rotation following corn can be attributed to effects of tillage and presence of macro-pores due to decomposition of alfalfa and oat roots from previous crops. Both the prior crop of corn and soybean received primary tillage in the fall followed by secondary tillage in the spring. The high runoff and low infiltration rates off the four-crop rotation alfalfa plots with LPI management may be a result of compaction as no primary tillage was done on both the previous crops of oat and alfalfa.

Alfalfa provides surface cover to protect against raindrop impact

Figure 8 shows the relationship between the amount of runoff and sediment load in the runoff water. Even though the amount of runoff from the soybean plots with organic management was small, the runoff water had high sediment loads. In general, regardless of input management, the alfalfa fields produced runoff with low sediment concentrations than the soybean fields. Similar to observations of watershed runoff data from Morris, the low sediment load on alfalfa covered fields is due to protection of soil against raindrop impact by higher surface cover.

Table 5 summarizes the average amount of applied rain needed to initiate runoff, and the steady state infiltration rates measured from the eight plots. Table 6 lists the average concentrations of sediments, dissolved and total phosphorus, and chemical oxygen demand (COD) in runoff water samples collected from each of the rainfall-runoff observations.

Two way analysis of variance to evaluate the effects of the four rotation-management treatments on the various infiltration and water quality parameters showed that :

- soybean under four-year rotation with organic management had significantly higher infiltration capacity than alfalfa with low input management.
- On the other hand, the runoff water coming from the same soybean plots had higher concentrations of sediments and total phosphorus.
- The rotation management treatments included in this rainfall simulation study did not show significant effects on the amounts of DMRP and COD.
- Further rainfall simulation experiments are needed to fully understand the interaction of crop sequence and management practices on a given soil.

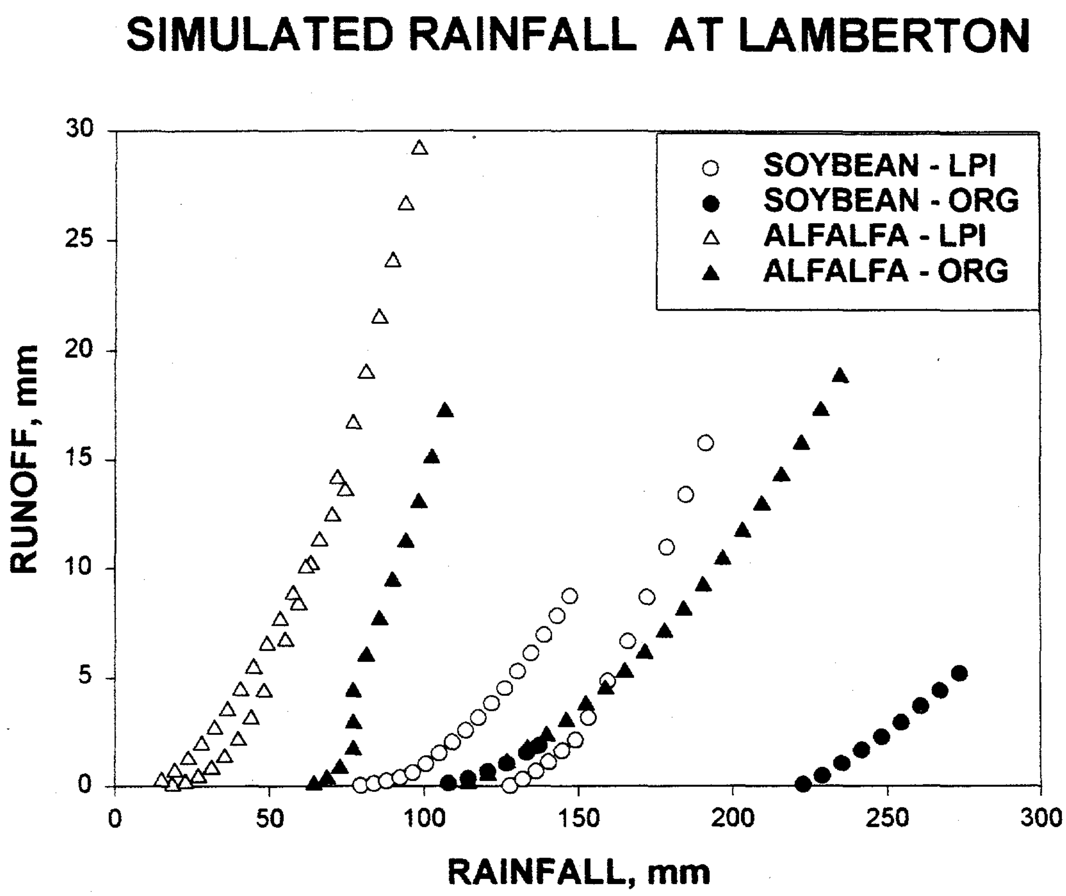

Fig. 7: Simulated rainfall and runoff from the eight variable input management study sites at Lamberton.

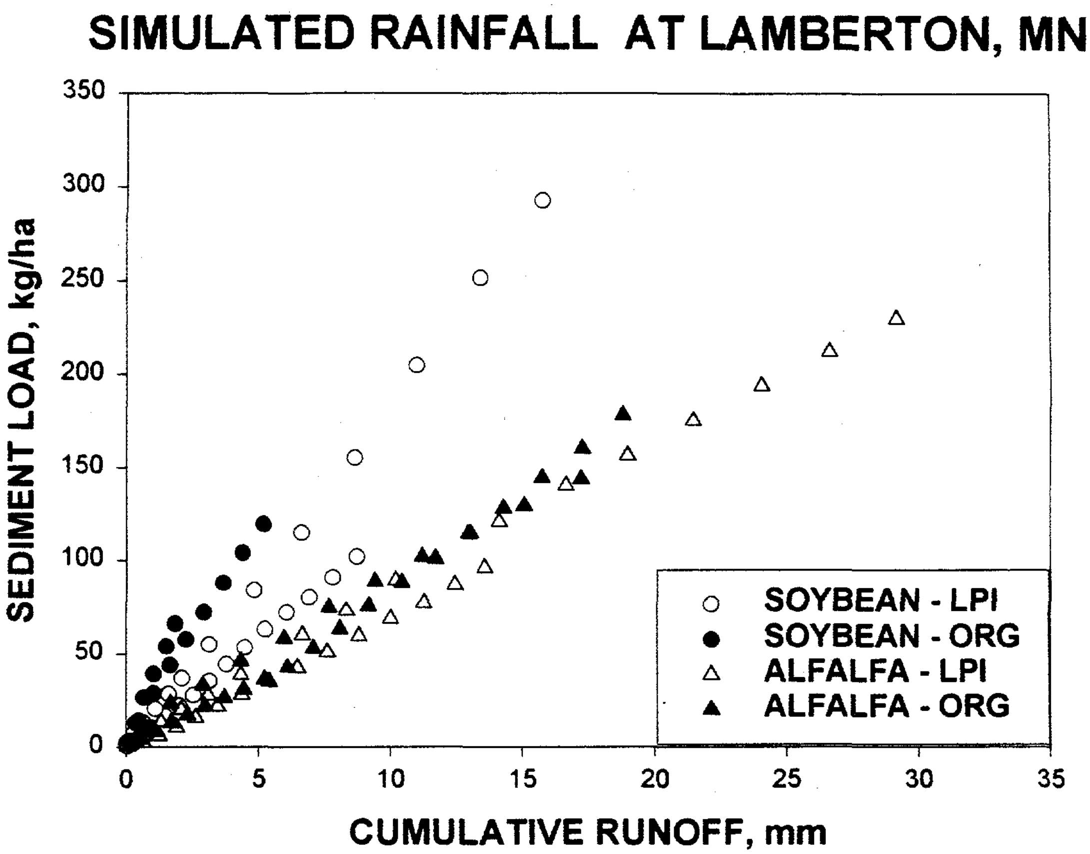

Fig. 8: Distribution of sediments as a function of cumulative runoff form the eight variable input management study plots at Lamberton.

Table 5: Average amounts of rain applied to initiate runoff and the final infiltration rates by simulated rainfall at Lamberton, Minnesota during Spring of 1997.

Management	Crop Rotation†	Surface Cover (%)	Amount of Rain Needed to Initiate Runoff (mm)	Final Infiltration Rate (mm/h)
Low Input	**soybean**-corn	27.0	103.7 ab	42.9 ab
	soybean-oat-**alfalfa**-corn	35.5	16.9 a	28.4 a
Organic	soybean-oat-**alfalfa**-corn	48.0	89.3 ab	43.0 ab
	alfalfa-corn-**soybean**-oat	25.5	165.3 b	69.3 b

† The crop written in **bold-face** letter denotes the residue from 1996 crop on which simulated rainfall was applied during April 21- 26, 1997. The means followed by different letters are significantly different by ANOVA at P=0.05.

Table 6: Average concentrations of sediments, dissolved phosphorus (DMRP), total phosphorus (TP), and chemical oxygen demand (COD) on water samples obtained by simulated rainfall at Lamberton.

Management	Crop Rotation†	Sediment††	DMRP	TP††	COD
		---------------	(mg/L)	---------------	
Low Input	**soybean**-corn	1437 ab	0.090	0.755 ab	102.8
	soybean-oat-**alfalfa**-corn	778 a	0.155	0.545 a	108.2
Organic	soybean-oat-**alfalfa**-corn	851 a	0.135	0.410 a	84.4
	alfalfa-corn-**soybean**-oat	2965 b	0.075	1.805 b	334.5

† The crop written in **bold-face** letter denotes the residue from 1996 crop on which simulated rainfall was applied during April 21- 26, 1997. †† The sediment and total phosphorus means followed by different letters are significantly different by ANOVA at P=0.05. The treatment effects on the DMRP and the COD are not significant.

Conclusions

Paired watershed study at Morris

Field study was initiated in 1996 to compare the volume of runoff and pollutants coming from alfalfa and corn-soybean fields in western Minnesota. Two pairs of alfalfa and corn-soybean watersheds were instrumented at Morris. Water from each watershed passes through a 6-inch Parshall and a 4-inch Palmer-Bowlus flume in sequence. A data logger and a transducer - gas bubbler setup measures the height of water in the flumes. The data logger activates an electronic sampler to collect runoff samples for water quality. Water samples collected from runoff events are analyzed for total sediment, phosphorus, nitrogen, biochemical and chemical oxygen demand.

Runoff hydrographs of the record snow-melt event during the spring of 1997 at Morris show that fields with alfalfa tended to yield more runoff than corn-soybean fields. This is attributed to higher amounts of snow trapped by alfalfa stubble. By water balance, alfalfa fields also infiltrated more water.

Chemographs relating the load of a suite of pollutants with runoff amounts indicated that alfalfa fields tend to yield more ammonium while the corn fields yielded more sediments, nitrates, DMRP, bio-available P, and total P. There was no appreciable trend in the distribution of BOD and COD. Statistically, the corn fields produced significantly higher amounts of sediments and total phosphorus of which the latter, at this stage of preliminary observation, could not be attributed to crop rotation effects. The runoff amounts and other water quality constituents between the corn-soybean and alfalfa fields were not significantly different for the Spring 1997 runoff event.

Simulated rainfall experiments at Lamberton

Simulated rainfall-runoff experiments were also conducted on existing crop rotation - input management study plots at Lamberton. In general, soybean fields under four-year (corn-soybean-oat-alfalfa) rotation with organic management had higher infiltration capacity than alfalfa fields following oat and with low purchased input management. Regardless of management, alfalfa fields yielded lower sediments in runoff water than the soybean fields.

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ATTACHMENT 5

PROJECT DIRECTORS REPORT

MnVAP

Minnesota Valley Alfalfa Producers
681 Prentice Street, P.O. Box 64
Granite Falls, MN 56241
Phone 320-564-2400
FAX 320-564-2451

June 20, 1997

Mr. Richard Peterson
Northern States Power Company
414 Nicollet Mall, 8th Floor
Minneapolis, Minnesota 55401

Dear Mr. Peterson:

The enclosed documents demonstrate that MnVAP's Minnesota Agri-Power Project is a viable project with a solid foundation of private and public support. It has matured soundly at a rational and realistic pace in accordance with our development schedule. Thus far, our only setback has been our inability to execute a financeable and operationally workable power purchase agreement in a timely manner. MnVAP expects that after NSP has reviewed these materials and the letter from Harold Frederick dated June 12, 1997, this shortcoming will be corrected quickly so that MnVAP can present a viable, executed power purchase agreement to its corporate partners and prospective lenders.

Since its formation in 1995, MnVAP has been extraordinarily successful. We have expanded our membership base and increased our production commitments and processing capacity on schedule. MnVAP has raised sufficient capital to proceed with development of a 700,000 ton alfalfa processing network, and MnVAP has employed the highest caliber professional staff to carry out this development. MnVAP successfully designed and implemented a fractionation process to separate alfalfa stem material from alfalfa leaf material. This had not previously been accomplished in the alfalfa processing industry; numerous alfalfa processing businesses are now attempting to replicate this feat.

A significant strength of the Minnesota Agri-Power Project is MnVAP's ability to ensure a reliable and economical fuel supply. The enclosed **Fuel Supply Plan**, which has been developed by MnVAP and the University of Minnesota, demonstrates this project attribute. (Additional copies of the Fuel Supply Plan will be provided at NSP's request.)

MnVAP is grateful to NSP for assembling a blue-chip corporate team of Stone & Webster Engineering Corporation, Westinghouse Electric Corporation, and Tampella Power Corporation to assess the feasibility of an alfalfa-fired biomass energy project in 1994 when NSP intended to develop and own the project that we now call the Minnesota Agri-Power Project. Even though NSP chose to abandon a development/ownership role in mid-1995, NSP's original corporate team remains intact and committed to the development of the Minnesota Agri-Power Project.

Stone & Webster Engineering Corporation (SWEC) will serve as the prime contractor for the Minnesota Agri-Power Project. SWEC will provide project management, engineering, design, procurement, and start-up oversight. SWEC will also provide the wrap-around guarantees on construction and operation. As stated in the enclosed letter, this arrangement will provide essential assurances to owners and lenders, and it will minimize the risks of construction delays or unsatisfactory plant performance that would jeopardize NSP's ability to meet the biomass mandate requirements.

Tampella Power Corporation was our original partner to provide the gasification island. Tampella was purchased by **Kvaerner Pulping**, and an engineering firm specializing in gasification technologies was spun off under the name **Carbona Corporation**. In April, 1997, gasification tests using MnVAP's alfalfa stem pellets as the fuel source were conducted by Carbona at Kvaerner's pilot plant in Tampere, Finland at a cost of more than $1.5 million. As stated in the enclosed letter from Carbona, preliminary results of the tests indicate that "this fuel is an excellent feedstock for the gasifier and produces a good quality fuel gas for the combustion turbine." The letter from Kvaerner Pulping reaffirms that Kvaerner will provide the gasification island for the Minnesota Agri-Power Project under a subcontract with SWEC, pending a final determination of successful gasification test results.

The attached letter from **Westinghouse Electric Corporation** evidences a renewed commitment to the Minnesota Agri-Power Project after Westinghouse reorganized its Power Generation Business Unit. Westinghouse will design, assemble, and install the hot gas clean-up and power generation systems. As soon as the characteristics of the gas are fully analyzed, Westinghouse will conduct combustion testing, which is scheduled for September, 1997. This combustion testing will serve as the basis for design refinements and final cost estimation.

Westinghouse remains interested in an equity position and/or providing sub-debt. As stated in the Westinghouse letter, such commitments cannot be made until Westinghouse has had an opportunity to perform a complete due diligence exercise, which, of course, requires review of the power purchase agreement and the corresponding proforma.

United Power Association (UPA) has served as our owner's engineer and developer since MnVAP and UPA executed a letter of intent on February 18, 1997. In spite of their discouragement with the power purchase agreement negotiations, UPA remains committed to performing all project developer tasks for the Minnesota Agri-Power Project. The enclosed letter documents this commitment. MnVAP and UPA will execute a joint development agreement as soon as NSP indicates that it intends to execute a power purchase agreement that would justify this next step. The letter also states that UPA will commit to equity participation if the power purchase agreement will enable owners to achieve an adequate financial return.

As an electric power cooperative with rural roots, UPA is an excellent partner for MnVAP. UPA is financially strong, and UPA has technical expertise in engineering, financing, permitting, and project management, which UPA has already assigned to this project. In addition, UPA is an experienced power plant operator. UPA is anxious to act as an investor, owners' engineer, and plant operator of the Minnesota Agri-Power Project.

Mercury Investment Co. is an investment group that invests in commercial developments solely and in cooperation with other organizations. Mercury Investment Co. has had an active interest in the Minnesota Agri-Power Project since 1995 when Mercury Investment Co. provided a short-term loan to MnVAP. Mercury Investment Co. states in the enclosed letter a desire to serve as the financial facilitator for the Minnesota Agri-Power Project. In addition, Mercury Investment Co. has offered to provide or arrange an equity contribution equal to the difference between the total equity requirement and the amount of equity contributed by MnVAP, UPA and our corporate partners. As expected, this offer is contingent on the positive findings of a due diligence review, which cannot be conducted until the power purchase agreement and other contracts are available to Mercury Investment Co.

The **Prudential Capital Group** is highly interested in financing the Minnesota Agri-Power Project. The Prudential Capital Group was introduced to MnVAP by Department of Energy staff who know of Prudential's interest in financing large alternative energy projects. Representatives of Prudential expressed disappointment when they learned that a power purchase agreement and a corresponding proforma were not yet available for their review, but they have assured MnVAP that they will initiate a due diligence exercise as soon as these documents are provided. Then, until financial closing, Prudential would advise MnVAP and other owners on measures to improve the financeability of the project and to reduce the risk premium on the interest rate. As stated in the enclosed letter, Prudential is most concerned about the terms of the power purchase agreement that directly affect the lenders' position and the sufficiency of the revenue stream to repay the debt.

The **Global Power Group of Chase Securities, Inc.** has also expressed great interest in the possibility of financing the Minnesota Agri-Power Project; but, not surprisingly, Chase cannot make a commitment to provide or arrange financing until a detailed due diligence investigation is completed.

You may find it interesting that Polsky Energy Corporation (PEC) has assisted MnVAP in maintaining Chase's interest in the Minnesota Agri-Power Project. In fact, PEC has been helpful on a number of technical and financial matters since MnVAP purchased PEC's interest in the project. While PEC is no longer MnVAP's development partner, PEC will continue to actively support the Minnesota Agri-Power Project because PEC has a strong financial incentive to do so. By structuring the buyout with a significant payment to PEC at financial closing, MnVAP ensured that PEC would provide development services to the project upon request.

NSP encouraged MnVAP to buy PEC's interest in the Minnesota Agri-Power Project at the time that MnVAP was considering this decision. Recently, however, NSP staff have questioned the viability of the Minnesota Agri-Power Project because MnVAP "lost" its development partner and its access to financing. PEC's on-going assistance on financing and other development tasks should alleviate NSP's concern.

The support of the **Department of Energy (DOE)** for the Minnesota Agri-Power Project has been nothing short of tremendous. In addition to delivering a research and design grant of $4.1 million, the staffs of DOE, **the National Renewable Energy Laboratory (NREL)** and **Oak Ridge National Laboratory (ORNL)** have served as invaluable advisors to MnVAP.

Mr. Raymond Costello, the Program Manager for DOE's biomass power and other renewable energy programs, identifies the Minnesota Agri-Power Project as a "critical component" of DOE's strategy to develop advanced biomass power options that are competitive, efficient, and environmentally beneficial. Dr. Costello reaffirms the intent of DOE to contribute a total of $40.0 million to ensure the success of the Minnesota Agri-Power Project; but, he cautions, failure to execute a long-term power purchase agreement would jeopardize this funding.

In their letters, technical experts from NREL and ORNL express confidence in the technical merits of the integrated gasification combined-cycle design and the expertise and corporate strength of our project team. Dr. Richard Bain of NREL discusses the international significance of the Minnesota Agri-Power Project and pledges NREL's continued support to ensure a successful commercial venture.

As you know, the **State of Minnesota** and the University of Minnesota have been steadfast supporters and key sponsors of the Minnesota Agri-Power Project since the beginning. Thus, I will not reproduce for this submittal the many letters MnVAP has received from the Governor, department Commissioners, legislators, University deans, and others representing the State and the University.

In the research and design phase of the Minnesota Agri-Power Project, the University of Minnesota is conducting a $2.2 million research effort to improve the economics of alfalfa production and processing. The University and USDA have developed new varieties of alfalfa that possess desirable characteristics for MnVAP's dual uses, and "best management practices" are being refined and introduced to MnVAP's producers. In addition, the University is conducting feeding trials on beef and dairy herds and turkeys to develop profitable markets for alfalfa leaf meal products. As the market for livestock feed products expands, MnVAP will be able to reduce the price required for the biomass fuel. Under a contract with MnVAP, the University is contributing more than $1.1 million to this comprehensive research program; and the State of Minnesota, through an appropriation to the Department of Agriculture, is contributing $200,000.

The Minnesota Agri-Power Project is strongly supported by key legislators on the Senate and House committees responsible for State policies and appropriations related to agriculture, environment, and regulated industries. In the 1997 Session of the Minnesota Legislature, the enclosed legislation was approved to benefit the Minnesota Agri-Power Project. MnVAP obtained: sales and personal property tax exemptions; direction to appropriate Commissioners to analyze and recommend options for State financing of biomass energy projects; waiver of the Certificate of Need requirement; and the cost recovery language that NSP and MnVAP sought together.

As MnVAP expands its alfalfa processing enterprise throughout southwestern and central Minnesota, and as the Minnesota Agri-Power Project creates new sales opportunities for Minnesota businesses, this political support will grow wider and deeper. The political appeal of the Minnesota Agri-Power Project creates a unique opportunity for MnVAP and NSP to work jointly on a legislative agenda that would be mutually beneficial.

I trust that this letter and the enclosed documents will satisfy NSP's concerns about the viability of the Minnesota Agri-Power Project. If you would like additional copies of these materials, please call me at (612) 483-4643. Thank you for your consideration. We look forward to concluding our negotiations and executing a power purchase agreement.

Sincerely,

Ken Campbell

Ken Campbell
Project Administrator

Stone & Webster

FOUNDED 1889

ATLANTA, GA
BOSTON, MA
CHATTANOOGA, TN
CHERRY HILL, NJ
DENVER, CO
HOUSTON, TX
NEW YORK, NY
WASHINGTON, DC
MIAMI, FL
PLEASANTON, CA

ABU DHABI, UAE
AL KHOBAR, SAUDI ARABIA
BANGKOK, THAILAND
DAMMAM, SAUDI ARABIA
KUALA LUMPUR, MALAYSIA
KUWAIT CITY, KUWAIT
MILTON KEYNES, ENGLAND
JAKARTA, INDONESIA
SEOUL, KOREA
TORONTO, CANADA

June 18, 1997

Mr. John Baloun
Chief Executive Officer
Minnesota Valley Alfalfa Producers
Post Office Box 64
Granite Falls, MN 56241

Dear Mr. Baloun :

MINNESOTA AGRI-POWER PROJECT
ENGINEERING, PROCUREMENT, AND CONSTRUCTION

Stone & Webster Engineering Corporation (Stone & Webster) is pleased to express our continuing confidence in the Minnesota Agri-Power (MAP) project and the activities of the Minnesota Valley Alfalfa Producers (MnVAP).

Stone & Webster has been an active participant in the MAP project since 1995. As originally conceived, we would have been a member of a consortium along with Westinghouse Electric Corporation (Westinghouse) and Tampella Power Corporation (Tampella) to engineer, design and construct the MAP project.

As the project has developed, the roles of MnVAP's industrial team members have also evolved. At present, our plan is for Stone & Webster to be the prime contractor for the MAP project. Kvaerner Pulping (Kvaerner) has replaced Tampella as a team member. Kvaerner will provide the gasification technology and certain critical mechanical equipment associated with biomass gasification. Westinghouse will provide the hot gas clean-up system, the combustion turbine, the steam turbine and associated auxiliary equipment. Stone & Webster will provide the project management; engineering, design and procurement; construction; start-up and testing (EPC contract). This arrangement will provide MnVAP and their bankers with a straight forward contractual relationship. Stone & Webster will have the primary responsibility for the successful completion of this project. The EPC contract arrangement will minimize the risks of delayed completion and unsatisfactory performance of the power plant. Guarantees will be obtained from our subcontractors for their respective scope of supply. Stone & Webster will provide the required overall guarantees necessary to finance the project.

Stone & Webster Engineering Corporation
P.O. Box 2325, Boston, Massachusetts 02107-2325
245 Summer Street, Boston, Massachusetts 02210
Tel: 617-589-5111 Fax: 617-589-2156

Stone & Webster will submit a formal lump sum, fixed price proposal to perform this EPC contract upon the completion of DOE Phase I, Project Definition, which is scheduled to be completed by the end of February, 1998.

Stone & Webster is pleased to be part of the MAP Team. We have the necessary project understanding, specialized capabilities, and competitive experience to support MAP activities. Our management and our team are committed to the successful completion of this project. We look forward to supporting MNVAP on this important project, with the assistance of other organizations that share these traits.

Very truly yours,

A.S. Lucks
Executive Vice President

Kvaerner Pulping

Via Facsimile

June 18, 1997

Mr. Ken Campbell, Project Administrator
Minnesota Valley Alfalfa Producers
453 Old Farm Road
Shoreview, MN 55126

Dear Ken:

As discussed during our recent telephone conversation, Kvaerner Pulping is eager to participate in the Minnesota Agri-Power ("MAP") Project. While we have not completed our analysis of the recent alfalfa gasification tests conducted at our Tampere, Finland pilot plant, the preliminary technical results are encouraging. It appears that alfalfa stem pellets can be gasified to produce a suitable fuel for combustion.

Pending a successful pilot plant testing evaluation, it is Kvaerner Pulping's intent to provide the gasification island for the MAP Project under a prospective subcontract agreement with Stone & Webster Engineering Corporation. As you are aware, Stone and Webster and Kvaerner Pulping have commenced negotiations of the prospective agreement.

The Kvaerner Group is a multi-national company based in London, with approximately $10 billion in annual revenues and 60,000 employees worldwide. Kvaerner Pulping is one of the Group's six primary core segments that specializes in technologies for the global pulp and paper, power generation and industrial markets. Given that the MAP Project is to be financed on a non-recourse basis, the Kvaerner Group's financial strength will be a project asset to facilitate financing.

Kvaerner appreciates the opportunity of participating in the Minnesota Agri-Power Project.

Sincerely,

KVAERNER PULPING INC.

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KVA

CARBONA

May 8, 1997

Mr. John Baloun
Minnesota Valley Alfalfa Producers
P. O. Box 64
Granite Falls, MN 56241

Subject: ***Alfalfa Gasification Tests***
Interim (Quick) Report

Dear John:

We have completed testing of the pelletized alfalfa stems in our pilot plant in Finland. As described in the test plan, we are herewith issuing the Interim (Quick) Report of the tests. A Preliminary Report and a Final Report are forthcoming.

I would like to take this opportunity to thank MnVAP in making the extraordinary efforts considering the adverse weather conditions in preparing and shipping the pelletized alfalfa to Finland. I am glad to report that this fuel is an excellent feedstock for the gasifier and produces a good quality fuel gas for the combustion turbine. The test results, though marred by some minor mechanical problem in the pilot plant, I hope will provide the team members with a "warm feeling" about the gasification technology!

Sincerely,
CARBONA CORPORATION

J. G. Patel
President

Enclosure

JGP:lif/MnVAP-L 127

Cc:

A. Hesje, MnVAP	C. Hanson, Univ. of MN
K. Campbell, MnVAP	R. Hanson, UPA
J. Spaeth, DOE	E. Ricci, Kvaerner Pulping
R. Bain, NREL	D. King, SWEC

CARBONA CORPORATION
4501 Circle 75 Parkway • Suite E-5300 • Atlanta, Georgia 30339
Tel: 770-956-0601 • Fax: 770-956-0063

Westinghouse
Electric Corporation

Emerging Technologies
Power Generation Business Unit
4400 Alafaya Trail, MC 381
Orlando, FL 32826-2399

FAX (407) 281-5014

May 22, 1997

Mr. Ken Campbell, Project Administrator
Minnesota Valley Alfalfa Producers
453 Old Farm Road
Shoreview, MN 55126
Fax: 612-483-4532

RE: Minnesota Agri-Power Project

Dear Ken:

You have been well aware that Westinghouse has been dealing with some difficult internal issues that directly impact our ability to support the MAP Project. We have resolved these issues and remain committed to the success of the MAP Project.

We have identified and committed the resources needed to complete our scope under Phase 1 of the DOE program. We have sent Stone and Webster a letter (and copied you) outlining the open issues related to our subcontract. I am confident that we can reach agreement quickly.

A second Westinghouse internal issue that will now have no impact on the MAP Project is where the 251B12 is assembled. In the management of our on-going business, it is necessary from time to time to make adjustments in the product mix in our various factories around the world. What this means to MnVAP is the 251B12 engine for the MAP project will be designed and supplied by Westinghouse. The engine may or may not be assembled where it is currently assembled in our Hamilton, Ontario, Canada factory.

In addition to our internal issues, you requested that Westinghouse once again consider participation in the project as equity owner or providing sub-debt. The same conditions must apply now as applied in the past when we were considering an equity position in the project. We are willing to consider providing a yet-to-be-defined amount of equity or sub-debt subject to, in our sole opinion, a satisfactory due diligence review of the project and subsequent approval by Westinghouse senior management. This due diligence effort will need to take place over the next year as the project becomes better defined. In order to complete this due diligence effort, we will once again need access to all pertinent project information, discussions and negotiations starting as soon as we reach agreement on this issue. We will start our due diligence process once we have received a complete executed copy of the power purchase agreement and its related proforma.

Please call me to discuss any of these issues as needed.

Sincerely,

Harry T. Morehead, Manager
New Program Development

Cc: F. Bevc/M. Flandermeyer/J. Larkin, Westinghouse, Orlando
J. Usem, Westinghouse, Minneapolis

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UPA

United Power Association
P.O. Box 800 • Elk River, MN 55330-0800 • (612) 441-3121

June 19, 1997

Mr. Ken Campbell
Minnesota Valley Alfalfa Producers
453 Old Farm Road
Shoreview, MN 55126

Dear Mr. Campbell:

This letter is written to confirm United Power Association's (UPA) continued commitment to the Minnesota Agri-Power (MAP) Project. UPA has provided and it is our intent to continue to provide project development services to the MAP Project. The key components of the development services agreement are summarized below.

1. Term – the initial term of the agreement will be through financial closing
2. Services – UPA will provide project development services, including technical oversight of design, engineering, and construction activities, assistance in power purchase agreement negotiations, environmental review and assistance, help finding financing and equity partners, and other services needed to advance the MAP Project.
3. DOE tasks – UPA will provide engineering and environmental services to complete tasks under the DOE contract, as determined by MnVAP.
4. Equity – UPA will become an equity participant conditioned on certain events, of which the two most significant are successful execution of a PPA satisfactory to UPA and adequate MAP Project financial return.

Since mid-February, UPA has provided MnVAP with significant labor resources. These services would not have been provided if UPA did not believe in the potential of the MAP Project. It is UPA's intention to help MnVAP bring this project to a successful completion.

Sincerely,

UNITED POWER ASSOCIATION

Gordon D. Westerlind
Vice President
Power Generation

302 W. Superior Street
700 Lonsdale Building
Duluth, Minnesota 55802
218.722.0320
Fax 218.725.6800

Mercury Investment Co.

June 18, 1997

Mr. Ken Campbell
Project Administrator
Minnesota Valley Alfalfa Producers
453 Old Farm Road
Shoreview, MN 55126

Dear Mr. Campbell:

In 1995, we provided a short-term loan to the Minnesota Valley Alfalfa Producers (MnVAP). In connection with making the loan, I studied your integrated alfalfa processing and biomass energy project and have followed your progress in the acquisition and operation of your alfalfa processing facility and in the development of the biomass energy project. I am interested in pursuing discussions with you and representatives of United Power Association (UPA) to determine whether our company should participate in the development and ownership of the Minnesota Agri-Power Project.

Among other business activities, our company is in the business of arranging investment capital. We are connected with a number of individuals and families that have made investments with our company or in connection with other members of my family and me. These individuals and families are in or have been in their own separate businesses and have made outside investments with us. Included are individuals or families that have been or are in the retail grocery business in the immediate five state area, the publishing business headquartered in St. Paul, the hospitality industry across the country and a variety of other fields. In the past five years investments have been made in office buildings, apartments, motels, retail sales, specialty chemical processing plants, medical equipment manufacturing and yogurt manufacturing. We also have connections with one or more "green" investment organizations that we believe will find your project of great interest.

I understand that MnVAP intends to execute a joint development agreement with UPA and that your principal vendors will be Stone & Webster Engineering Corporation, Kvaerner Pulping and Westinghouse Electric Corporation. These are excellent organizations, and we would have confidence participating in a project with them. I also understand that MnVAP will be executing a power purchase agreement with Northern States Power (NSP) in the near future under which NSP will purchase all of the electricity produced by your 75-megawatt integrated gasification combined cycle power plant.

We are prepared to act as the financial facilitator for your project and to arrange significant equity through our own company and through individuals and families with whom we work. We understand that MnVAP intends to raise about 51% of the required equity through the sale of additional shares and that UPA and perhaps some other vendors would make an equity contribution in the 20-25% range. We are prepared to provide or arrange equity for the balance. Of course, a firm commitment will be conditional upon execution of an appropriate power purchase agreement that will provide the source of funds for repayment of debt and return on equity. We must also review the contracts for construction, operation and fuel prior to financial closing. We will also be required to make a due diligence review as these documents become available.

Please contact us as soon as you have executed a power purchase agreement with NSP. We will then continue our review of your project and begin discussions of ownership interests.

Sincerely,

Abbot G. Apter
President

AGA/ma

Prudential

Ric E. Abel
Vice President
Corporate and Project Workouts

Prudential Capital Group
100 Mulberry Street, Four Gateway Center, Newark NJ 07102
Tel 201 802-4195 Fax 201 802-2333
ric.abel@prudential.com

June 19, 1997

Mr. Ken Campbell, Project Administrator
Minnesota Valley Alfalfa Producers
453 Old Farm Road
Shoreview, Minnesota 55126

Dear Mr. Campbell:

We are pleased to express Prudential's preliminary interest in providing financing for the alfalfa processing and biomass power project (the "Project") to be developed by the Minnesota Valley Alfalfa Producers ("MnVAP") . We understand that MnVAP will be executing a power purchase agreement with Northern States owner (NSP) in the near future under which NSP will purchase all of the electricity produced by your 75-megawatt integrated gasification combined cycle power plant.

The Prudential Insurance Company of America, through its investment unit, Prudential Capital Group, has provided more than $3 billion of financing to over 100 cogeneration, infrastructure and alternative energy projects. As a leading lender in the project market, we look to finance projects that have satisfactory contractual arrangements, stable, sustainable cash flows, community support and the support of experienced development and management teams. Based on the information that you have provided to us in our preliminary discussions, the Project appears to be viable and is one which we would consider financing.

We understand that the owners and the Department of Energy will make equity contributions of 35% of the total capital cost. Of course, a firm commitment will be conditional upon execution of an appropriate power purchase agreement that will provide the source of funds for repayment of the senior debt facility. We must also review the results of the gasification and combustion testing and the contracts for construction, operation, and fuel prior to financial closing. We would like to conduct a due diligence review as these documents become available.

You have inquired about likely financing terms. The only term of the senior debt facility which we can anticipate at this time is that it be secured by a first lien on the project and an assignment of the power purchase agreement and/or a satisfactory agreement between us and NSP. As the principal source of repayment of the senior debt facility, the power purchase agreement must unconditionally require NSP to purchase all power produced by the project for the duration of the debt term or longer. Other provisions of the debt financing, including interest rate and repayment schedule, will depend on the terms of the power purchase agreement and your vendor contracts.

This letter is intended as a formal expression of interest and as a basis for discussion only, it does not constitute a commitment to lend. If we were to issue a commitment to lend, it would be in writing and would only be issued upon satisfaction of usual conditions precedent, including without limitation receipt of internal credit authorizations.

Please contact us as soon as you have executed a power purchase agreement with NSP. We will then continue our review of your project and discuss specific requirements and terms. Thank you for considering our financing services.

Sincerely,

R. E. A. rk

REA/dlh

CHASE

Chase Securities Inc.
Ten South LaSalle Street, 23rd Floor
Chicago, IL 60603
Tel 312-541-4408
Fax 312-201-8324

David McSweeney
Managing Director
Global Power Group

June 19, 1997

Mr. Ken Campbell
Project Administrator
Minnesota Valley Alfalfa Producers
453 Old Farm Road
Shoreview, Minnesota 55126

Dear Mr. Campbell:

We have received and reviewed with great interest the preliminary information that Polsky Energy Corporation ("PEC") has provided to us concerning the alfalfa processing and biomass power project that your company is developing with Stone & Webster Engineering Corporation, Kvaerner Pulping and Westinghouse Electric Corporation, which we understand is to involve a 75 megawatt integrated gasification combined cycle electric power plant.

Based on the information that we have received from PEC to date, and because of our strong relationship with PEC, we would be extremely interested in exploring with PEC and you whether or not, and on what terms, we might be able to arrange financing for this project. Based on preliminary information provided, the project economics appear reasonable and commensurate with similar financeable projects. We would like to make clear that this letter does not constitute a commitment to provide or arrange any financing. You also must understand that before we are in a position to make any definitive proposal for financing this project, or to detail any likely terms of any financing we might arrange, we would need to undertake, and be satisfied with the results of a detailed due diligence investigation, including, but not limited to, a report from an independent engineer. This investigation would include, among other things, our being satisfied with the terms and conditions of all material project contracts, the project's capital structure, project counterparties, environmental compliance, nature of collateral and other issues. We would also need to obtain required internal approvals and to reach agreement with you on the terms of any such proposal.

Again, we wish to confirm our strong interest in learning more about this project and look forward to the opportunity to work with you again.

Sincerely

David McSweeney

Dave McSweeney

Department of Energy
Washington, DC 20585

Mr. Kenneth Campbell
Project Administrator
Minnesota Valley Alfalfa Producers
453 Old Farm Road
Shoreview, Minnesota 55126

Dear Mr. Campbell:

As I am sure you are aware, the Department of Energy (DOE) is currently undertaking a very aggressive development program which examines the potential biomass can bring to satisfying this Nation's need for new electric power generation. Included in this program are those critical projects which lead to the development of advanced biomass power options that are competitive, highly efficient and provide the added advantages of environmental integrity. The Minnesota Agri-Power Project is considered by the Department as a critical component to that strategy.

The Minnesota project integrates the DOE Biomass Power Program's most important goals which include: Energy Independence, National Security and Environmental Stability. In a more regionalist sense, the project will promote employment and economic development, prove that crop systems dedicated to power production are viable systems and finally, demonstrate reliability from state-of-the-art biomass conversion technologies such as gasification combined-cycle systems. The Department believes this project incorporates the best elements of these objectives into one commercial venture.

DOE's support of this project has translated into a financial commitment of $4.0 million under a cooperative agreement (Contract Number DE-FC36-96GO10147). Within the current planning horizon, it is the intent of DOE to continue its financial support by contributing the previously discussed maximum figure of $40.0 million over the life of the project. This would bring the total federal contribution to $44.0 million. It is also to be understood that the dispersal of these additional funds are conditional upon availability of funds through the appropriation's process, and satisfaction of those contractual requirements that have been previously agreed to, and in particular, the project obtaining a viable long-term power purchase agreement.

On a personal note, I would like to take this opportunity to thank you and the rest of the MnVAP team for the cordial welcome I received on my recent visit to Minnesota and look forward to developing my association with the MnVAP team.

Sincerely,

Raymond Costello, Ph.D
Program Manager
Solar Thermal, Biomass Power
and Hydrogen Technologies
Energy Efficiency and Renewable Energy

NREL
National Renewable Energy Laboratory

June 16, 1997

Mr. Kenneth R. Campbell
Project Administrator
Minnesota Valley Alfalfa Producers
453 Old Farm Road
Shoreview, MN 55126

Dear Ken:

I am writing in support of your efforts to advance the "Alfagas" project from a concept to commercial reality. I believe you have put together an outstanding team with expertise in the technology (Carbona, Westinghouse, the Institute of Gas Technology); engineering, procurement and construction (Stone & Webster); the power business (United Power Association); the agricultural business (MNVAP and the member farmers); and the agricultural educational community (The University of Minnesota). Adding in the support of the local community (Granite Falls and surrounding area), State government support, and Federal government support (DOE and USDA) makes the Alfagas project very strong.

The project is being followed very closely in the international gasification community, because it is a pioneer effort in gasification technology scale-up and integration. Projects just started in Europe as part of the European Union Thermie initiative (the Arbre project in the U.K., the Kotke project in Finland, and the Italian project) are for the most part modeled on the MNVAP and other "Biomass Power for Rural Development" projects.

Present commercial biomass-to-electricity projects, many of which are cogeneration systems in the pulp and paper industry, are all based on small-scale Rankine cycle technology and have process efficiencies for electricity production of 15-25%. The Alfagas process, based on Brayton cycle technology, should have an efficiency in the 35% range, with resulting benefits in reduced feedstock use and lower environmental impact. Staged conversion systems such as gasification, cleanup, combustion also have the potential for very low emissions of priority pollutants. Recent work at NREL has indicated that such a project will also result in a process with very small net greenhouse gas emissions. This project should be ideal for "green marketing" by UPA and the utility purchasing your "green" electricity. Green power, in combination with support of the rural economy should make this project very attractive to the political and agricultural communities.

Although there are challenges in scale-up and introduction of new technologies, I feel that there is a very good chance of success in this project, and feel confident that technical and financial challenges can met if a successful conclusion to your power purchase agreement negotiation with Northern States Power is reached.

Best wishes in your endeavor.

Sincerely,

Richard Bain

Dr. Richard L. Bain
Technology Manager, Biomass Power Program
Center for Renewable Chemical Technologies and Materials

cc. Jim Spaeth, Golden Field Office

OAK RIDGE NATIONAL LABORATORY
MANAGED BY LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE U.S. DEPARTMENT OF ENERGY

POST OFFICE BOX 2008
OAK RIDGE, TENNESSEE 37831-6422

June 16, 1997

Mr. Ken Campbell
Minnesota Valley Alfalfa Producer's Cooperative
453 Old Farm Road
Shoreview, Minnesota 55126

Dear Ken:

I am writing this letter to you regarding the Minnesota Valley Alfalfa Producers Cooperative.

The Department of Energy's Biomass Power Program has asked Oak Ridge National Laboratory to provide technical assistance and support to the feedstock components of projects funded through the Biomass Power for Rural Development Initiative.

We are pleased to have this opportunity to work with the Minnesota Valley Alfalfa Producers Cooperative on the Minnesota Agri-Power Project. We will continue to work closely with the Department of Energy's Biomass Power Program to ensure that information being developed in the Department of Energy's Bioenergy Feedstock Development Program, and in other Biomass Power for Rural Development Projects, as appropriate, is made available to Minnesota Agri-Power Project participants.

Through continued support and cooperation with all partners in these projects, progress will be made toward eventual commercialization of highly integrated technologies. Oak Ridge National Laboratory is committed to the success of the Department of Energy's Biomass Power for Rural Development Initiative.

Sincerely,

Mark Downing
Technical Monitor for Feedstocks
Bioenergy Feedstock Development Program
Oak Ridge National Laboratory

Version as sent to Governor

A bill for an act

relating to renewable energy; providing for action by the public utilities commission on purchases of wind and biomass power; exempting certain plants from certificate of need proceedings; requiring a study; amending Minnesota Statutes 1996, section 216B.2422, subdivision 5; proposing coding for new law in Minnesota Statutes, chapter 216B.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF MINNESOTA:

Section 1. [216B.1645] [POWER PURCHASE CONTRACTS OR INVESTMENTS.]

Upon the petition of a public utility, the public utilities commission shall approve or disapprove power purchase contracts or investments entered into or made by the utility to satisfy the wind and biomass mandates contained in sections 216B.2423 and 216B.2424. The expenses incurred in accordance with the contract and the reasonable investments made by a public utility with the approval of the commission shall be included by the commission in its determination of just and reasonable rates. Upon petition by a public utility, the commission shall approve or approve as modified a rate schedule providing for the automatic adjustment of charges to recover the expenses or costs approved by the commission.

Sec. 2. Minnesota Statutes 1996, section 216B.2422, subdivision 5, is amended to read:

Subd. 5. [BIDDING; EXEMPTION FROM CERTIFICATE OF NEED PROCEEDING.] (a) A utility may select resources to meet its projected energy demand through a bidding process approved or established by the commission. A utility shall use the environmental cost estimates determined under subdivision 3 in evaluating bids submitted in a process established under this subdivision.

(b) A certificate of need proceeding is not required for an electric power generating plant that has been selected in a bidding process approved or established by the commission, or such other selection process approved by the commission, to satisfy, in whole or in part, the wind power mandate of section 216B.2423 or the biomass mandate of section 216B.2424.

Sec. 3. [EVALUATION OF BIOMASS FACILITIES.]

The commissioner of agriculture shall evaluate alternative financing mechanisms by which the cost of financing biomass energy projects can be reduced to improve the financial viability of such projects and produce savings for electric energy consumers in the state.

The analysis must include the extent to which financial participation of public and private institutions can achieve interest savings for the incremental development of biomass energy projects. Financing options to be reviewed must include:

(1) use of the bonding capacity of existing public financing authorities;

(2) private financing options for biomass energy facilities;

(3) establishment of a new development authority to facilitate public financial participation in biomass energy projects;

(4) issuance of tax exempt or taxable state general obligation bonds to produce interest savings for development of biomass energy facilities; and

(5) production credit payments for biomass energy production.

In conducting this analysis, the commissioner shall work with the commissioners of finance, public service, and trade and economic development and with stakeholders involved in farm-grown, closed-loop biomass energy projects. The analysis with recommendations must be submitted to the legislature by January 15, 1998.

of, and the storage, use, or consumption of, products and services including end user equipment used for construction, ownership, operation, maintenance, and enhancement of the backbone system of the regionwide public safety radio communication system established under sections 473.891 to 473.905, are exempt. For purposes of this subdivision, backbone system is defined in section 473.891, subdivision 9.

Sec. 27. Minnesota Statutes 1996, section 297A.25, is amended by adding a subdivision to read:

Subd. 70. [ALFALFA PROCESSING FACILITIES CONSTRUCTION MATERIALS.] Purchases of construction materials and supplies are exempt from the sales and use taxes imposed under this chapter, regardless of whether purchased by the owner or a contractor, subcontractor, or builder, if:

(1) the materials and supplies are used or consumed in constructing a facility which either (i) develops market-value agricultural products made from alfalfa leaf material, or (ii) produces biomass energy fuel or electricity from alfalfa stems in accordance with the biomass mandate imposed under section 216B.2424; and

(2) the total capital investment made in the value-added agricultural products and biomass electric generation facilities is at least $50,000,000; or

(3) the materials and supplies are used or consumed in constructing, equipping or modifying a district heating and cooling system cogeneration facility that:

(i) utilizes wood waste as a primary fuel source; and

(ii) satisfies the requirements of the biomass mandate in section 216B.2424, subdivision 5.

Sec. 28. Minnesota Statutes 1996, section 297A.25, is amended by adding a subdivision to read:

Subd. 71. [FIREWOOD.] The gross receipts from the sale of and the storage, use, or consumption of wood used for fires for heating, cooking, or any other purpose, except for the generation of electricity, steam, or heat to be sold at retail, are exempt.

or corporation in connection with a business or enterprise operated for profit.

Sec. 8. Minnesota Statutes 1996, section 272.02, is amended by adding a subdivision to read:

Subd. 9. [PERSONAL PROPERTY; BIOMASS FACILITY.] (a) Notwithstanding clause (8), item (a), of subdivision 1, attached machinery and other personal property, excluding transmission and distribution lines, that is part of a system that generates biomass electric energy that satisfies the mandate, in whole or in part, established in section 216B.2424, or a system that generates electric energy using waste wood, is exempt if it meets the requirements of this subdivision.

(b) The governing bodies of the county, city or town, and school district must each approve, by resolution, the exemption of the personal property under this subdivision. Each of the governing bodies shall file a copy of the resolution with the county auditor. The county auditor shall publish the resolutions in newspapers of general circulation within the county. The voters of the county may request a referendum on the proposed exemption by filing a petition within 30 days after the resolutions are published. The petition must be signed by voters who reside in the county. The number of signatures must equal at least ten percent of the number of persons voting in the county in the last general election. If such a petition is timely filed, the resolutions are not effective until they have been submitted to the voters residing in the county at a general or special election and a majority of votes cast on the question of approving the resolution are in the affirmative. The commissioner of revenue shall prepare a suggested form of question to be presented at the referendum.

(c) The exemption under this subdivision is limited to a maximum of five years, beginning with the assessment year immediately following the year during which the personal property is put in operation.

Sec. 9. Minnesota Statutes 1996, section 272.115, is amended to read: