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AN APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO ALFALFA BIO-MASS ENERGY AND MARKETING COOPS

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ABSTRACT

AN APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO ALFALFA BIO-MASS ENERGY AND MARKETING COOPS

by Jerry E. Fruin

Minnesota Valley Alfalfa Producers Cooperative (MNVAP), a farmer-owned cooperative based in west central Minnesota, has contracted to provide 75 megawatts of electric power produced from alfalfa stem biomass. The cooperative is considering a novel enterprise--the production of both electrical power and alfalfa leaf meal products from alfalfa hay. Seven hundred thousand tons of alfalfa hay from 200,000 acres grown by more than 1,000 farmers over twelve counties will need to be transported and separated into leaves and stems before power generation can occur. The alfalfa leaves would be used in various animal feeds ranging from 17% to 30% crude protein. Electrical power generated from this project will be more environmentally friendly than coal-based power due to lower sulfur emissions, sequestration of carbon from the atmosphere by subsequent alfalfa crops, and the production of ash that can probably be land applied as fertilizer rather than landfilled.

The cutting characteristics and hay quality will result in two or more “lots” at each location. The utilization of each “lot” will depend upon its characteristics and will guide its movement to one of several separator locations. A Geographic Information System (GIS) locational database will be used to develop and implement the concept of a “virtual warehouse” in the biomass shed. There will be a road network overlay containing speeds, weight and bridge limits and other constraints for routing management.

Each lot record with its location will contain quality data such as the following: alfalfa type (biomass or conventional), cutting number, quantity produced and yield, bale type, crude protein content, leaf content, hay relative feed value, leaf relative feed value, incidence and amount of rain after cutting, color characteristics, and type of storage.

At full operation there will be 4 to 6 processing plants strategically located throughout the biomass shed. These plants will separate the alfalfa leaves from stems, produce value-added alfalfa leaf products and process and tranship the stems to the power plant.

The virtual warehouse concept coupled with product blending plant scheduling and transportation models will allow the assignment of each lot to the appropriate processing plant and finished product to maximize the finished product value while controlling transportation, handling and related costs and reducing energy use in transportation and processing. An example of the use of the GIS database to measure and evaluate truck traffic impacts on the road network near alternative power plant sites is provided.

AN APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO ALFALFA BIO-MASS ENERGY AND MARKETING COOPS[1]

Jerry E. Fruin

Background

Minnesota Valley Alfalfa Producers Cooperative (MNVAP), a farmer-owned cooperative based in west central Minnesota has contracted to provide 75 megawatts of electric power produced from alfalfa stem biomass. This decision to produce power followed feasibility and planning studies in which the Department of Applied Economics of the University of Minnesota participated. The cooperative is considering a novel enterprise--the production of both electrical power and alfalfa leaf meal products from alfalfa hay. Seven hundred thousand tons of alfalfa hay from 200,000 acres grown by more than 1,000 farmers over twelve counties will need to be transported and separated into leaves and stems before power generation can occur. The alfalfa leaves would be used in various animal feeds ranging from 17% to 30% crude protein in mixes and as meal, pellets, cubes, etc. The stems would be gasified at high temperature and pressure with the resulting gas ultimately being burned in a combustion turbine. Electrical power generated from this project will be more environmentally friendly than coal-based power due to lower sulfur emissions, sequestration of carbon from the atmosphere by subsequent alfalfa crops, and the production of ash that can probably be land applied as fertilizer rather than landfilled.

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Transportation and storage costs of 700,000 tons represent a major expense and hurdle in the feasibility of this project. The cutting characteristics and hay quality will result in two or more "lots" at each location. The utilization of each "lot" will depend upon its characteristics and will guide its movement to one of several separator locations. A Geographic Information System (GIS) locational database will be used to develop and implement the concept of a "virtual warehouse" in the biomass shed. Each farm record will include latitude and longitude coordinates along with the conventional rectangular survey definition of range township and section number. There will be a road network overlay containing speeds, weight and bridge limits and other constraints for routing management.

Each lot record with its location will contain quality data such as the following: alfalfa type (biomass or conventional), cutting number, quantity produced and yield, bale type, crude protein content, leaf content, hay relative feed value, leaf relative feed value, incidence and amount of rain after cutting, color characteristics, and type of storage. Data quality measures will be based on the results of on-going work by the University of Minnesota Center for Alternative Plant and Animal Products such as NIRS (Near Infrared Spectroscopy) calibration and testing techniques.

In addition to the farm and lot records, there will be a regional GIS overlay so that for each farm one can call up soil types and crop equivalency ratings, 40 year average annual precipitation and growing degree days, soil moisture on the previous October 1st (end of the growing season), and May 15th (start of the growing season), and current year precipitation. This information will be used to forecast expected MNVAP's alfalfa production and used for production planning, developing marketing plans and financial projections.

At full operation there will be 4 to 6 processing plants strategically located throughout the biomass shed. These plants will separate the alfalfa leaves from stems, produce value-added alfalfa leafproducts and process and tranship the stems to the power plant. It is anticipated that additional but site specific value added processing will be done at some locations (e.g., blended in alfalfa leaf meal with feed by-products from ethanol or beet plants or the production specialty products, i.e., pet foods). It is likely that some high quality or other unique hay might not be processed but marketed directly to each user.

The virtual warehouse concept coupled with product blending plant scheduling and transportation models will allow the assignment of each lot to the appropriate processing plant and finished product to maximize the finished product value while controlling transportation, handling and related costs and reducing energy use in transportation and processing.

A Road Impact Application

Total transportation costs are a very important factor in any plant siting process. Total transportation costs for the MNVAP power plant include the movement of alfalfa hay from the farm to an alfalfa processing plant site, fuel pellets from the alfalfa processing plant site to the power plant, alfalfa feed products from alfalfa processing plant to feed firms and end users, and biomass residual (ash) from the power plant to farms with suitable soil characteristics. This report, however, is primarily concerned with the traffic pattern that would result from minimizing the costs of moving hay from farm to the separating plants and then transporting the fuel pellets from the separating plants to two power plant site locations..

There will be a number of other traffic types generated by the alfalfa biomass project. These include trips to and from work by plant employees, feed shipped to feed companies and/or

farmers and ash to be shipped back to farms for fertilizer that was not included in this study. This is not all additional traffic, although the traffic patterns may differ substantially from the current situation. For instance, existing shipments of grain, soybean and hay off the farm from the contracted alfalfa acreage to markets is probably 60 to 75% of the expected hay tonnages. Also there may be a reduction in ag input traffic, e.g., nitrogen fertilizer. Feed products and ash may be backhauled after hay or fuel deliveries, reducing the total number of truck trips needed in and out of the plants.

Nine alfalfa processing plants were included in the cost models. These nine sites include the existing plant at Priam and one adjacent to the proposed power plant site at Granite Falls or the alternative site in Yellow Medicine County (YMC). The other potential sites are geographically disbursed throughout the area in communities that have existing value-added agricultural cooperatives such as corn or sugar beet processing. These locations were selected because of potential synergies in the production and marketing of animal feeds from agricultural processing byproducts and possible public and private infrastructure savings if alfalfa processing plants are located adjacent to or near other value-added coops. An estimate of the mileage from each potential processing site to the two alternative power plant sites is provided in Table 1.

Table 1. Mileage to Power Plant Sites

Separator Locations	Distance To Granite Falls Site	Distance To Yellow Medicine County Site
Marshall	31	26
Appleton	37	40
Renville	16	21
Buffalo Lake	47	51
Sleepy Eye	66	64
Canby	40	40
Priam	31	35
Morris	63	66

The power plant will consume about 350,000 tons of alfalfa fuel pellets which will require the production and delivery of about 700,000 tons of alfalfa feedstock. (350,000 tons of alfalfa leaf meal products will also be produced).

To approximate the geographical dispersion of the 700,000 tons of alfalfa hay throughout the region, we used the GIS farm location database. We assigned the production based on the farm locations of the MNVAP members in early 1998. These growers are located in 24 Minnesota counties generally within 85 miles of Granite Falls with a maximum distance between 120 and 130 miles from Granite Falls and the YMC site.

Since MNVAP's current members are contracted to deliver only a portion of the 700,000 tons of feedstock that will be required at full-scale operation in 2004. The total 700,000 tons were allocated to the existing members to simulate the expected distribution of production in the hayshed. This was done pro rata except that production in each county was limited to a total of

70,000 tons or 10% of the total. This had the effect of generally assigning more production in the more distant counties. Reasons for this distribution may be that potential growers further from the plant were not as aware of the benefits and opportunities provided by MNVAP during its early stages and that alternative crops such as sugar beets, corn and soybean may be relatively more profitable near the proposed plant site than in some other areas in the 85 mile radius. The tonnages of alfalfa assigned to each county is shown in Table 2. It should be noted that this analysis did not consider the use of rail for hay, fuel or feed shipments.

Methodology

A transportation/transhipping model was developed that would determine the minimal transportation costs from farms to the 9 processing sites and the transhipping of fuel pellets to each of the alternative power plant sites. This model was solved for several sets of conditions (or scenarios). The mileage between points was used as a proxy for actual transportation costs for this analysis. The results of these model solutions were then further analyzed to determine the number of truckloads of hay, fuel pellets and feed pellets that would be transported to or from

Table 2. Alfalfa Tonnage Allocation by County

County Number	County	Allocated 700000 Tons	Percent of Total Allocation
6	Bigstone	28,000	4.0%
7	Blue Earth	5,600	0.8%
12	Chippewa	40,558	5.8%
21	Douglas	10,052	1.4%
26	Grant	19,362	2.8%
27	Hennepin	2,520	0.4%
34	Kandiyohi	56,000	8.0%
37	Lac Qui Parle	56,000	8.0%
41	Lincoln	50,785	7.3%
42	Lyon	49,588	7.1%
43	McLeod	9,436	1.3%
47	Meeker	14,000	2.0%
51	Murray	14,000	2.0%
53	Nobles	14,000	2.0%
59	Pipestone	16,100	2.3%
61	Pope	16,051	2.3%
64	Redwood	43,582	6.2%
65	Renville	49,000	7.0%
72	Sibley	14,000	2.0%
73	Stearns	26,320	3.8%
75	Stevens	15,134	2.2%
76	Swift	37,912	5.4%
78	Traverse	56,000	8.0%
87	Yellow Medicine	56,000	8.0%
	MNVAP	700,000	100%

each location annually and on a daily basis. These results (daily truckloads) were then combined with the average daily traffic (ADT) on the road network obtained from Minnesota Department of Transportation (MNDOT) maps showing ADT's for the state, the impacted counties and the

Granite Falls area. The state map shows total traffic and breaks out truck traffic for 1996. The MNDOT county and municipality maps only show total ADT's and may be for years prior to 1996.

Results

Tables 3 and 4 give results for a series of scenario solutions minimizing total ton miles required for the proposed Granite Falls and YMC power plant sites, respectively. The first column lists the alfalfa processing plants locations. Subsequent columns show the alfalfa tonnage that would go to each of the alfalfa processing plants if total ton-miles from farm to alfalfa processing plants of hay, and fuel pellets to the power plant are minimized subject to the scenario conditions.

The first scenario minimizes transportation cost (ton miles of hay and fuel pellets) without regard to the number or size of alfalfa processing plants. In both cases the alfalfa processing plants located at the potential power plant sites got by far the largest tonnage of hay. 381,486 tons would go to Granite Falls and 310,687 tons would go to the YMC site.

The second scenario for both sites assumed that only the five alfalfa processing plants with the largest volumes in scenario 1 were potential locations. The alfalfa processing plant at Granite Falls and the YMC site received most of the reallocated tonnage.

The third and fourth scenarios for each power plant site established a maximum alfalfa processing plant capacity of 200,000 tons of hay at the power plant site. This is assumed to be a realistic alfalfa processing plant size. Scenario three included all nine potential alfalfa processing plants. The fourth scenario included only the five locations that received the bulk of the tonnage in scenario 3. The results of scenario four were subsequently used in the truck traffic impact

analysis. That is, it was assumed that if the power plant is located at Granite Falls, alfalfa processing plants would be located at Granite Falls, Marshall, Appleton, Renville, and Priam and would process the tonnage indicated for scenario 4 in Table 3. Similarly it was assumed that if the power plant was located at the YMC site, alfalfa processing plants would be located near the YMC site and Marshall, Appleton, Renville, and Priam to process the tonnages indicated for scenario 4 in Table 4.

Scenarios five and six limit alfalfa processing plant capacity to 100,000 tons. All 9 sites are included in scenario five but only the seven sites with the most tonnage in scenario five are included in scenario six. Scenarios seven and eight do not allow a processing site at the power plant and were undertaken to determine cost and truck traffic impacts if it was decided not to separate and stems and leaves at the power plant site. This might be reuqired for safety purposes as alfalfa dust is quite flammable or due to traffic volume or regional development considerations.. There are no constraints on alfalfa processing plant processing capacity in scenario seven. Scenario eight requires all processing to be done at the alfalfa processing plant with the largest volumes in scenario seven.

Scenario four was used for the truck impact study rather than scenario eight to study the "worst case" scenario. The increase in truck traffic will be less concentrated near the power plant in scenario 8 than in scenario 4 as the increased number of fuel pellet trucks required for scenario 8 will be less than half the number of hay trucks diverted from the power plant site.

Unlike the first 8 solutions which assumed a minimal transfer cost from power plant site alfalfa processing plants to the power plant, scenarios 9-12 were assigned a higher transfer cost (done by increasing nominal mileage) between the on-site alfalfa processing plant and the power

plant. This sensitivity analysis was done to see how sensitive the solution is to the cost of handling and moving pellets between an on-site processing plant and the power plant. Scenarios 9 and 10 reflect a transfer cost of about $2 per ton of pellets; scenarios 11 and 12 reflect a transfer cost of about $4 per ton of pellets. It appears that a 200,000 ton processing capacity is justified at both of the potential power plant sites if transfer costs are $2.00 or below but a smaller capacity may be appropriate as transfer costs rise towards $4 per ton of pellets.

Table 5 and 6 show annual and daily hay trucks arriving at each location for each scenario. Hay trucks are assumed to haul 20 tons each and deliveries are made 250 days a year. Table 7 and 8 show annual and daily fuel and feed pellet trucks leaving the alfalfa processing plants. Fuel and feed trucks carry 25 tons each and operate 250 days per year. (Fuel and feed truck numbers per location are identical except fuel pellets are not trucked from the alfalfa processing plant located at power plant sites.)

Transportation Impacts

To determine the impacts of changes in local transportation patterns, the truckloads from the minimum transportation solution for scenario four (five plant sites, 200 tons of alfalfa processed at the power plant site) were added to the ADT's obtained from the MNDOT traffic maps. A summary of the additional traffic for the segments with the largest increases is shown in Table 9 and 10. Note that these are a computation of truck traffic due to alfalfa processing and the power plant. These movements are in place of and not completely in addition to farm to market movements of the crops that be grown on the land dedicated to alfalfa biomass. There was no explicit allowance for backhaul traffic except that ash was not added to the truck volumes. Each fuel, feed and hay truck was counted twice, once full and then empty when it left the plant.

Since both of the alternative power plant sites are near Granite Falls, there is substantial overlap among the impacted highways for each site. The highest total vehicle counts from the ADT maps were for 7200 vehicles a day on US 212 and SR 67 in downtown Granite Falls, 5800 vehicles a day on SR 23 leaving Marshall and 5600 vehicles a day on US 212 in Granite Falls east of its junction with SR 67. Highest truck traffic in the region was 635 per day on US212 in Granite Falls east of SR 67, 510 trucks per day on SR 23 leaving Marshall, and 480 trucks per day on SR 67 south of downtown Granite Falls.

Traffic Impacts

Table 9 shows that the greatest total impact for the Granite Falls site is on SR 23 north of US 212 near the power plant site. Daily hay, fuel and feed trucks load and unloaded, are estimated at 190 trips. (Note that these will go both north and south so the directional impact will be divided in both directions from the plant.) This is a 9% increase in ADT and a 59% percent increase in trucks. For comparison SR 23 currently handles about 83% as much truck traffic and twice as much vehicle traffic on the approach to Wilmar north of Priam.

The second largest increase for the Granite Falls site is on US 59 and SR 7 coming south from Appleton. This represents an 8% increase from the 1996 1500 ADT. SR 59 handles 2350 vehicles per day closer to Granite Falls. The third largest increase is 102 trucks per day on US 212 east of Granite Falls. This represents less than a 2% increase in ADT's. All other road or highway serving the Granite Falls site are predicted to have increases of less than 100 trucks per day.

Table 10 shows traffic impacts by road segment for the YMC site. There are also 3 segments with 100 or more additional trucks. These are SR 23 near YMC, south of Granite Falls

with an increase of 192 trips or 6.3%. (These trips will go in both directions from the plant so the increase will be less in each direction.) The next largest increases are on SR 67 south of Granite Falls and SR 23 north of Marshall. Because of the current ADT's of 5100 and 5800 on those highways, the percentage increases are only 2.4% and 1.9%.

Summary and Conclusions

This paper describes the proposed MNVAP GIS databases that will be used for raw product forecasting, plant assignment, production forecasting, market planning and truck routing by MNVAP. A demonstration of using the database information to determine highway impacs due to increased truck is presented.

We found the largest predicted increase in truck numbers on any highway segment is 190, and 192, vehicles per day for Granite Falls, and YMC, respectively. This estimate is expected to be considerably higher than the actual result for 3 reasons.

1. The evaluation does not include backhauls (except ash). It is likely that feed will be backhauled in the fuel pellet trucks or vice versa.
2. Traffic at both sites will be going and coming from both directions because the plant sites are midway on designated highway segments. Consequently the average increase in each direction will be something closer to half of the total of 190 or 192 trips per day.
3. This a worst case scenario in that alfalfa processing plants were allowed next to the power plant sites to minimize transportation costs. If the processing occurs elsewhere, it will require only 40% as many fuel pellet trucks as the hay trucks they replace. An offsetting increase in hay trucks will occur at the processing plants, but the impact will be divided between three or four locations.

TABLE 3 MINIMUM TRANSPORTATION COST SOLUTIONS FOR GRANITE FALLS PLANT SITE

SCENARIO	1	2	3	4	5	6	7	8	9	10	11	12
	Free Flow 9 SITES	Free Flow 5 SITES	200,000 TON CAPACITIES 9 SITES	200,000 TON CAPACITIES 5 SITES	100,000 TON CAPACITIES	100,000 TON CAPACITIES	Free Flow NO GF 8 SITES	Free Flow NO GF 4 SITES	Free Flow $2.00 9 SITES	Free Flow $2.00 5 SITES	Free Flow $4.00 9 SITES	Free Flow $4.00 5 SITES
Separator Locations												
Granite Falls	381,486	433,314	200,000	200,000	100,000	100,000	0	0	237,502	256,026	148,855	164,708
Marshall	38,521	38,521	130,548	131,977	100,000	100,000	161,887	177,741	121,469	121,469	131,977	131,977
Appleton	90,962	90,962	113,674	166,131	100,000	100,000	150,376	189,517	93,919	127,374	134,446	172,478
Renville	33,374	38,964	77,439	94,985	100,000	100,000	208,288	225,834	70,678	88,224	106,383	123,929
Buffalo Lake	2,520	0	11,956	0	25,439	0	11,956	0	11,956	0	11,965	0
Sleepy Eye	5,590	0	5,590	0	5,600	0	5,590	0	5,590	0	5,590	0
Canby	15,853	0	15,853	0	88,065	100,000	16,962	0	15,853	0	15,853	0
Priam	98,228	98,228	106,897	106,897	100,000	100,000	106,897	106,897	106,897	106,897	106,897	106,897
Morris	33,454	0	38,032	0	80,886	99,990	38,032	0	36,125	0	38,032	0
TOTAL TONS HAY	699,988	699,989	699,989	699,990	699,990	699,990	699,988	699,989	699,989	699,990	699,998	699,989

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TABLE 4 MINIMUM TRANSPORTATIONCOST SOLUTION FOR YELLOW MEDICINE COUNTY SITE

SCENARIO	1	2	3	4	5	6	7	8	9	10	11	12
Separator Locations	Free Flow 9 SITES	Free Flow 5 SITES	200,000 TON CAPACITIES 9 SITES	200,000 TON CAPACITIES 5 SITES	100,000 TON CAPACITIES	100,000 TON CAPACITIES	Free Flow NO GF 8 SITES	Free Flow NO GF 4 SITES	Free Flow $2.00 9 SITES	Free Flow $2.00 5 SITES	Free Flow $4.00 9 SITES	Free Flow $4.00 5 SITES
Yellow Medicine Co.	301,319	353,147	200,000	200,000	100,000	100,000	0	0	224,570	243,095	137,866	137,866
Marshall	121,469	121,469	135,286	151,139	100,000	100,000	221,570	237,424	134,400	134,400	145,390	161,243
Appleton	93,919	93,919	113,674	149,800	100,000	100,000	150,376	189,517	93,919	127,374	134,446	172,478
Renville	27,636	33,226	74,608	92,154	100,000	100,000	148,606	166,152	70,678	88,224	103,960	121,506
Buffalo Lake	2,520	0	11,956	0	25,439	0	11,956	0	11,956	0	11,956	0
Sleepy Eye	5,590	0	5,590	0	5,600	0	5,590	0	5,590	0	5,590	0
Canby	15,853	0	15,853	0	100,000	100,000	16,962	0	15,853	0	15,853	0
Priam	98,228	98,228	106,897	106,897	100,000	100,000	106,897	106,897	106,897	106,897	106,897	106,897
Morris	33,454	0	36,125	0	68,951	99,990	38,032	0	36,125	0	38,032	0
TOTAL TONS HAY	699,988	699,989	699,989	699,990	699,990	699,990	699,989	699,990	699,988	699,990	699,990	699,990

TABLE 5 GRANITE FALLS PLANT HAY TRUCKS

SCENARIO	1	2	3	4	5	6	7	8	9	10	11	12
	Free Flow 9 SITES	Free Flow 5 SITES	200,000 TON CAPACITIES 9 SITES	200,000 TON CAPACITIES 5 SITES	100,000 TON CAPACITIES	100,000 TON CAPACITIES	Free Flow NO GF 8 SITES	Free Flow NO GF 4 SITES	Free Flow 2 9 SITES	Free Flow 2 5 SITES	Free Flow 4 9 SITES	Free Flow 4 5 SITES
# of Trucks of Hay												
Granite Falls	19,074	21,666	10,000	10,000	5,000	5,000	0	0	11,875	12,801	7,443	8,235
Marshall	1,926	1,926	6,527	6,599	5,000	5,000	8,094	8,887	6,073	6,073	6,599	6,599
Appleton	4,548	4,548	5,684	8,307	5,000	5,000	7,519	9,476	4,696	6,369	6,722	8,624
Renville	1,669	1,948	3,872	4,749	5,000	5,000	10,414	11,292	3,534	4,411	5,319	6,196
Buffalo Lake	126	0	598	0	1,272	0	598	0	598	0	598	0
Sleepy Eye	280	0	280	0	280	0	280	0	280	0	280	0
Canby	793	0	793	0	4,403	5,000	848	0	793	0	793	0
Priam	4,911	4,911	5,345	5,345	5,000	5,000	5,345	5,345	5,345	5,345	5,345	5,345
Morris	1,673	0	1,902	0	4,044	5,000	1,902	0	1,806	0	1,902	0
ANNUAL TRUCKS	34,999	34,999	34,999	35,000	35,000	35,000	34,999	34,999	34,999	35,000	35,000	34,999
Hay Trucks / Day												
Granite Falls	76	87	40	40	20	20	0	0	48	51	30	33
Marshall	8	8	26	26	20	20	32	36	24	24	26	26
Appleton	18	18	23	33	20	20	30	38	19	25	27	34
Renville	7	8	15	19	20	20	42	45	14	18	21	25
Buffalo Lake	1	0	2	0	5	0	2	0	2	0	2	0
Sleepy Eye	1	0	1	0	1	0	1	0	1	0	1	0
Canby	3	0	3	0	18	20	3	0	3	0	3	0
Priam	20	20	21	21	20	20	21	21	21	21	21	21
Morris	7	0	8	0	16	20	8	0	7	0	8	0
DAILY TOTAL	140	140	140	140	140	140	140	140	140	140	140	140

TABLE 6 YELLOW MRDICINE COUNTY PLANT HAY TRUCKS

SCENARIO	1	2	3	4	5	6	7	8	9	10	11	12
	Free Flow 9 SITES	Free Flow 5 SITES	200,000 TON CAPACITIES 9 SITES	200,000 TON CAPACITIES 5 SITES	100,000 TON CAPACITIES	100,000 TON CAPACITIES	Free Flow NO GF 8 SITES	Free Flow NO GF 4 SITES	Free Flow 2 9 SITES	Free Flow 2 5 SITES	Free Flow 4 9 SITES	Free Flow 4 5 SITES
# of Trucks of Hay												
Yellow Medicine Co.	15065.95	17657.35	10000	10000	5000	5000	0	0	11228.5	12154.75	6893.3	6893.3
Marshall	6,073	6,073	6,764	7,557	5,000	5,000	11,079	11,871	6,720	6,720	7,270	8,062
Appleton	4,696	4,696	5,684	7,490	5,000	5,000	7,519	9,476	4,696	6,369	6,722	8,624
Renville	1,382	1,661	3,730	4,608	5,000	5,000	7,430	8,308	3,534	4,411	5,198	6,075
Buffalo Lake	126	0	598	0	1,272	0	598	0	598	0	598	0
Sleepy Eye	280	0	280	0	280	0	280	0	280	0	280	0
Canby	793	0	793	0	5,000	5,000	848	0	793	0	793	0
Priam	4,911	4,911	5,345	5,345	5,000	5,000	5,345	5,345	5,345	5,345	5,345	5,345
Morris	1,673	0	1,806	0	3,448	5,000	1,902	0	1,806	0	1,902	0
ANNUAL TRUCKS	34,999	34,999	34,999	35,000	35,000	35,000	34,999	35,000	34,999	35,000	35,000	35,000
Hay Trucks / Day												
Yellow Medicine Co.	60	71	40	40	20	20	0	0	45	49	28	28
Marshall	24	24	27	30	20	20	44	47	27	27	29	32
Appleton	19	19	23	30	20	20	30	38	19	25	27	34
Renville	6	7	15	18	20	20	30	33	14	18	21	24
Buffalo Lake	1	0	2	0	5	0	2	0	2	0	2	0
Sleepy Eye	1	0	1	0	1	0	1	0	1	0	1	0
Canby	3	0	3	0	20	20	3	0	3	0	3	0
Priam	20	20	21	21	20	20	21	21	21	21	21	21
Morris	7	0	7	0	14	20	8	0	7	0	8	0
DAILY TOTAL	140	140	140	140	140	140	140	140	140	140	140	140

TABLE 7 GRANITE FALLS PLANT FUEL AND FEED TRUCKS

	Free Flow 9 SITES	Free Flow 5 SITES	200,000 TON CAPACITIES 9 SITES	200,000 TON CAPACITIES 5 SITES	100,000 TON CAPACITIES	100,000 TON CAPACITIES	Free Flow NO GF 8 SITES	Free Flow NO GF 4 SITES	Free Flow 2 9 SITES	Free Flow 2 5 SITES	Free Flow 4 9 SITES	Free Flow 4 5 SITES
# Fuel Trucks												
Granite Falls	0	0	0	0	0	0	0	0		0	0	0
Marshall	770	770	2,611	2,640	2,000	2,000	3,238	3,555	2,429	2,429	2,640	2,640
Appleton	1,819	1,819	2,273	3,323	2,000	2,000	3,008	3,790	1,878	2,547	2,689	3,450
Renville	667	779	1,549	1,900	2,000	2,000	4,166	4,517	1,414	1,764	2,128	2,479
Buffalo Lake	50	0	239	0	509	0	239	0	239	0	239	0
Sleepy Eye	112	0	112	0	112	0	112	0	112	0	112	0
Canby	317	0	317	0	1,761	2,000	339	0	317	0	317	0
Priam	1,965	1,965	2,138	2,138	2,000	2,000	2,138	2,138	2,138	2,138	2,138	2,138
Morris	669	0	761	0	1,618	2,000	761	0	723	0	761	0
ANNUAL TOTAL	6,370	5,334	10,000	10,000	12,000	12,000	14,000	14,000	9,250	8,879	11,023	10,706
# Fuel Trucks /day												
Granite Falls	0	0	0	0	0	0	0	0	0	0	0	0
Marshall	3	3	10	11	8	8	13	14	10	10	11	11
Appleton	7	7	9	13	8	8	12	15	8	10	11	14
Renville	3	3	6	8	8	8	17	18	6	7	9	10
Buffalo Lake	0	0	1	0	2	0	1	0	1	0	1	0
Sleepy Eye	0	0	0	0	0	0	0	0	0	0	0	0
Canby	1	0	1	0	7	8	1	0	1	0	1	0
Priam	8	8	9	9	8	8	9	9	9	9	9	9
Morris	3	0	3	0	6	8	3	0	3	0	3	0
DAILY TOTAL	25	21	40	40	48	48	56	56	37	36	44	43
# Feed Trucks/day												
Granite Falls	31	35	16	16	8	8	0	0	19	20	12	13
Marshall	3	3	10	11	8	8	13	14	10	10	11	11
Appleton	7	7	9	13	8	8	12	15	8	10	11	14
Renville	3	3	6	8	8	8	17	18	6	7	9	10
Buffalo Lake	0	0	1	0	2	0	1	0	1	0	1	0
Sleepy Eye	0	0	0	0	0	0	0	0	0	0	0	0
Canby	1	0	1	0	7	8	1	0	1	0	1	0
Priam	8	8	9	9	8	8	9	9	9	9	9	9
Morris	3	0	3	0	6	8	3	0	3	0	3	0
DAILY TOTAL	56	56	56	56	56	56	56	56	56	56	56	56

TABLE 8 YELLOW MEDICINE COUNTY PLANT FUEL AND FEED TRUCKS

SCENARIO	1	2	3	4	5	6	7	8	9	10	11	12
	Free Flow 9 SITES	Free Flow 5 SITES	200,000 TON CAPACITIES 9 SITES	200,000 TON CAPACITIES 5 SITES	100,000 TON CAPACITIES	100,000 TON CAPACITIES	Free Flow NO GF 8 SITES	Free Flow NO GF 4 SITES	Free Flow $2.00 9 SITES	Free Flow $2.00 5 SITES	Free Flow $4.00 9 SITES	Free Flow $4.00 9 SITES
# Fuel Trucks												
Yellow Medicine Co.	0	0	0	0	0	0	0	0	0	0	0	0
Marshall	2,429	2,429	2,706	3,023	2,000	2,000	4,431	4,748	2,688	2,688	2,908	3,225
Appleton	1,878	1,878	2,273	2,996	2,000	2,000	3,008	3,790	1,878	2,547	2,689	3,450
Renville	553	665	1,492	1,843	2,000	2,000	2,972	3,323	1,414	1,764	2,079	2,430
Buffalo Lake	50	0	239	0	509	0	239	0	239	0	239	0
Sleepy Eye	112	0	112	0	112	0	112	0	112	0	112	0
Canby	317	0	317	0	2,000	2,000	339	0	317	0	317	0
Priam	1,965	1,965	2,138	2,138	2,000	2,000	2,138	2,138	2,138	2,138	2,138	2,138
Morris	669	0	723	0	1,379	2,000	761	0	723	0	761	0
TOTAL	7,973	6,937	10,000	10,000	12,000	12,000	14,000	14,000	9,508	9,138	11,242	11,243
# Fuel Trucks /day												
Yellow Medicine Co.	0	0	0	0	0	0	0	0	0	0	0	0
Marshall	10	10	11	12	8	8	18	19	11	11	12	13
Appleton	8	8	9	12	8	8	12	15	8	10	11	14
Renville	2	3	6	7	8	8	12	13	6	7	8	10
Buffalo Lake	0	0	1	0	2	0	1	0	1	0	1	0
Sleepy Eye	0	0	0	0	0	0	0	0	0	0	0	0
Canby	1	0	1	0	8	8	1	0	1	0	1	0
Priam	8	8	9	9	8	8	9	9	9	9	9	0
Morris	3	0	3	0	6	8	3	0	3	0	3	0
ANNUAL TOTAL	32	28	40	40	48	48	56	56	38	37	45	45
# Feed Trucks/day												
Yellow Medicine Co.	24	28	16	16	8	8	0	0	18	19	11	11
Marshall	10	10	11	12	8	8	18	19	11	11	12	12
Appleton	8	8	9	12	8	8	12	15	8	10	11	14
Renville	2	3	6	7	8	8	12	13	6	7	8	10
Buffalo Lake	0	0	1	0	2	0	1	0	1	0	1	0
Sleepy Eye	0	0	0	0	0	0	0	0	0	0	0	0
Canby	1	0	1	0	8	8	1	0	1	0	1	0
Priam	8	8	9	9	8	8	9	9	9	9	9	9
Morris	3	0	3	0	6	8	3	0	3	0	3	0
DAILY TOTAL	56	56	56	56	56	56	56	56	56	56	56	56

TABLE 9 MAXIMUM COMBINED TRUCK TRAFFIC WITHOUT BACKHAULS FOR GRANITE FALLS SITE

RANK BY TRUCK NUMBERS	HIGHWAY SEGMENT	LOCATION	1996 ADT	1996 TRUCKS	HAY TRUCKS	FUEL TRUCKS	FEED TRUCKS	EMPTY RETURN TRIPS	TOTAL BIOMASS TRIPS	PERCENT INCREASE IN ADT	PERCENT INCREASE TRUCKS
1	SR 23	North from US 212 at junction east of Granite Falls	2100	320	40	32	23	95	190	9.05%	59.38%
2	US 59,SR 7	South from Appleton	1500	155	33	13	13	59	118	7.87%	76.13%
3	US 212	Granite Falls east of SR 67	5600	635	20	24	7	51	102	1.82%	16.06%
4	SR 23	North from Marshall	5800	510	26	11	11	48	96	1.66%	18.82%
5	SR 23	South of Wilmer	4450	425	21	9	9	39	78	1.75%	18.35%
6	US 212	West of Renville	2050	425	19	8	8	35	70	3.41%	16.47%
7	SR 23	Northeast of power plant site	2900	350	20	9	5	34	68	2.34%	19.43%
8	US212,SR 67	Granite Falls west of junction	7200	390	10	13	7	30	60	0.83%	15.38%
9	SR 67	South of junction 212	3950	480	10	11	6	27	54	1.37%	11.25%
10	US 59,SR7	Northwest of Granite Falls near junc. US 212	2350	190	5	13	7	25	50	2.13%	26.32%

TABLE 10 MAXIMUM COMBINED TRUCKS WITHOUT BACKHAULS FOR YELLOW MEDICINE SITE

RANK BY TRUCK NUMBERS	HIGHWAY SEGMENT	LOCATION	1996 ADT	1996 TRUCKS	HAY TRUCKS	FUEL TRUCKS	FEED TRUCKS	EMPTY RETURN TRIPS	TOTAL BIOMASS TRIPS	PERCENT INCREASE IN ADT	PERCENT INCREASE TRUCKS
1	SR 23	Near YMC Site	3050	405	40	40	16	96	192	6.30%	47.41%
2	SR 67,SR 23	South of Granite Falls	5100	480	20	28	14	62	124	2.43%	25.83%
3	SR 23	North from Marshall	5800	510	30	12	12	54	108	1.86%	21.18%
4	US 59,SR 7	South from Appleton	1500	155	30	12	6	48	96	6.40%	61.94%
5	SR 23	South from Priam	4450	425	21	9	9	39	78	1.75%	18.35%
6	US212,SR 67	Granite Falls west of junction	7200	390	10	12	15	37	74	1.03%	18.97%
7	US 212	Granite Falls east of SR 67	5600	635	10	16	11	37	74	1.32%	11.65%
8	US 212	East of Renville	2050	425	18	7	7	32	64	3.12%	15.06%