CHARITON VALLEY BIOMASS PROJECT

Draft Fuel Supply Plan

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Chariton Valley Biomass Project (Phase I)
Deliverable 2 – Draft Fuel Supply Plan

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EXECUTIVE SUMMARY

Project Background

The Chariton Valley Biomass Project is a cooperative effort among two-dozen agricultural and energy interests to grow multi-season grasses such as switchgrass as a source of renewable energy in southern Iowa. Project partners propose to cofire this biomass with coal to continuously generate up to 35 MW of biomass-derived electric power at Alliant Energy's Ottumwa Generating Station (OGS). To accomplish this, the project will require up to 200,000 tons of biomass annually from 50,000 acres, and will involve as many as 500 farmers.

Executive Summary Overview

This executive summary describes progress and results of fuel supply planning for the Chariton Valley Biomass Project. The executive summary is structured loosely in parallel to the main report as follows: 1) background information, 2) lessons learned from three case studies, 3) the fuel supply chain; detailing the production, harvesting, storage and delivery of switchgrass from the field to OGS, 4) delivered switchgrass costs, 5) discussion of a draft contract agreement between Prairie Lands (the switchgrass cooperative) and the independent farmers, 6) a comparison of an automatic bale receiving system vs. a manual system, 7) discussion of the project's impact on truck traffic at OGS, 8) project labor requirements, 9) a queue analysis, and 10) summary tables and conclusions.

Background Information: Existing Conditions in Project Region

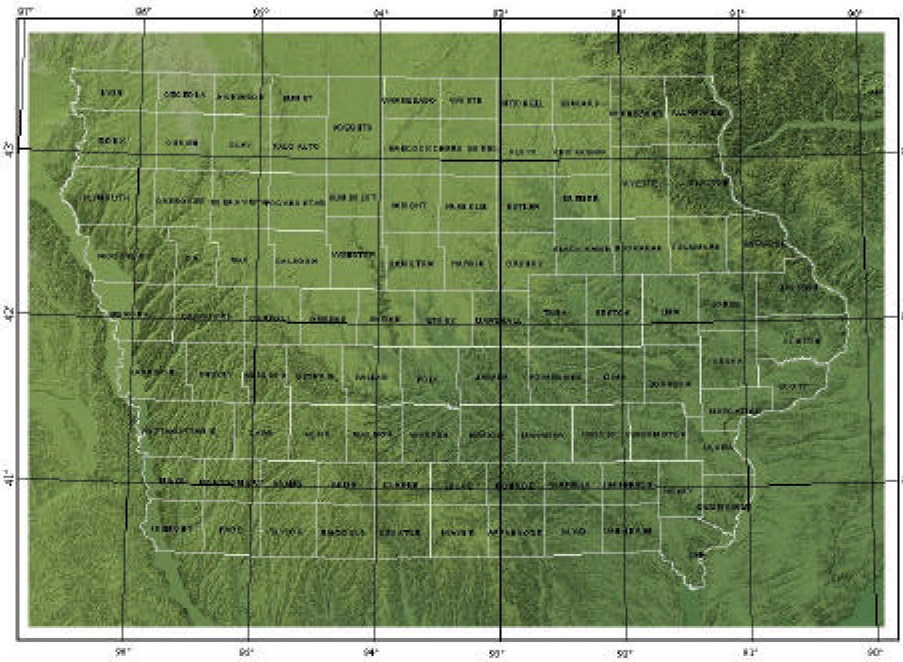
Farmland and Regional Background

The Chariton River watershed encompasses 3,000 km^2 in southern Iowa (see Exhibit ES-1). Common crops during the late 20th century were corn, soybeans, a variety of cool season forages and pasture species, and woodlots. The main limitations to crop production in southern Iowa have been steep, erosive landscapes, clayey soils that alternate between being too wet and too dry, and acidic subsoils. As a result, a large proportion of the land is enrolled in the Conservation Reserve Program, with corresponding areas being planted to switchgrass (Burras and McLaughlin, January 2002).

Conditions at OGS

The OGS is a 726 MW coal-fired power plant located on a 375-acre site adjacent to the Des Moines River. Currently, outbound coal transport and ash hauling comprise a majority of the existing truck traffic for OGS. Coal is the only source of fuel for Ottumwa, and all coal is received via rail. Of the 3.5 million tons of coal that the facility receives via rail annually, 400,000 to 500,000 tons are sold to local industry and transported from OGS via trucks (approximately 16,000 to 20,000 trucks per year). Bottom and fly ash are stored on-site until sold. Fly ash is either transported off-site immediately upon unloading from storage silos (mostly during the construction season—March through October), or is processed on-site to make C-Stone. The C-Stone is then stockpiled on-site until it is sold. Coal, bottom ash, fly ash, and C-Stone are all shipped via truck to OGS customers.

Exhibit ES-1 Chariton River Watershed



Case Studies of Straw Supply Chains

To date, there are no examples of switchgrass being used on the scale considered by the Chariton Valley Biomass Project, so this analysis refers to several case studies where straw has been supplied on a large scale. Switchgrass and straw have similar handling characteristics, density and storage requirements, weight, and baling characteristics. Three case studies were analyzed: large straw delivery systems for combined heat and power (CHP) facilities in Denmark, a straw-fired power plant in England, and a straw export network in Washington and Oregon. The Denmark and England case studies demonstrate practical experience with straw delivery and receiving systems for both cofiring and direct-fired biopower generation. The straw export network example highlights current U.S. experience with straw harvesting, storage, and delivery methods. Each is summarized below:

- *Straw-fired CHP plants in Denmark*—Due to a Danish government mandate, by 1997, fifty-nine straw-fired CHP plants were in operation. The Studstrup power plant is a model for OGS; two years of operation concluded that this 150 MW plant can efficiently cofire up to 20% straw, at a straw supply rate of 20 tons/hr. The plant's delivery, unloading, and storage processes all provide helpful information for this project.

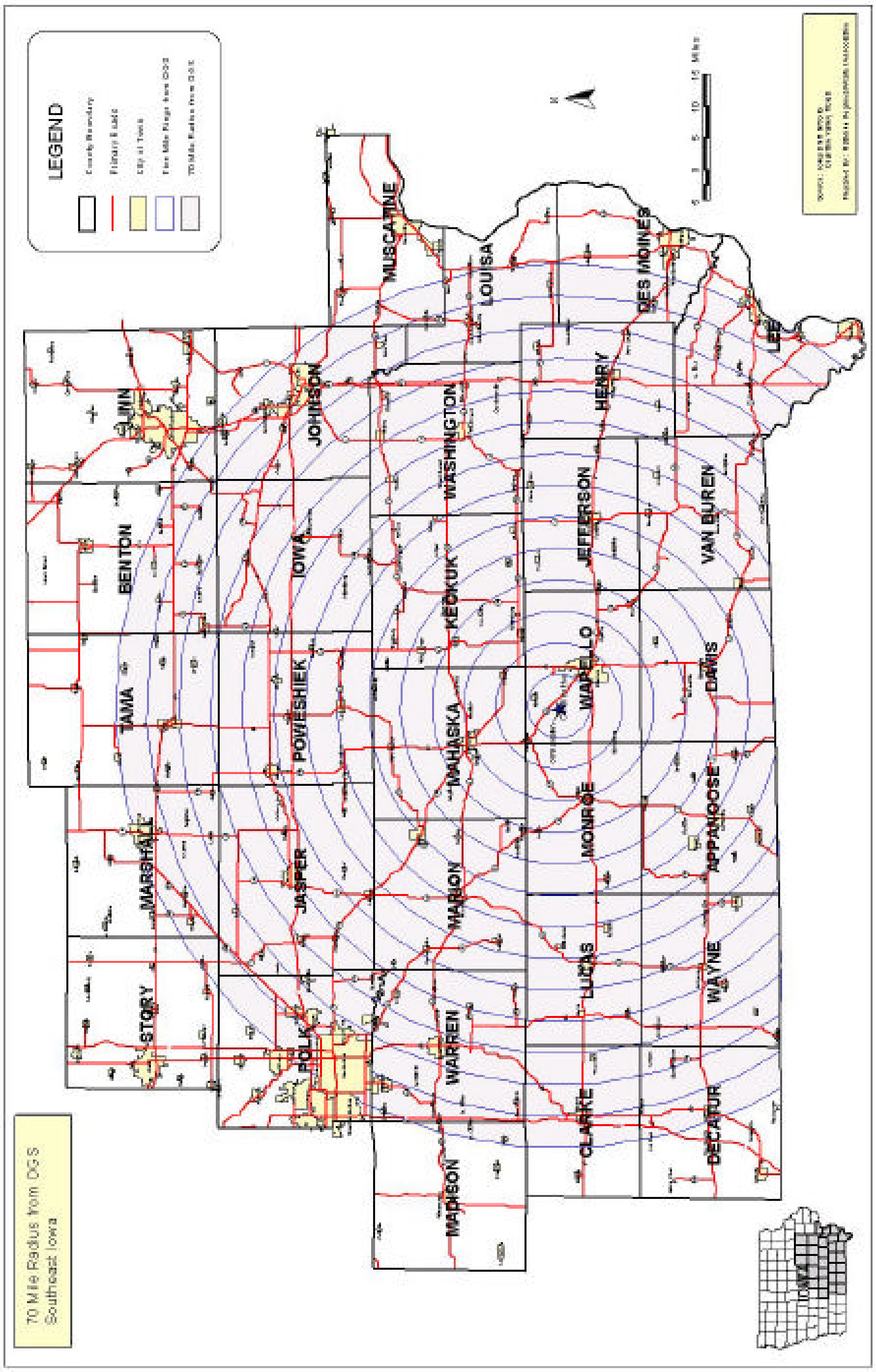
- *Ely power plant in England*—This 36 MW facility consumes approximately 200,000 tons of straw and has long-term straw contracts. The plant's delivery and unloading processes provide helpful information for this project.

- *Straw export network in the Pacific Northwest*—A collective group of farmers exports an annual average of 500,000 tons of straw to Asia. This effort provides helpful information on how a large amount of straw can be stored, shipped, and delivered reliably.

Description of Proposed Fuel Supply Chain

The switchgrass will be obtained from farmers located within a 70-mile radius from OGS (map shown in Exhibit ES-2); this area contains up to 419,745 acres of potential switchgrass-producing land. To meet Alliant's maximum expected cofiring rate, at least 12% of this potential acreage will have to produce 4 tons/acre of switchgrass.

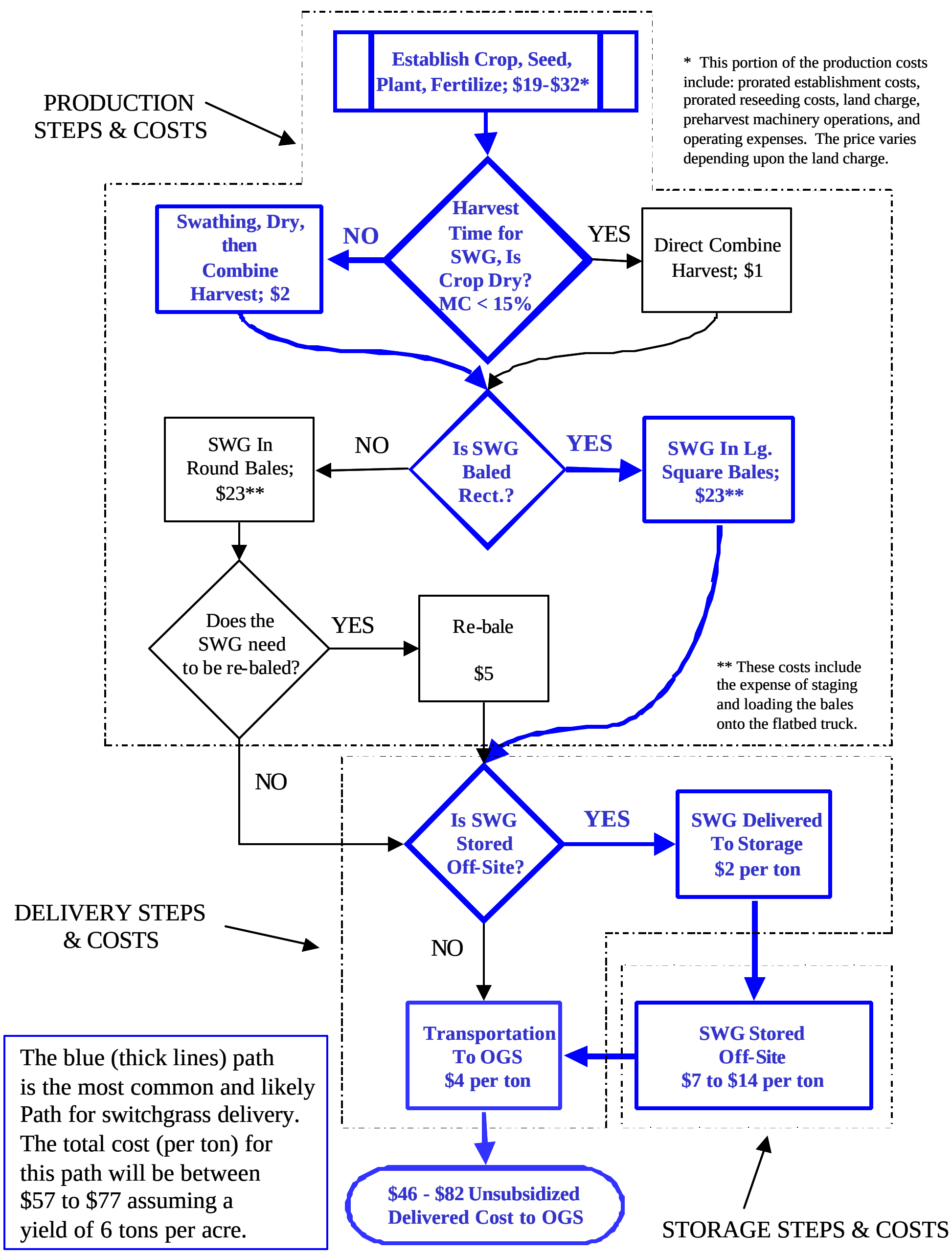
Exhibit ES-2 Project Area – 70-mile Radius Surrounding OGS



Producing and Delivering Switchgrass to OGS

Two major steps would be involved to supply 200,000 tons of switchgrass to OGS annually - production and delivery. A third step - storage - would not apply to all of the delivered fuel, but most of the fuel would be stored off-site. As depicted in the flowchart below (Exhibit ES-3), the production steps include establishing, fertilizing, harvesting, and baling the crop. The transportation steps include moving the fuel from the field to both on and off-site storage sites, and eventually transport to OGS for consumption.

Exhibit ES-3 Fuel Supply Plan Flowchart



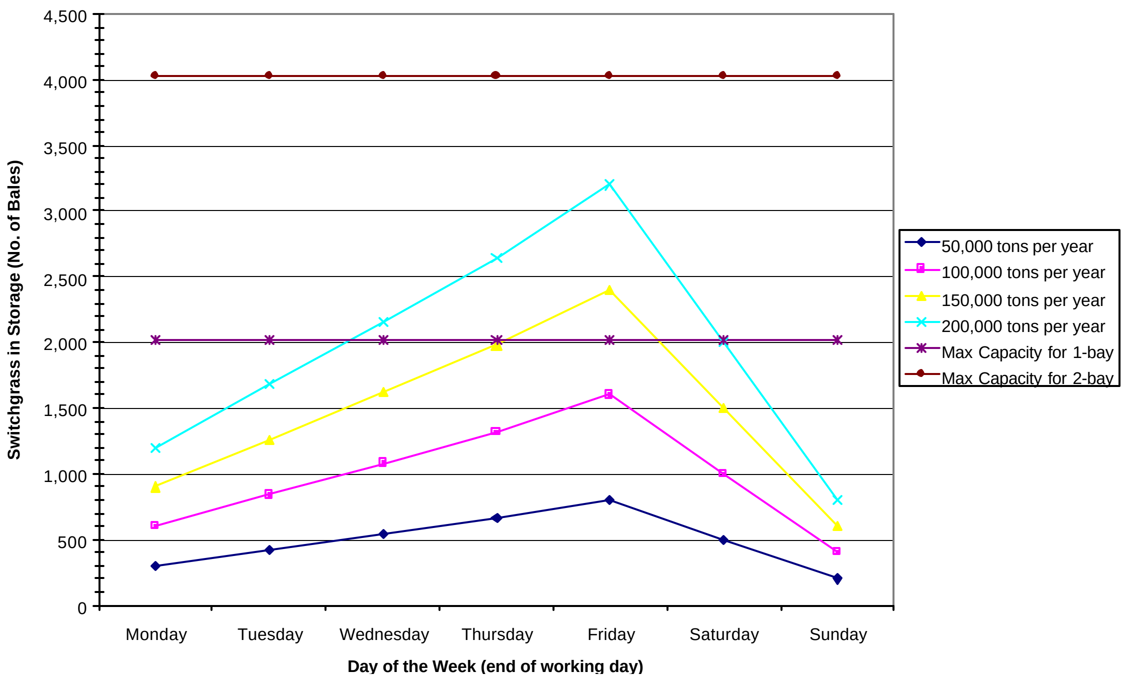
Harvesting is one of the major steps in producing switchgrass. It could begin as early as late August/early September, and due to severe weather conditions in southern Iowa, it will likely end in November. To meet the requirements of the designed bale processing and receiving system, the farmer has to supply the switchgrass in large square bales. Round bales, however, also have their advantages, which are discussed in the report. If the farmer does decide to round bale in the field, he must find a way to convert these bales to large square bales before they reach the OGS gate (re-baling costs are about $5/ton).

The farmer will use flatbed trucks to supply the fuel since they are accommodating and feasible for OGS. Rail transportation was not heavily considered due to possible conflicts in fuel delivery with the existing coal deliveries, higher cost of using rail for short distances, and extra material handling steps for delivering and receiving the fuel. Appendix E includes a comparative discussion of rail delivery. Trucks hauling large square (3' x 4' x 8') bales of switchgrass on 53-ft. extended flatbed trailers were assumed to be the preferred delivery mode. This arrangement maximizes switchgrass stability on the truck and allows for the greatest quantity of switchgrass per truckload while remaining within Iowa's legal delivery weights and dimensions. Each trailer is assumed to be loaded with bales stacked three high, two wide, and seven deep for a total of 42 bales per truck and a payload weight of about 42,000 lbs (1,000 lbs per bale) or 21 tons.

Storage Requirements

Since the switchgrass harvesting season would last for three months and cofiring operations would occur almost year-round, there would be a need for switchgrass storage. To facilitate the storage requirements for the project, a combination of on-site and off-site storage facilities is planned. Two on-site facilities were used during the test cofiring campaign. When the switchgrass is delivered to OGS, it will first be stored in the storage barn located near the processing center. This building will have one or two storage bays. Each of these bays will store a maximum of 2,072 bales of switchgrass—approximately 3 days worth of switchgrass at a consumption rate of 12.5 tons per hour. The other on-site facility is nicknamed "the Straw Palace," which will serve as the second point of storage. The Straw Palace can hold up to 4,000 tons or around 8,000 large square bales of switchgrass. This structure will be used as a holding area for excess switchgrass that cannot fit within the storage barn. In this preliminary analysis, the minimum amount of switchgrass needed in the storage barn was calculated for a five-day workweek for fuel receiving. A graph showing the dynamic on-site inventory in the storage barn through the course of a typical week is shown in Exhibit ES-4.

Exhibit ES-4 Inventory Level in Storage Barn



After filling the two on-site facilities, the remaining switchgrass will be stored in an off-site facility. Storage cannot be avoided due to the large demand for switchgrass (200,000 tons/year) and the short (3 month) harvest season due to the harsh Iowa winters. After storing the fuel for a designated amount of time, the switchgrass will then be delivered to OGS via flatbed truck.

There are several off-site storage options, listed in order of increasing cost: 1) under reusable tarp, 2) unprotected on crushed rock, 3) within a pole frame structure (open sides), 4) unprotected on ground, 5) within a pole frame structure (closed sides), and 6) in a steel storage shed (covered storage). The storage cost of each option includes the costs of dry matter losses, which are related to the amount of switchgrass damaged due to natural elements. These losses render the unprotected storage on crushed rock slightly more costly than tarp storage. Likewise, because of dry matter losses, unprotected storage on ground is actually the third most costly option. Although it is the most expensive option, the steel storage shed offers the best fuel quality. Storing the switchgrass in a shed ensures that its moisture content (MC) will be lower than 15% when arriving at OGS. The 15% MC requirement is the maximum allowable level that the receiving and processing system is designed to accept. The steel storage shed will add up to $14/ton ($3.77/ton over and above unprotected storage on ground) to the delivered fuel cost for the project. According to our calculations, a 200,000 tons/year switchgrass feed rate plus a 3-month harvest season would require a minimum of 363 storage sheds, each with a 450-ton capacity. The initial cost for these sheds would be approximately $22.5 million.

Delivered Cost of Switchgrass

The total estimated delivered cost for switchgrass is calculated based on production/harvesting costs (including the farmers' required return), storage costs, and delivery costs (Prairie Lands' overhead and on-site processing costs to get the switchgrass to the burner tip are not included). This estimate does not include any regulatory incentives. The best-case scenario assumed in the fuel supply plan has the farmers producing the switchgrass at around $44/ton. This figure is the total cost associated with seeding, land charges, planting, growing, harvesting, and baling the switchgrass (including farmers' return). Harvesting/baling is the single most expensive component at $25/ton. Steel shed storage adds another $14/ton to the production cost. Lower cost storage options such as reusable tarps ($7/ton) and pole barns ($7 to $12/ton) were considered, but each could have problems surviving the southern Iowa winters. The delivery and handling charge was estimated to be $6/ton (transportation at $4/ton plus handling at $2/ton). Therefore, if steel shed storage is used, the total estimated delivered cost is $64/ton ($44 + $14 + $6) and if tarps - the lowest cost storage option - are used, the delivered cost would be about $57/ton ($44 + $7 + $6).

Draft Contract Agreement

A draft contract between the farmer and Prairie Lands is provided in Appendix B. This document provides the framework for fuel supply standardization from every farmer. The following items are included in the scope of work for each farmer:

- Size, shape, moisture content of baled switchgrass
- Field-by-field harvest plan development
- Collection of harvest and yield-related data
- Fuel supply delivery timeframe
- Amount of fuel to be supplied to OGS
- Timeframe for payment of services
- Agreement of delivered fuel price

Life Cycle Cost Analysis: Comparison of Automated vs. Manual Bale Receiving Systems

An economic analysis was done to compare automated versus manual switchgrass bale receiving systems. The automated overhead bridge crane system can unload the baled switchgrass from the flatbed truck, weigh it, and measure each bale's moisture content. The automated crane system is based upon the system used by the straw-fired power plants in Denmark and England. The manual forklift system requires the truck driver to unload the bales in the processing bay, place them on the conveyor or into the storage area, and then clean up the area.

A twenty-year life cycle cost analysis was performed to determine which system had the lower overall cost stream (in present value terms). The analysis used an initial capital cost of $15.1 million for the automated system and $13.8 million for the manual system. Annual costs include annual electricity costs to power the switchgrass receiving and processing equipment, labor, and maintenance. The annual maintenance costs were assumed to be 2% of the initial capital costs (Easterly, 1994). The manual system assumed 10 full time employees would be required, and the automated system would require 3 full time employees. The annual electricity costs for the manual system were approximately $30,000 per year lower than the automated system, since the HP requirement would be 320 HP less for the manual system. Using a discount rate of 8%, the life cycle costs for the manual system and the automated system were $28.2 million and $24.7, respectively. From this preliminary life cycle cost analysis, it is recommended that the project use the automated bale receiving system.

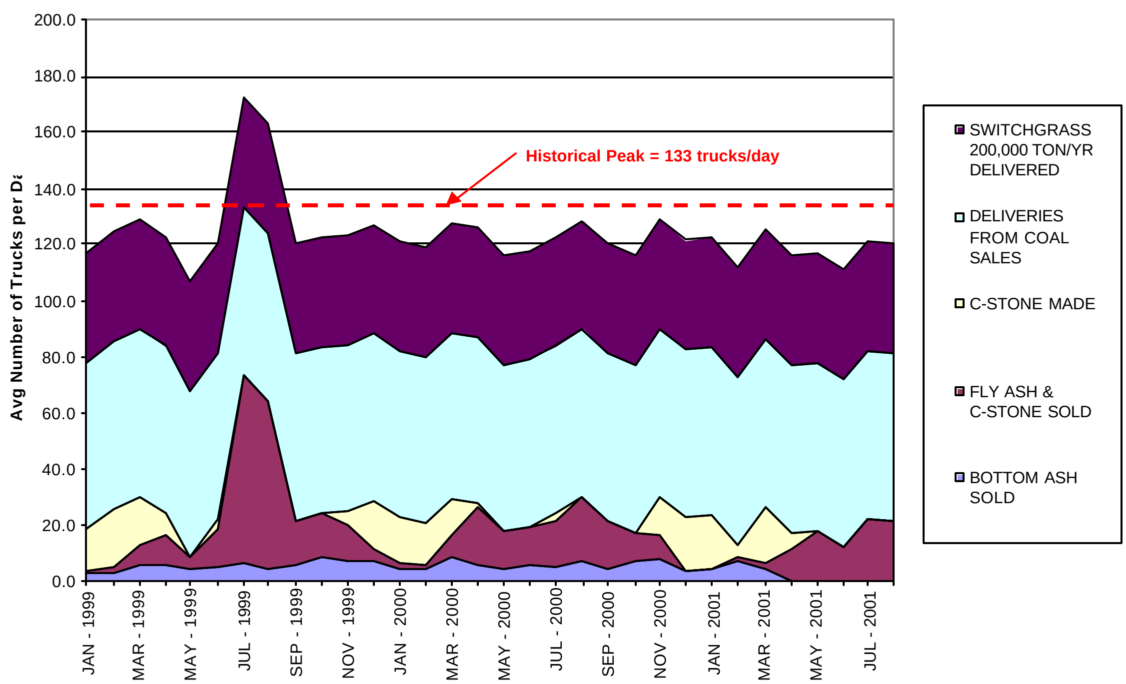
Results of Preliminary Switchgrass Truck Traffic Analysis

An estimate of the frequency of switchgrass truck and train deliveries was performed using data from other consultants and research. The analysis considered the following switchgrass supply scenarios:

- 50,000; 100,000; 150,000; and 200,000 tons per year
- 1, 2, and 3 shifts per day delivery schedules
- 5 and 7 day delivery needs
- 1 and 2 bay fuel receiving areas at OGS
- different harvest schedules
- different off-site storage options

Since Alliant's staff has shown preference toward a truck-based delivery network, most of the analysis addresses issues associated with this mode of transportation. Alliant staff and Shinn Trucking, the coal trucking fleet serving OGS, provided information on the plant's existing traffic patterns and volume (the coal trucking fleet transports coal from OGS to local industries who purchase coal from OGS). Other project partners provided additional information on switchgrass delivery plans. The anticipated delivery frequency was estimated based on the annual switchgrass supply level and the operating schedule for the switchgrass receiving facility. The graph below (Exhibit ES-5) shows historical traffic volume through the gates at OGS, with the top layer of the graph being the anticipated switchgrass traffic.

Exhibit ES-5 Anticipated Truck Traffic Volumes at OGS



The key conclusion is that the historical traffic peak at OGS (represented by the light blue peak in Exhibit ES-6, late summer 1999) is higher than would be expected if switchgrass were supplied to OGS at the maximum rate of 200,000 tons/year. Plant personnel were able to manage traffic flows and volumes during the historical peak without significant reported problems. Therefore, traffic expected for the switchgrass project, even at the maximum supply volume, should be manageable without disrupting other traffic at OGS under most circumstances.

It is noted that short-term traffic volumes could potentially exceed the historical peak if another high fly ash / c-stone selling event were experienced (as in late summer 1999). The proposed location for the switchgrass receiving and processing, along with plans to truck switchgrass in through the North entrance, will mitigate any congestion effects if a new historical truck traffic peak is experienced.

Labor Requirements

The biomass project will have annual labor requirements to produce and deliver 200,000 tons of switchgrass to OGS. The following tasks will be required to make the fuel supply aspects of the project successful:

1. Acquire sufficient land to grow 200,000 tons of switchgrass per year.
2. Establish the switchgrass stand within the first year. If necessary, reseeding will occur during the second year.
3. Apply the necessary fertilizers, nutrients, and herbicides to nurture the switchgrass (noted as producing switchgrass crops in Exhibit ES-5).
4. Harvest and bale the switchgrass.
5. Store the switchgrass under covered off-site storage, or
5a. Deliver the switchgrass directly to OGS (Labor done by the loaders / unloaders and the contract truckers).
6. Oversee the incoming deliveries at OGS (Labor done by spotter truck drivers and the crane operator).
7. Manage the trucking logistics of switchgrass deliveries (Performed by Prairie Lands Administration).

Exhibit ES-6 below shows the level of participation that will be required for the successful delivery of 200,000 tons/year of switchgrass to OGS. The column showing the minimum people required is the case where the farmers would perform all of the labor described, while the column showing the maximum people required is the case where the farmers would contract out their work.

Exhibit ES-6 Total Participation Required for Biomass Project

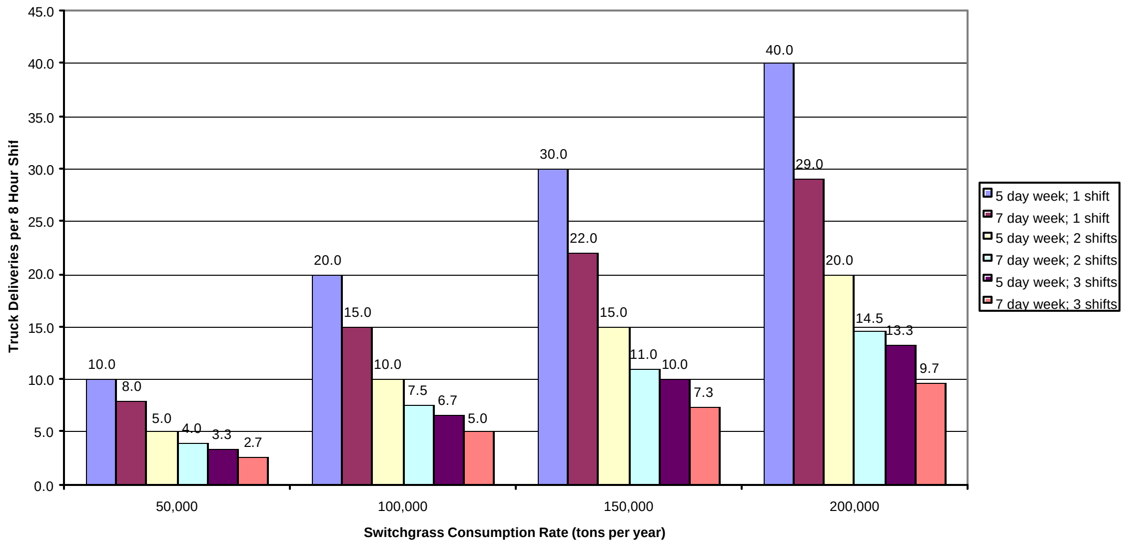
Function / Labor Requirement	Min. People Required	Max. People Required
Acquire Land / Farmer Participation	500	500
Establish the stand	-	70
Producing Switchgrass Crops*	-	44
Harvesting and Baling	-	71
Contract Truckers	-	33
Loaders / Unloaders	-	32
Prairie Lands Administration	2	2
Spotter Truck Drivers	-	2
Crane Operator	1	1
Total Number of Participants	503	639

* This also includes the labor required for reseeding in year 2.

Queue Analysis

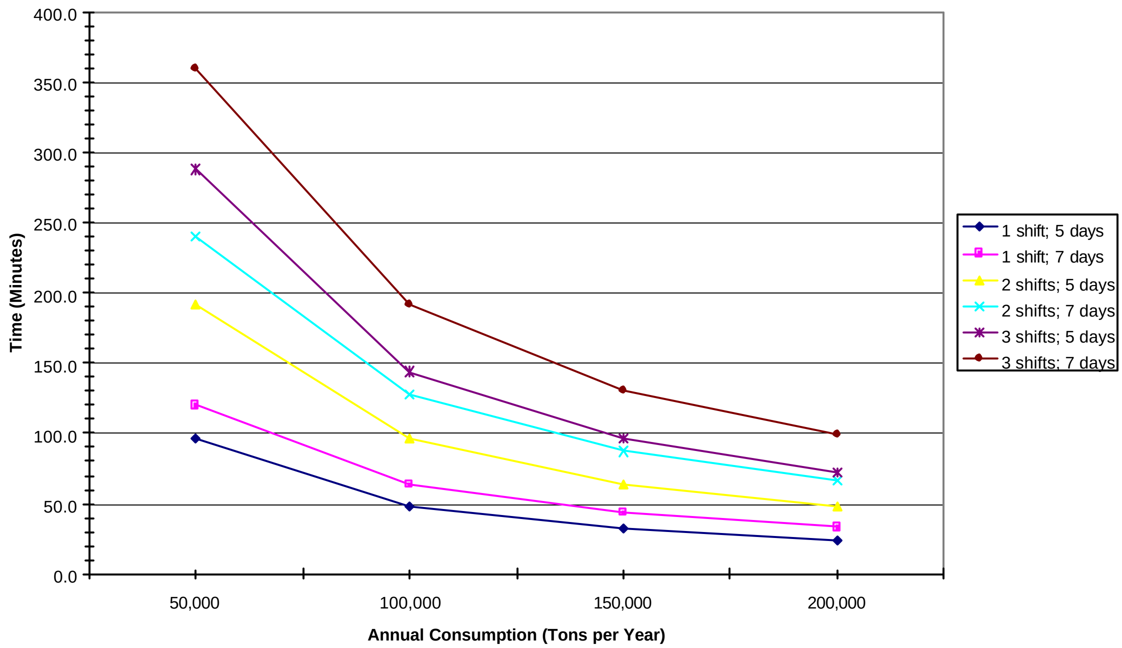
Vehicle capacity data was collected to determine the anticipated truck (or rail) volume entering OGS on a daily basis. The graph in Exhibit ES-7 shows the predicted hourly truck volume increase depending on the amount of 8-hour shifts worked per week for various consumption rates. For annual consumption of 200,000 tons per year, 40 flatbed trucks will need to arrive daily for a 5-day week schedule. In this scenario, either 40 trucks could arrive in one shift or 20 trucks could arrive in two shifts.

Exhibit ES-7 Flatbed Truck Switchgrass Delivery Frequency



Using these frequencies, the unloading times for the manual or automated systems were determined and are shown in Exhibit ES-8. These unload times were based upon two unloading mechanisms working simultaneously. For a single shift operation, five days a week, the unloading time needs to be less than 24 minutes. The unloading time would include the time to queue up the next truck. The manual operation requires between 18 to 22.5 minutes while the automatic operation requires 15 minutes to unload the truck and stack the bales in the storage barn. For the automated system, a single shift, five-day operation will maximize the use of the labor and equipment while minimizing the amount of time required for switchgrass-carrying trucks to be on the grounds of OGS. The manual system probably would require overtime in order to unload the same amount of bales as the automated system is capable of unloading.

Exhibit ES-8 Maximum Unload Time per Crane / Forklift



Conclusions, Next Steps, Summary Tables

The historical traffic peak at OGS is higher than would be expected if switchgrass were supplied to OGS at the maximum rate of 200,000 tons/year. Plant personnel were able to manage traffic flows and volumes during the historical peak without significant reported problems. Therefore, traffic expected for the switchgrass project, even at the maximum supply volume, should be manageable without disrupting other traffic at OGS under most circumstances.

It is noted that short-term traffic volumes could potentially exceed the historical peak if another high fly ash / c-stone selling event were experienced (as in late summer 1999). The fact that switchgrass will be brought in and out of the north entrance would mitigate the congestion effects if a new historical truck traffic peak were experienced.

In addition to having a lower life cycle cost than the manual bale receiving system, the automated crane system would be more reliable. The Danish have used cranes on straw-fired combined heat and power systems with a firing rate as low as 2 tons/hour, which is less than 10% of the amount needed at OGS. Automated cranes have worked reliably in various overseas operations, and provide the best bale handling solution for switchgrass at OGS.

Some issues remain unresolved for the fuel supply plan. First, the production costs need to be reduced to make the switchgrass project more economically viable. Second, many farmers are still concerned with baling the switchgrass in large square form as required by the receiving and processing system. The large square baling equipment represents a large capital investment for those farmers without access to the large square balers. “Rebaling” at $5/ton is a potential option for those farmers. Third, the network of off-site storage sheds and locations needs further development. A better-planned and developed network will lower the delivered cost of switchgrass. As a related issue, actual dry matter losses for the six alternative storage options should be evaluated (in the Chariton Valley) to help configure the optimal storage scenario/network.

1.0 INTRODUCTION

1.1 Project Background Information

The Chariton Valley Biomass Project is a cooperative effort among two-dozen agricultural and energy interests to grow warm and cool-season grasses as a source of renewable energy in Iowa. Project partners propose to cofire these grasses with coal to continuously generate up to 35 MW of biomass-derived electric power at Alliant Energy's Ottumwa Generating Station (OGS). To accomplish this, the project will require about 200,000 tons of biomass per year from harvests on up to 50,000 acres. If the project achieves commercial viability, as many as 500 farmers will be involved in providing this renewable fuel supply. The research and demonstration phases of the project are being cost-shared by the U.S. Department of Energy.

Initiated in 1995, the Chariton Valley Biomass Project has started to conduct a series of cofire test campaigns to demonstrate the technical feasibility of cofiring biomass with coal at OGS. Installation and testing of permanent equipment and modifications will be completed during these campaigns. Plans are to conduct three tests over a five-year period from 2000 through 2004 prior to the beginning of commercial-scale biomass cofire operations.

Currently, more than 80 cooperating producers work with the Chariton Valley Biomass Project to grow and harvest biomass on their land. This biomass is produced on land enrolled in the Conservation Reserve Program (CRP). In support of the Chariton Valley Biomass Project, in 1995 the US Department of Agriculture's (USDA) Farm Service Agency granted authorization for the harvest of biomass from up to 4,000 acres of land enrolled in the CRP. Cooperating producers currently receive no compensation for the biomass harvested from their CRP land; their efforts are coordinated through a biomass producers' organization, Prairie Lands Bio-Products, Inc.

Exhibit 1-1 shows the locations of switchgrass fields for the cooperating producers currently participating in the project, and their locations relative to existing switchgrass storage sheds and OGS. Concentric circles are drawn around OGS with radii in 5-mile increments to indicate transportation distances from cooperator fields and storage sheds to the power plant. Nearly all current cooperator fields and storage sheds are within 50 miles of OGS. While all cooperator acreage is presently located in Lucas, Monroe, Wayne, or Appanoose counties (the counties within the Chariton Valley Resource Conservation and Development district), switchgrass will be obtained from any fields within an economic transportation distance (about 70-miles or less) if the project reaches commercial operation.

In addition to the cofire test campaigns at Ottumwa Station, project partners are conducting research to improve the agronomic practices and net environmental benefits associated with producing and using farm-raised biomass for energy generation. Iowa State University and the University of Iowa are conducting this research primarily on cooperating biomass producers' land. The research addresses a range of issues important to the development of a biomass energy industry in southern Iowa: establishment and harvesting techniques, variety and fertility trials, biomass fuel quality analysis, economic analysis of biomass production at the farm and regional levels, wildlife habitat benefits, water quality protection, soil carbon sequestration, and reduction in greenhouse gas emissions.

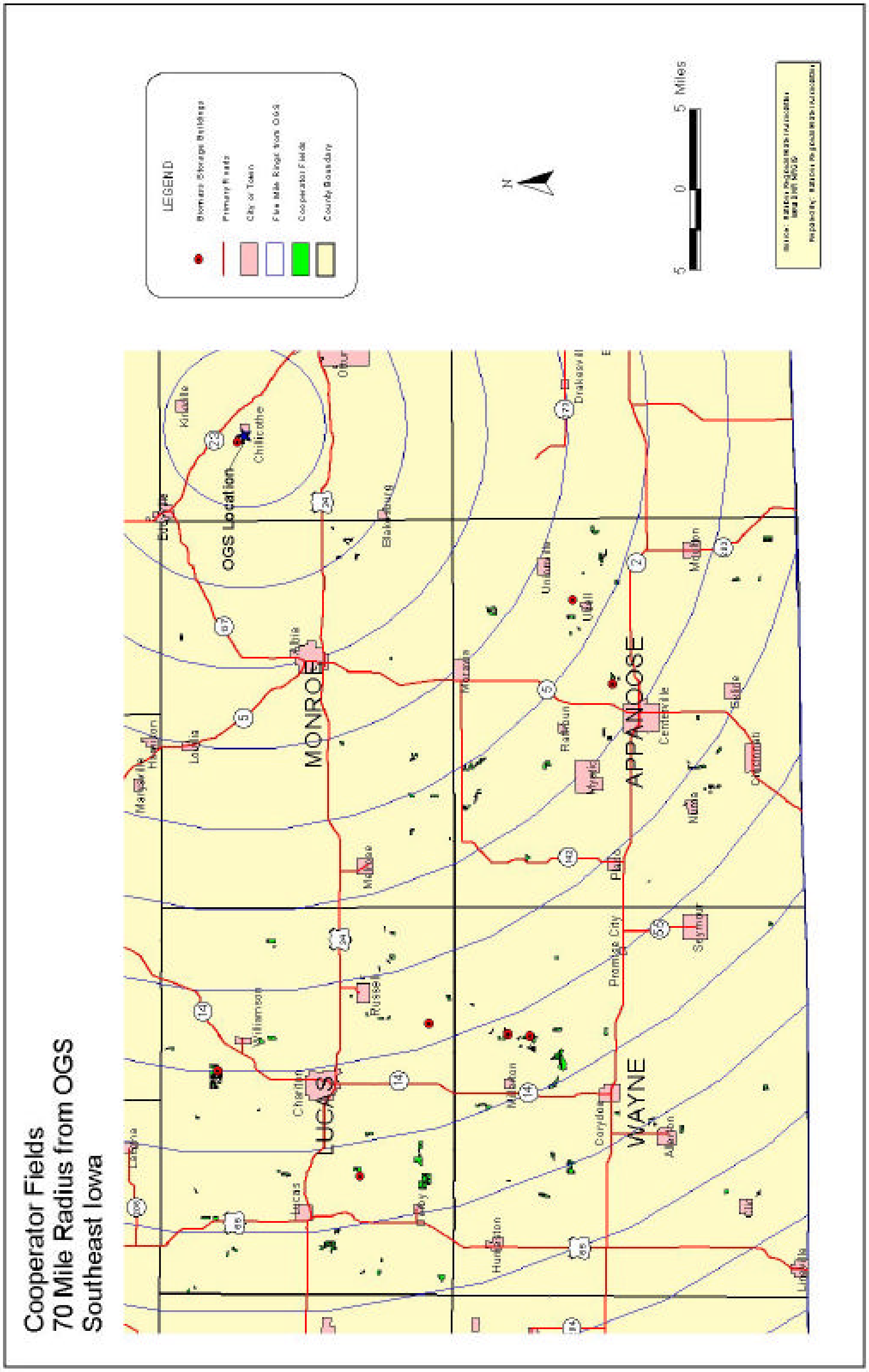


Exhibit 1-1 Primary project region and existing cooperator fields for Chariton Valley Biomass Project

1.2 Report Overview

This report discusses preliminary plans and estimated costs for establishing, harvesting, storing, and delivering switchgrass from Southern Iowa farms to Ottumwa Generating Station (OGS), including plans for receiving operations and facilities at the power plant.

Section 2 of this report discusses case studies of existing large-volume straw handling systems and relates them to preliminary plans for the Chariton Valley Biomass Project fuel supply chain. The discussion addresses the need for storage and the costs associated with various storage options. The case studies also shed light on the round bale vs. square bale question.

Section 3 of this report provides an overview of the switchgrass fuel supply chain, including harvesting and baling, storage, and transport/delivery. Delivered switchgrass costs are discussed. A draft contract agreement (between Prairie Lands and the farmers) that defines terms and conditions for costs, quantities, and quality of switchgrass fuel for the project is discussed in Section 3 and presented in Appendix B.

Section 4 discusses switchgrass receiving at the OGS. Logistics of the fuel receiving process at the power plant, including increased traffic volumes and potential impacts on existing traffic are discussed for the cofire test campaigns and the proposed commercial operations. Results from a life cycle cost analysis are provided to justify plans for constructing a fully-automated biomass receiving and processing facility at the power plant.

Section 5 discusses and tabulates the labor requirements for each major step in the fuel supply chain. The requirements for producing and transporting the fuel are included. The production steps include establishing, maintaining, harvesting, and baling. Transportation steps include shipping, handling, and storage.

A preliminary queue analysis is presented in Section 6. The volume of switchgrass deliveries by truck are discussed for supplying up to 200,000 tons per year for various delivery schedules. The unloading schedule is discussed for these delivery schedules. Finally, the on-site storage requirements for the storage barn are discussed for the five day week operation.

2.0 CASE STUDIES

To date, there are no examples of switchgrass being harvested and used on the scale considered for the Chariton Valley Biomass Project (CVBP), however there is plenty of documented experience with supplying straw at similar or greater annual volumes. Europeans have used straw as a fuel in combined heat and power (CHP) facilities on the same scale as that proposed for Chariton Valley. Farmers in the Pacific Northwest export straw to Asia for animal fodder on an even larger scale than the amounts proposed for Chariton Valley. Since straw and switchgrass are very similar, valuable lessons can be taken from these existing large-scale straw supply systems. The Chariton Valley Biomass Project has drawn upon the experience gained from these operating straw supply systems in developing its draft fuel supply plan.

This section discusses straw delivery systems for several energy projects in Denmark, a straw-fired power plant in England, and the Straw Export Network in Washington and Oregon. The Denmark and England case studies demonstrate practical experience with straw delivery and receiving systems for both cofiring and stand-alone biomass energy operations. The firing rates are similar to that being considered for OGS. The Straw Export Network example highlights current U.S. experience with straw harvesting, storage, and delivery methods. Key areas of influence of these existing supply systems on the CVBP are highlighted.

2.1 Straw-fired CHP Plants in Denmark

For many years, Denmark has been a leader in straw fired power plants. In 1990, the country prohibited the field burning of the estimated 2.3 million tons of surplus straw. (CADDET, 1998) This policy gave the farmers the options of either using the straw for livestock purposes or mulching the remainder onto the fields, which led to the idea of using the straw as fuel source for district heating plants. This idea was first spawned in 1983 by a group of farmers near Aarhus, as a response to growing environmental awareness and rising oil prices. This farmer cooperative actually had its first district heating plant in operation by 1986. Once the field burning policy was enforced, more farmers were supplying straw to the existing district heating plants and starting new CHP facilities.

The Danish Parliament directed its power stations to use 1.2 million tons of straw and 200,000 tons of wood chips per year to lower the country's dependence on fossil fuels by a minimum of 6% by the year 2000. In 1994, a total of 731,000 tons of straw was used for district heat and power generation. (CADDET, 1997) By 1997, fifty-nine straw-fired plants were in operation supplying district heat and electricity. Exhibit 2-1 shows the annual straw consumption and electricity generation from a select few CHP facilities.

Exhibit 2-1: Straw-fired CHP Facilities

CHP Plant Name	Straw Consumption (tons/year)	Electrical Output from Straw (GWh/year)
Masnedo, Denmark	**50,000**	44
Haslev, Denmark	23,000	16
Studstrup, Denmark	160,000*	240*
Rudkobing, Denmark	13,768	10
Sabro, Denmark	4,558	N/A (district heat only)

* these numbers are based upon a maximum firing rate held for 8,000 hrs/yr.

The coal-fired power station at Studstrup, Denmark is considered a model for OGS. Two years of large-scale operation concluded that this power plant could efficiently cofire up to 20% straw on an energy basis. This Danish plant produces around 150 MW of electricity, about 20% of the electrical generation capacity of OGS. (Wieck-Hansen, et. al., 2000) After making some modifications to the burner system and adding a straw pre-processing plant, the plant was able to supply approximately 20 tons of straw per hour.

Straw bales are delivered in large square bales via trucks to the Studstrup power station. The station accepts straw six days a week, eleven hours a day (seven hours on Saturday). The system was designed with excess storage capacity in case a significant amount of straw was needed on the weekend. The bales have size and weight restrictions to minimize product variations and potential material handling problems. (Wieck-Hansen, et. al., 2000)

Once the bales are received into the Studstrup power station, straw is unloaded with two overhead cranes that lift 12 bales simultaneously. During this process, the bales are weighed and moisture content is measured. The weight, moisture content, and name of the straw supplier is recorded and given to the driver. To measure the moisture levels, a probe is inserted into the bales at several locations and an average measurement is derived to determine the moisture content for settlement purposes. The bale's moisture content is recorded using microwave technology and stored on a central computing system. A 15% moisture content is the preferable maximum in order to maintain high plant efficiency.

After the straw bales are removed from the truck at Studstrup, they are either transferred to an empty space in the storage building, or transported to the processing equipment by a two-tiered conveying system located at the end of the storage building. (Wieck-Hansen, et. al., 2000) Debaling is done via waste shear shredders, which have two rotors driven by 150 hp hydraulic motors; coarse hammers break and tear the bale flakes and the shredded straw is conveyed to a rock and metal separator. (Miles, T., 2002) After debaling, the switchgrass is sized and sent to the boiler.

2.2 Ely Straw-Fired Power Plant

The Ely Straw Burning Power Station in England became operational in September 2000. This facility consumes approximately 200,000 tons of straw and produces 36 MW of electricity. Ely station is capable of using other biofuels and up to 10% natural gas. (EPRL, 2000) The Anglican Straw organization supplies 50,000 to 70,000 tons of straw and the other 150,000 tons is purchased from 200 farmers through 29 merchants and contractors and hauled by contract haulers. (Miles, T., 2002) Eighty percent of the straw is from a 55-mile radius and 50% is supplied from within 30 miles; the farthest distance is 120-150 miles. (Miles, T., 2002) Farmers say that low prices are causing the Ely plant to suffer straw shortages.

Straw delivered to the power station is bundled in large square bales and has a moisture content below 25%. Ely accepts bales in either 4' x 4' x 8' or 3' x 4' x 8' dimensions. A special purpose company manages the logistics of the fuel delivery, which includes a dedicated fleet of 10 covered trucks. Once delivered to the facility, the straw is unloaded, weighed and tested by four semi-automatic cranes. It is then stored in two enclosed barns, which have the capacity to hold up to three days worth of straw. The unloading cranes will also automatically feed the straw into a conveyor system that delivers the straw to a twine cutter and bale breaker, shedding the bales. (EPRL, 2000) Debaling is done with vertical screws, which is believed to be a good system for switchgrass. (Miles, T., 2002) Its advantages are: slow speed (no fires), low maintenance, good metering, tolerant of twine, rocks and metal, accessible for maintenance, and apparently safe to operate. (Miles, T., 2002)

2.3 Straw Export Network in Oregon

In the Pacific Northwest, straw burning has been banned since the 1980s due to environmental concerns similar to those in Denmark. Instead of using it as a fuel, Oregon and Washington farmers have found Asian markets for the straw. Japan in particular wants the straw because it cannot produce high-quality forage. Today, a collective group of farmers with 400,000 acres of grass seed cultivation in western Oregon exports a large majority of its grass seed straw to Asia. Over the past three years, this Straw Export Network exports an annual average of 500,000 tons of straw from Oregon. (Miles, 2002)

Usually 250,000 of the 400,000 acres are harvested annually with an average yield of 2.5 tons/acre. All of the straw is harvested in square bales, and then delivered to processors who compress it to twice the density (from 10 to 20 lbs/ft^3) and store it year-round. The processors are typically within a 30-mile radius of the farm. All shipping between farm, processor, and the dock is done via flatbed trucks with 40-ft. long containers. (Miles, 2002)

Storing harvested straw has been a learning experience for this Network. Straw storage is a vital quality control factor due to its annual growth cycles and short harvesting time frame. The annual harvesting season is between early July and early September. Some of the straw needs to be covered since lightning induced fires have been prone to occur with bales located outdoors. The debate upon how much straw can be left uncovered is still unresolved because the cost of these permanent storage facilities can be up to ten times the expense of in-field storage. Currently, half of the harvested straw is stored indoors and the other half is stored under tarps next to the storage buildings. (www.fiberfutures.org, 2001)

2.4 Comparison to Chariton Valley Switchgrass Project

The Studstrup station's cofiring experience will be useful at OGS since the Danish power station is the only one cofiring straw with coal. The Danish plant, like the Ely facility, uses large square bales and meticulously monitors its incoming biomass fuel for moisture content, weight, and size. Studstrup's straw handling system with overhead cranes could be implemented at OGS and will be evaluated against a more labor-intensive process. Ely's debaling system is believed to be a good option for switchgrass.

Since the projected amount of biomass fuel consumption is identical at OGS and Ely, the characteristics of the material handling systems could be very similar. OGS can consider using a dedicated fleet of trucks to manage the logistics of switchgrass delivery. The respective fuel supply areas are quite similar (70 mile radius vs. 50 mile radius), and the 3-day storage capacity and semi-automatic crane system can provide useful information for OGS.

From the case studies presented, the Chariton Valley Switchgrass Project seems to be a viable opportunity. Although cofiring switchgrass with coal has not been accomplished in the U.S. on the scale proposed by Chariton Valley, power plants in the U.K. and Denmark have proven that biomass fuel can be a reliable feedstock for electricity production. In addition, the Straw Export Network in the Pacific Northwest has shown that a large amount of straw (500,000 tons per year) can be stored, shipped, and delivered reliably.

Cost estimates at various stages of straw fuel supply are: transportation ($14/ton), direct harvesting costs for contract baling, with no payment to farmer ($20/ton), steel storage buildings ($11 to $13/ton), and delivered cost of straw to the power plant ranges from $31 to $54/ton, depending on fuel supply radius. (Miles, T., 2002)

2.5 Summary of Case Studies

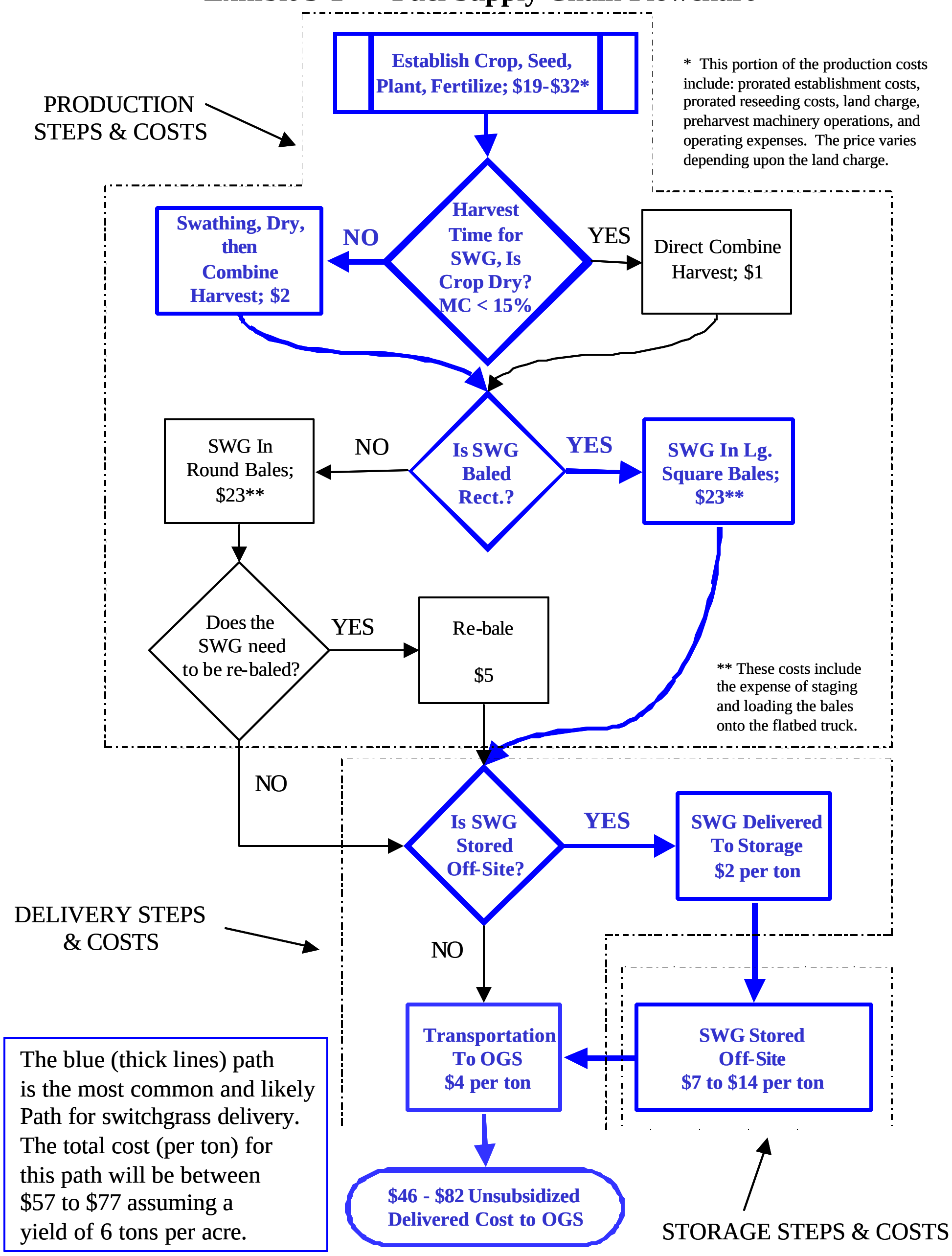
The following table lists the elements of each case study that are directly relevant to this project.

Case Study	Lessons Learned
Studstrup power plant, Denmark	**HIGH VOLUME OPERATIONS** **USE OF AUTOMATIC CRANE** **15% MOISTURE CONTENT** **USE OF LARGE SQUARE BALES AND TRUCKS** **SIMILAR FUEL SUPPLY RADIUS** **STORAGE CAPACITY**
Ely power plant, England	**USE OF LARGE SQUARE BALES** **VERTICAL SCREW DEBALING SYSTEM** **SIMILAR FUEL SUPPLY RADIUS**
Straw Export Network, OR & WA	**STORING, SHIPPING, AND DELIVERING LARGE QUANTITIES OF STRAW** **USE OF LARGE SQUARE BALES**

3.0 SWITCHGRASS FUEL SUPPLY CHAIN

The switchgrass fuel supply chain includes production, harvesting and baling, delivery/receiving, and storage. The flowchart in Exhibit 3-1 shows the possible fuel supply processes with their associated cost and range of choices to be made before the switchgrass is delivered to OGS. These decisions include how to harvest, how to bale, and where to deliver the switchgrass. The farmers are responsible for these elements and for ensuring that the fuel arrives at OGS meeting the specifications in the Independent Contractor Agreement. This chapter discusses the steps within the fuel supply chain from the field to the OGS gate. The recovery cost of switchgrass, which is the breakeven amount the farmer needs to recuperate his cost of supplying the fuel, is then discussed. The contractual agreement between the farmer and Prairie Lands is briefly discussed at the end of the chapter.

Exhibit 3-1 Fuel Supply Chain Flowchart



Exhibits 3-2 and 3-3 show the amount of available acreage for growing switchgrass in the 70 mile radius around OGS. Exhibit 3-2 focuses on class 5 (and above) grassland and row crop acreage that could be converted to switchgrass farms, while Exhibit 3-3 shows the amount of class 5 (and above) grassland, pasture, and hay acreage that could be converted to switchgrass farming.

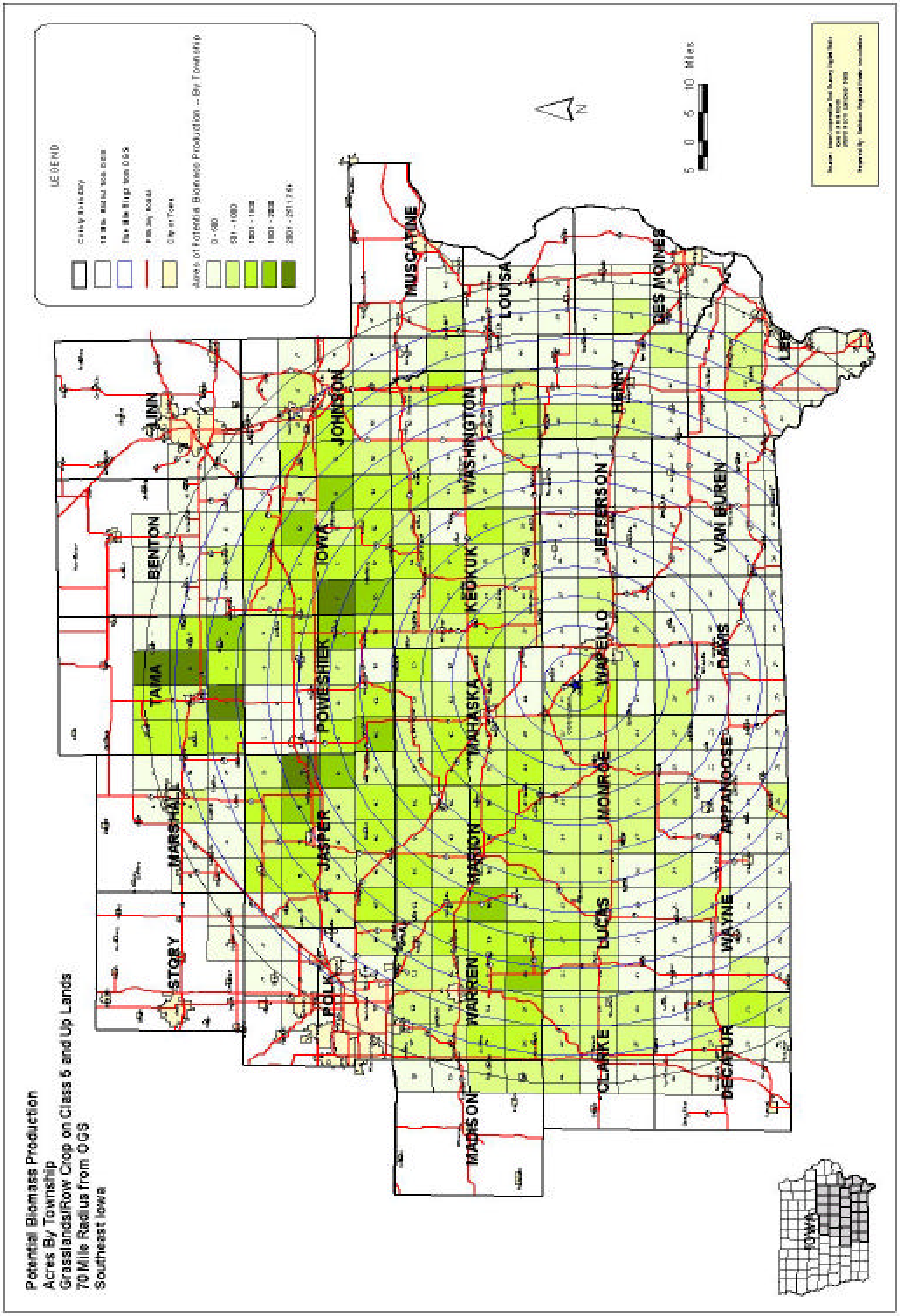


Exhibit 3-2 Potential biomass production acres, using Class 5 and above grasslands and row crop acres

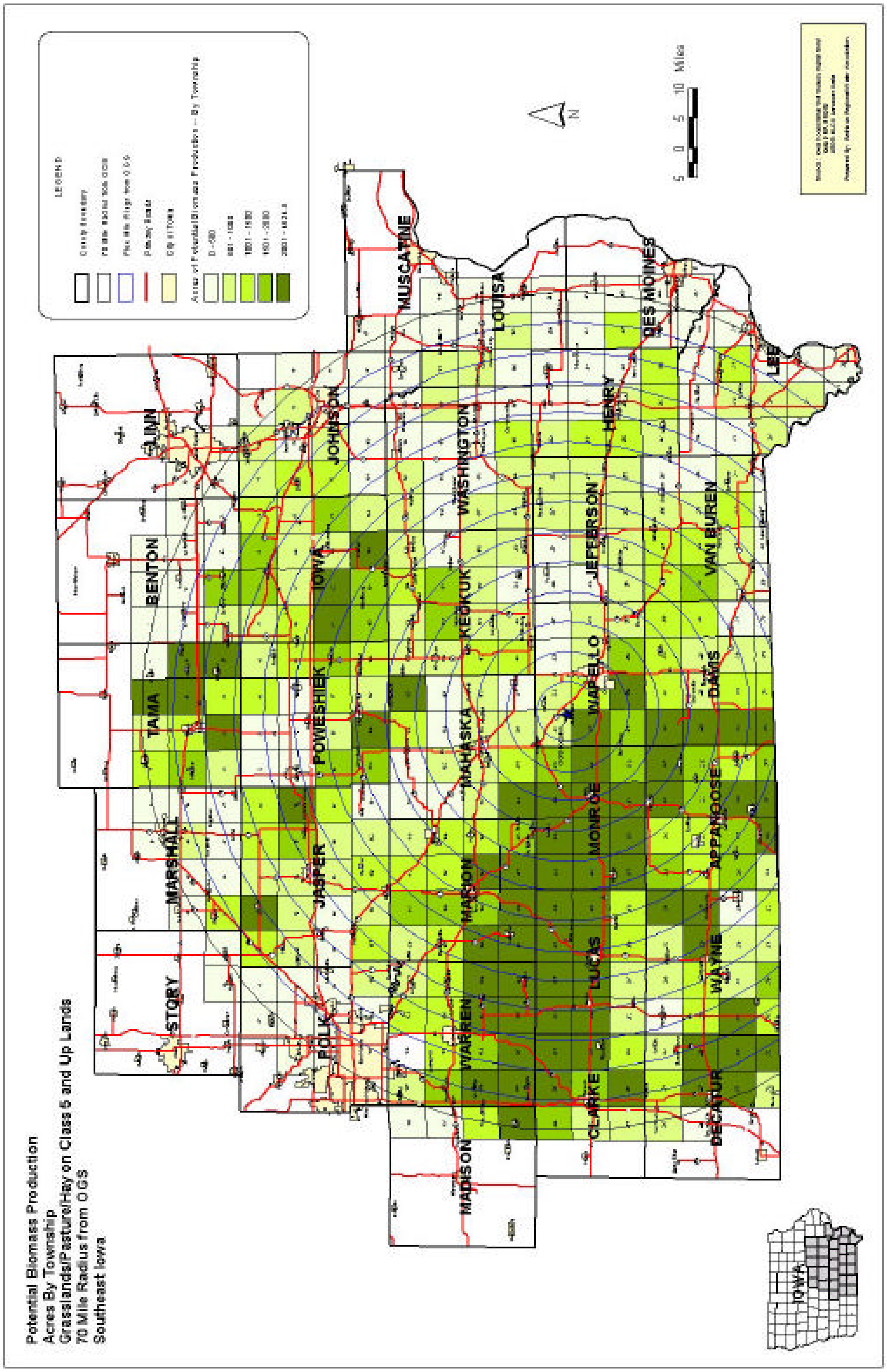


Exhibit 3-3 Potential biomass production acres, using Class 5 and above grasslands, pasture, and hay acres

3.1 General Description of Fuel Supply Chain

On the next two pages, Exhibit 3-4 and 3-5 provide a pictoral overview of the fuel supply chain that will be discussed in this chapter. Exhibit 3-4 shows the fuel supply process to OGS during the anticipated three month harvest season. The following steps 1, 2, 3, and 4 provide the optimal and lowest cost fuel supply process. Steps 5 through 8 add additional cost to the fuel. Exhibit 3-5 displays the process during the non-harvest season, when all of the bales will originate from the off-site storage locations.

Exhibit 3-4 Fuel Supply Chain –Harvest Season

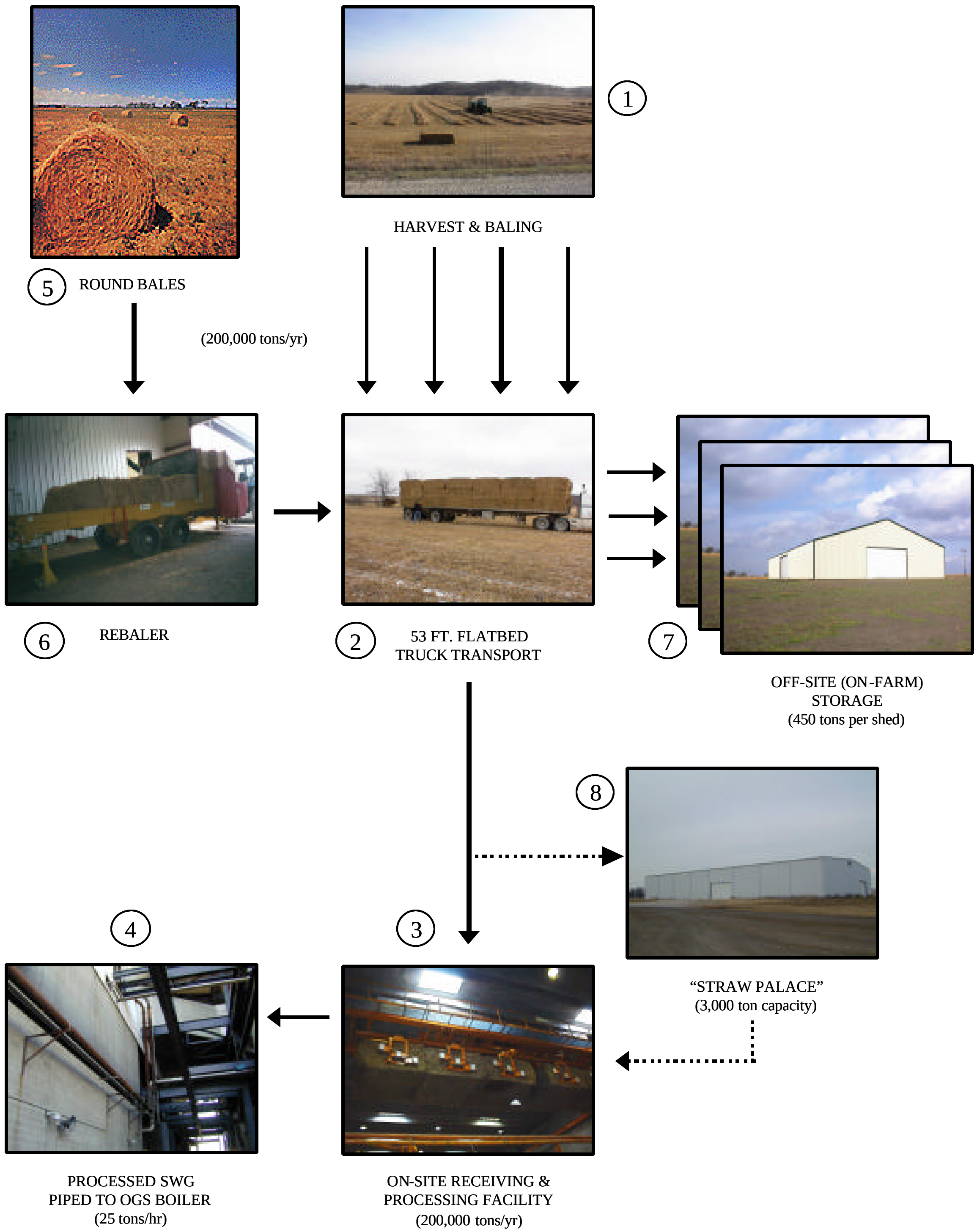
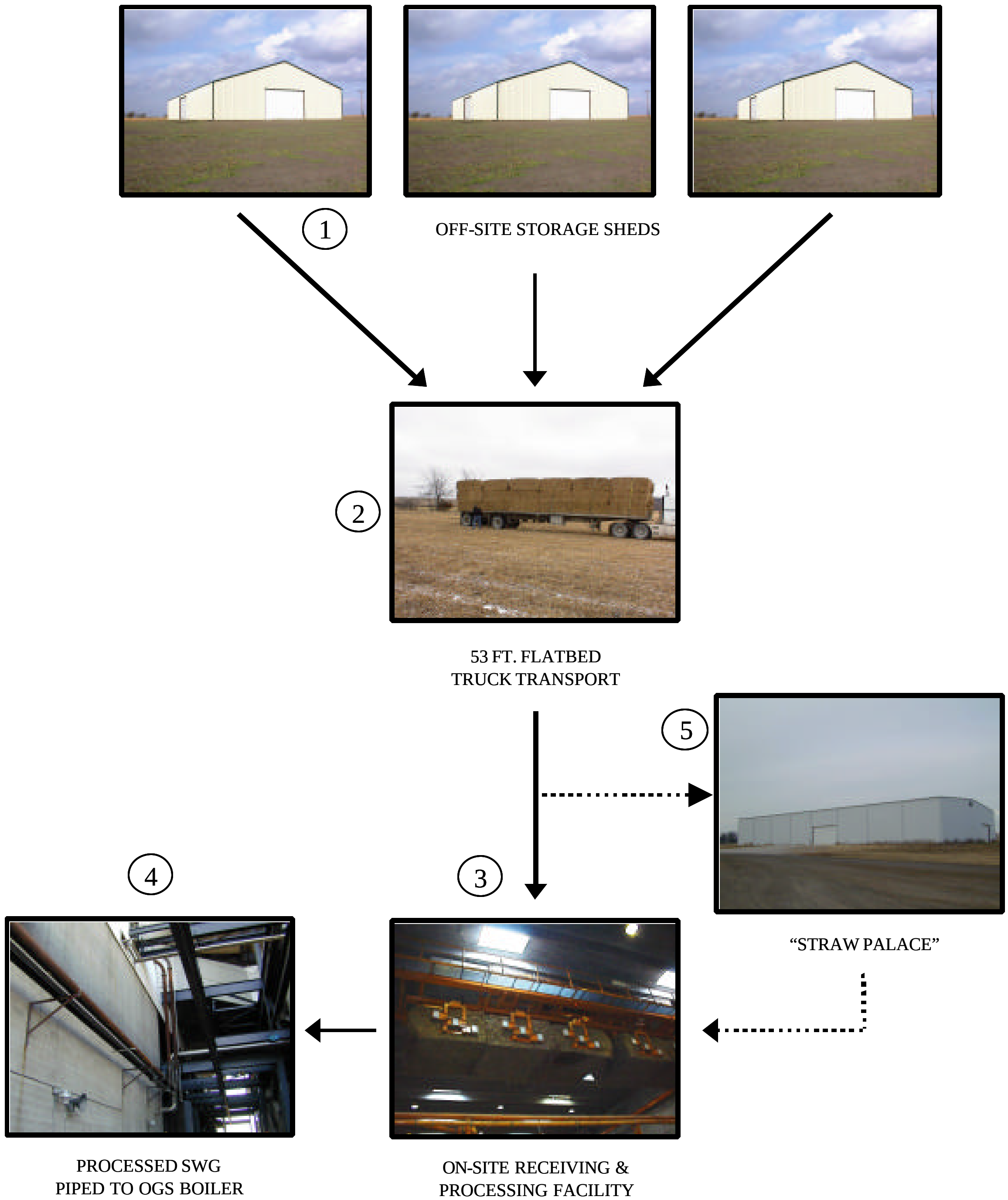


Exhibit 3-5 Fuel Supply Chain – Non-Harvest Season



3.2 Switchgrass Production

Switchgrass is a perennial grass native to Iowa. Its growth depends on the time of year it is planted (which determines the amount of seed used, success rate of seeding, and the need to re-seed), the type of land it is planted on, and the type of machinery used for seeding. (ISU, 2001) The major steps in switchgrass production are preharvest machinery operations, harvesting and storing, and ongoing land maintenance. The first step, preharvest, includes disking, harrowing, and mowing. Seeding, fertilization, and herbicide application are included in both the preharvest and the ongoing land maintenance stages.

Exhibit 3-6 Typical Switchgrass Field

The switchgrass crop has two distinct phases: the establishment year and the production years. The common approaches to establishing switchgrass are to plant into a tilled seedbed or into herbicide-killed sod using no-till planting equipment. (Brummer, E.C., et.al., 2001) A soil test should be used as a guide, but in general during the establishment stage, herbicide is normally used and phosphorous and potassium applications are common; nitrogen use is not recommended for the seeding year. (Brummer, E.C., et.al., 2001) In addition, a firm seedbed and weed control are required for a good crop yield.

Exhibit 3-7 Spraying Switchgrass Field

Since the crop is a perennial, it does not need to be replanted after a successful establishment. During the production years, however, nitrogen should be applied annually and harvesting the switchgrass as a feedstock should begin two to three weeks after a killing frost (i.e., after 4 or more hours at 28 degrees F). (Brummer, E.C., et.al., 2001)

The switchgrass will be delivered from farmers located no further than 70 miles from OGS. According to Chariton Valley, up to 419,745 acres are potential switchgrass producing land as shown in Exhibits 3-2 and 3-3 (Jacobsen, 2002). This potential acreage includes existing grasslands and herbaceous lands, and pasture and hay lands that were converted to grassland and herbaceous lands. To meet the project's maximum anticipated switchgrass feed rate, at least 12% of this potential acreage will have to produce switchgrass with a yield of four tons/acre or higher.

3.3 Harvesting and Baling

This section discusses two harvesting options and the advantages of baling the switchgrass in large square versus round form. The key criterion for the power plant will be the ease of storage and handling, while maintaining a low moisture content. The farmers' biggest concerns are maintaining low costs and effectively storing their product.

Switchgrass can be harvested in one of two ways: 1) mowing and direct baling; and 2) mowing followed by drying and baling. In mowing and direct baling, the stem is cut and the grass is discharged into rows. In other words, the grass can be baled directly after mowing – direct baling requires that the grass have a moisture content below 15%. This procedure maximizes the product quality and is a one step process for harvesting.

Mowing followed by drying and baling is another common harvesting method due to the strict moisture content requirements of direct baling. This method is a three-step procedure that exposes the straw to rain deterioration and requires another machinery process. Mowing refers to laying the stems down in rows on top of the stubble. The crop is given several days to dry-out before the baling process starts. Prior to the baling process, the grass is raked into windrows. Once in the windrows, the material is then ready to be baled by the farmer. The production cost numbers and labor estimates discussed later in this report assume that the mowing followed by raking and baling process is used.

Exhibit 3-8 Baling already harvested switchgrass

The starting time and the duration of the switchgrass-harvesting season is variable. The harvesting will start sometime in September after the killing frost. The season length is dependent upon weather and growing conditions. The switchgrass harvest season will likely end in November due to severe winter weather conditions in Southern Iowa starting late in the month. With these assumptions, the harvest season will be about three months long with approximately 60 working days.

Because of the planned design of the biomass feed system at OGS, the farmer will be required to supply switchgrass in large square bales approximately 3' x 4' x 8'. Large square bales are preferred over round bales because of their ease of stacking, ease of transportation, reduced storage requirements, and their ability to use an automated stack and reclaim system. The round bale, however, also has its advantages. Not all farmers have the large square baling equipment; many still have round balers because the large square baler is up to three times more expensive. The round bale also packs the switchgrass (or straw, hay, etc.) more efficiently because the switchgrass is oriented along the circumferential direction. More efficient packaging allows the bale to have a greater density. Another advantage of the round bale is that it is better at shedding water - keeping the switchgrass dry is important for both minimizing the boiler efficiency penalty (the penalty from cofiring rather than coal-only combustion) and for ensuring proper, uninterrupted operation of the biomass feed system. (www.fiberfutures.org, 2001)

For the reasons listed above, the large square bales will be the form that OGS receives switchgrass (i.e., not round). However, a farmer might decide that he wants to bale his fields with his own round baling equipment and find someone to process the round bales into large square bales (rebaling costs about $5/ton). This two-step process might be less costly than contracting a third-party to bale with a large square baler. Each individual farmer will address the economics of this issue.

Exhibit 3-9 Flatbed truck loaded on the farmer's field

3.4 Delivery

After the harvest, the baled switchgrass is staged and loaded onto a flatbed trailer. The loaded trailers are transported either to off-site or on site storage facilities, depending on the time of year and the power plant's fuel needs. Truck and rail are the two commonly used modes of transporting fuel, however this section only discusses switchgrass transportation by truck. Trucks are the preferred delivery option, since they are incorporated into the current system design.

Biomass delivery by rail is discussed in Appendix E, but it is not a viable alternative for OGS due to possible conflicts with coal deliveries, and higher costs.

Flatbed trailers (53' long) pulled by semi-trucks are the preferred method for delivering switchgrass to OGS. These trailers will load the 3'x4'x8' bales so they will be stacked 7 long (8' dimension each), 3 high (3' dimension each), and 2 wide (4' dimension) for a total payload of 42 large square bales (approximately 21 tons). The bales will overhang 1.5 feet in the front and the rear of the trailer, but this is acceptable practice according to the Iowa Department of Transportation. Flatbed trucks can also drive onto the fields so the farmers can load the switchgrass bales directly onto the truck. (TipTrailers, 2001) The trucking operation will deliver switchgrass to OGS between the hours of 7 a.m. and 3 p.m. Monday through Friday. The truck will deliver the fuel directly from the fields or from an off-site storage location.

The main concern associated with truck delivery is that it might not be dependable during winter weather conditions. However, on-site storage facilities will serve as a buffer when switchgrass deliveries cannot be made for a few days. If truck deliveries could not be made for a long period such that the switchgrass in storage were depleted completely, OGS would use 100% coal for its steam generation needs until the switchgrass is delivered – a break in the switchgrass supply chain would have minimal impact on the OGS.

3.5 Storage

A combination of on-site and off-site storage facilities will be used to store switchgrass so the cofiring operation has a steady supply of fuel. During the 3-month harvesting season (Sep. – Nov.), approximately 18% (2 of 11 cofiring months) of the baled switchgrass will go to on-site storage and 82% (9 of 11 cofiring months) will be sent to off-site storage. OGS usually shuts down during October for plant maintenance, so the cofiring operation will only occur for 11 months. The portion that is in off-site storage will be sent to OGS during the 9-month non-harvesting season. Each storage type is described below.

3.5.1 On-site Storage

Two on-site facilities are currently in operation. When the switchgrass is delivered to OGS, it will first be stored in an on-site storage barn next to the processing building. The storage barn will have two storage bays, and each bay is intended to store 2,072 bales, or 1,036 tons of switchgrass. Both bays when full have the capacity to supply 82 hours worth of fuel at a design maximum feed rate of 25 tons per hour. The storage barn will have an area on one side where the truck can enter and exit and the unloading mechanism can remove the switchgrass off the trailer. The other side of the barn will be the beginning of the processing line where the baled switchgrass will be converted to a form suitable for cofiring. An overview of the proposed site location for the storage barn is located in Appendix A.

The other on-site facility is nicknamed "the Straw Palace," and it serves as the second point of storage (see Exhibit 3-11). The Straw Palace is an existing building that can hold up to 4,000 tons or around 8,000 large square bales of switchgrass. This structure will be used as "buffer" storage for excess switchgrass that cannot fit in the storage barn. The location of the Straw Palace is shown on the site plan included in Appendix A.

Exhibit 3-10 Existing Storage Area Used During Test Burn

Exhibit 3-11 Straw Palace

3.5.2 Off-site Storage

As stated, approximately 9 months of switchgrass will have to be stored off-site due to the 3-month harvest season. According to Prairie Lands, approximately 500 farmers are planning to grow switchgrass on 50,000 acres of farmland. Therefore, during approximately nine of the eleven months that OGS would cofire switchgrass, off-site storage would be needed – a maximum of about 164,000 tons of switchgrass would need to be stored. This section discusses the off-site storage methods available to the farmer, their associated costs, Iowa's experience with these methods, and the project's off-site storage requirements. The six storage methods available are outside unprotected (on-ground or on-crushed rock), reusable tarps, pole-framed structures (open-sided or enclosed), and steel sheds. An associated dry matter (DM) loss is incorporated into each storage method's cost estimate. The DM loss is simply the amount of switchgrass that will be damaged in storage due to excess weather exposure. All DM losses are estimated by an Iowa State University study. However, these DM losses are not specific to the Chariton Valley region – the actual DM losses might be substantially different than those reported in the study.

Bales Stored Under a Reusable Tarp On Crushed Rock

In this storage method, the switchgrass bales are stacked four bales high on crushed rock under a reusable tarp (see Exhibit 3-12). The annualized cost over a 5-year period using an interest rate of 8% is $5.03/ton. Tarps would need to be purchased about every 5-years, thus explaining the chosen amortization period. The dry matter loss for this storage method is approximately 7%. The dry matter losses occur due to the moisture and condensation accumulating around the base and the tarp edges. If an average production cost of $50/ton is used based on costs developed by Iowa State University (ISU), the dry matter loss can add $3.50/ton to the fuel price and increase the annualized storage cost to $8.53/ton.

Exhibit 3-12 **Bales Stored Under a Tarp**

This method was evaluated because it has a low capital cost and it was the storage option used by the Oregon Straw Export Network. However, during some undocumented testing by Prairie Lands, the outside storage under a tarp did not work well in the harsh Iowa winters. The high winds and their directional changes made it difficult to keep the tarp over the baled switchgrass, thus exposing it to moisture accumulation. Condensation also formed along the outside of the tarp, which added to the switchgrass moisture level. According to the undocumented testing by Prairie Lands, the actual dry matter losses for this method might be underestimated. This storage method should be further investigated or only used as a temporary means of storage during early spring or late fall.

Bales Stored Outside Unprotected On Crushed Rock

This storage method stacks the large square bales four bales high, unprotected, on crushed rock. The annualized cost for this storage method over a 5-year period at an 8% interest rate is $1.07/ton. The dry matter loss for this storage method is approximately 15%. If the average production cost is $50/ton, the dry matter loss can add $7.50/ton to the fuel price, which increases the annualized cost to $8.57/ton.

This method presents a small cost advantage to the project, however the quality of the bales left unprotected over a long period would be questionable. Since the large square bales have a tendency to retain water, the baled switchgrass will have a higher moisture content when stored unprotected. Like the tarp storage method, the actual dry matter loss might be higher than estimated by ISU. Thus, this storage option is not recommended.

Bales Stored in Pole-Framed Structure On Crushed Rock – Open-Sided or Enclosed

In this method, the baled switchgrass is stored on a crushed rock surface with a pole-framed structure. The height of the switchgrass stacks can be up to 18 ft. high (or 6 bales). Two different pole-framed structures are available, an open-sided structure and an enclosed structure, both of which have an assumed 15-year life. They have an estimated 4% and 2% dry matter loss, respectively. Assuming the switchgrass production cost is $50/ton and the construction costs are amortized over a 15-year period at 8%, the storage costs for these two options are $8.62/ton (open-sided) and $14.24/ton (enclosed).

The open-sided pole-framed structures were explored due to the relative ease of construction and low initial cost for a permanent storage building. The drawback is that the roof was not capable of supporting at least 12 inches of wet snow. (Sellers, 2002) The enclosed structures were able to support the snow with additional framing, however the cost increase is substantial. Also, from undocumented reports, the high wind / high rain combination often experienced in southern Iowa lets too much rain in for the open-sided pole barn to be considered a good choice. If these weather factors specific to Chariton Valley are considered, the dry matter losses and the overall storage costs for pole-framed structures could well be higher than estimated by ISU.

Bales Stored Unprotected on the Ground (the default storage option)

In this method, the baled switchgrass is stored on the ground, unprotected. This method has an estimated 25% dry matter loss. Assuming the switchgrass production cost is $50/ton, the effective “storage cost” for this option is $12.50/ton. The effective “storage cost” for this default option is between that of the open-sided pole barn ($8.62/ton) and that of the closed-sided pole barn ($14.24/ton).

Bales Stored in Pre-Manufactured Steel Storage Sheds

Pre-manufactured steel storage sheds are another storage option for baled switchgrass. The sheds are approximately 70 ft. by 120 ft. and are constructed to fit approximately 450 tons of switchgrass (900 bales). These sheds maintain the moisture content at a level desired by OGS and have an estimated dry matter loss of 2%. Assuming the $50/ton switchgrass production cost and the construction costs are amortized over a 15-year period at 8%, the storage cost for this option is $17.10/ton.

This method has been used for the test burns and has heretofore been preferred by Prairie Lands and CVRC&D due to the need for long-term storage during the research campaigns. CVRC&D believes that the switchgrass will have to be stored for several years (during the research campaigns) so it concluded that the investment in good storage buildings would be vital to maintaining switchgrass quality. Sheds have the highest initial capital cost of the six options, but this storage solution was the only one that survived the Iowa winter and maintained the switchgrass in acceptable condition for OGS (Glenn, 2002). To determine the most economical choice for the project during commercial operation, documented studies should take place to determine the real DM losses for each storage method (under commercially-relevant storage periods), as an input to the determination of the optimal switchgrass storage method in southern Iowa. Ultimately, each switchgrass producer will choose his optimal storage method. Reducing storage costs, by using a storage option other than steel storage sheds, may represent an opportunity for reducing the delivered cost of switchgrass at the OGS.

3.5.3 Off-Site Storage Requirements for the Project

The amount of switchgrass needed to be stored off-site depends on the number of months available for harvesting switchgrass and the amount of excess storage buffer. It is most likely that switchgrass harvesting will be performed for about three months out of the year. Without any margin for safety, this scenario would require a minimum of nine months worth of switchgrass (82% of the annual consumption, or 164,000 tons) that would need to be stored off-site. Exhibit 3-13 summarizes the costs of each storage method. The project cost is a weighted average storage cost assuming 82% of the switchgrass consumed at OGS will require off-site storage.

As shown graphically in Exhibit 3-14, the minimum number of storage sheds decreases linearly with the longer harvest season. According to Exhibit 3-14 if all the switchgrass was stored in the steel sheds and the harvest season was 3 months long, then 363 sheds would be required.

Exhibit 3-13 Off-Site Storage Cost Summary Table

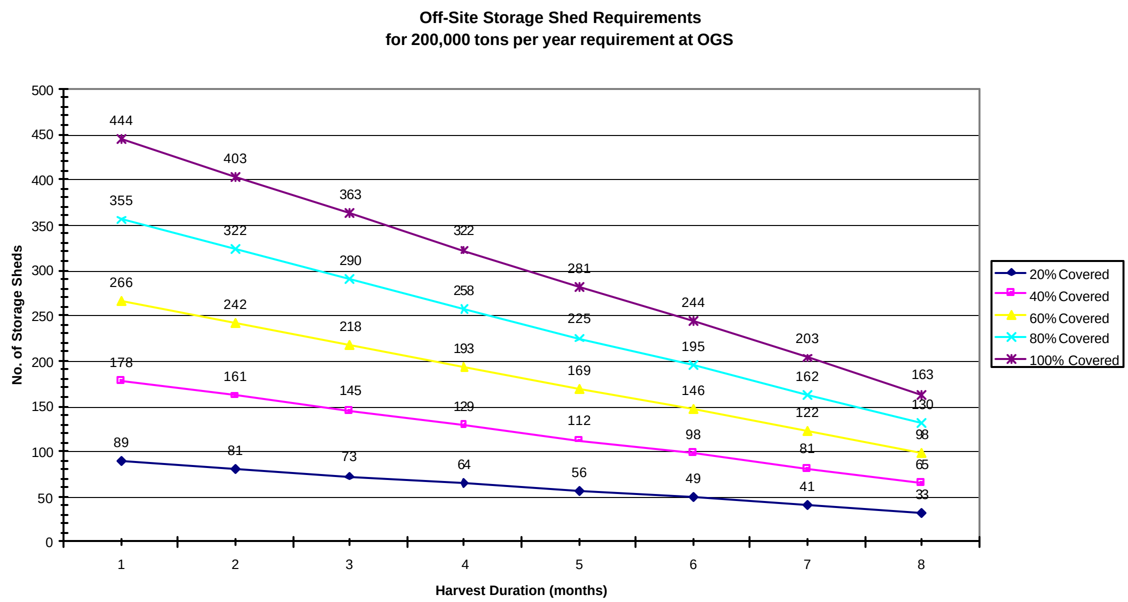
Storage Method	Cost w/o Dry Matter Loss ($/ton)	Dry Matter Loss at $50/ton	Cost w/Dry Matter Loss ($/ton)	**Project Cost** ($/ton) (82% SWG requiring off-site storage)
Reusable tarp on crushed rock	$5.03	$3.50	$8.53	**$7.00**
Outside, Unprotected on crushed rock	$1.07	$7.50	$8.57	**$7.03**
Pole frame structure–open sided on crushed rock	$6.62	$2.00	$8.62	**$7.06**
Pole frame structure–enclosed on crushed rock	$13.24	$1.00	$14.24	**$11.68**
Pre-manufactured steel storage shed	$16.10	$1.00	$17.10	**$14.02**

It is also useful to think about the above off-site storage costs using the default storage option (storing the bales on the ground, unprotected) as a reference cost. This is useful because the default storage option (a "do nothing" option) is not without cost – the delivered cost of switchgrass at OGS would reflect the significant dry matter losses if no active storage option were pursued. Unprotected, on-ground storage costs $12.50/ton ($10.25/ton project cost). Exhibit 3-13a summarizes the off-site storage costs, incremental to the default storage option. Negative numbers represent cost savings relative to the default storage option.

Exhibit 3-13a Off-Site Incremental Storage Cost Summary Table (incremental to unprotected, on-ground storage)

Storage Method	Incremental Cost w/Dry Matter Loss ($/ton)	**Incremental Project Cost** ($/ton) (82% SWG requiring off-site storage)
Reusable tarp on crushed rock	-$3.97	**-$3.25**
Outside, Unprotected on crushed rock	-$3.93	**-$3.22**
Pole frame structure–open sided on crushed rock	-$3.88	**-$3.19**
Pole frame structure–enclosed on crushed rock	$1.74	**$1.43**
Pre-manufactured steel storage shed	$4.60	**$3.77**

Exhibit 3-14 Number of Off-Site Storage Sheds Required for Project



3.6 Switchgrass Delivered Costs

The cost of producing switchgrass depends on the land charge, crop yield (tons/acre), frost or spring seeding, seed planting mechanism, fertilizers, and nutrients. Iowa State University (ISU) conducted a study to determine the estimated switchgrass production costs on a scale comparable to this project. From this economic study, the farm gate cost of switchgrass ranges from $44/ton to more than $74/ton for yields of 4 to 6 tons/acre. (Duffy, et. al., 2001)

The cost of delivering switchgrass depends on the baling method, storage method, and the number of times the switchgrass is handled. Every time the switchgrass is moved, the fuel cost increases—the desired logistical process would minimize material handling to limit the fuel cost.

Until the actual production, storage, and transportation costs of switchgrass are finalized, the total delivered cost for switchgrass will be unknown. The current estimate for calculating the production cost itemized in Exhibit 3-15 assumes the following:

1. switchgrass will be frost seeded and grown on converted grasslands or pastures
2. land will be prepared by mowing and the use of the herbicide Roundup™
3. an airflow planter will seed 6 pounds of pure live seed per acre and spread the fertilizers
4. average yield of switchgrass will reach 6 tons/acre
5. average land charge will be $50/acre
6. the herbicides atrazine and 2,4 D will be used

Exhibit 3-15 Determining Fuel Delivery Cost (Duffy, et.al., 2000)

Fuel Supply Step	**Cost/Ton**
Production Costs	
Preharvest Machinery Operations	$3.28
(includes spreading liquid nitrogen, applying phosphorus and potassium, and spraying chemicals)	
Operating Expenses	$7.12
(includes re-applying nitrogen, potassium, phosphorus, and applying herbicides)	
Interest on Operating Expenses	$0.32
Harvesting and Storing Expenses	$24.98
(includes mowing / conditioning, raking, baling (large square), staging and loading bales)	
Land Charge	$4.16 to 16.67
Prorated Establishment Charges *(11 yrs @ 8% interest rate)*	$3.91
Prorated Reseeding Costs *(10 yrs @ 8% interest rate)*	$0.59
Subtotal	**$44 to $57/ton**
Transportation Cost (40 miles)	$3.67
Storage Costs *(from Exhibit 3-1)*	$7.00 to 14.02
Handling Costs	$2.28
Fuel Delivery Cost * (assuming 6 tons/acre yield)	**$57 to $77/ton**

* The fuel delivery cost calculated in this table is the amount the farmer needs to recuperate in order to break even. This cost is different from the actual fuel delivery price, which is the amount Alliant will pay for the switchgrass. Project incentives are not discussed in this report but are necessary to calculate the fuel delivery price.

These production and delivered costs of switchgrass were checked against the hay market prices. According to CVRC&D, the fair quality hay will be comparable to the switchgrass that will be used in the cofiring operation. This check was performed to check the validity of the numbers published in the ISU report. Exhibit 3-16 shows the auction price of fair quality alfalfa hay ranges from $40 to $60 per ton in Iowa. These prices shown in Exhibit 3-16 are farm gate prices and do not include transportation.

Exhibit 3-16 Hay Market Prices in Iowa

IOWA:

Northeast IA: Fort Atkinson, IA Hay Auction. (07-17-2002) 74 loads, Hay prices 10.00-20.00 per ton Higher. Alfalfa: Fair to Good small square bales 85.00-95.00; Fair small square bales 75.00-85.00; Low to Fair 60.00-70.00. Good to Premium 3X3X8 square bales 90.00-110.00; Fair to Good 3X3X8 square bales 60.00-90.00; Fair 3X3X8 square bales 50.00-60.00. Good to Premium large round bales 70.00-85.00; Fair to Good large round bales 50.00-70.00; Fair 40.00-60.00.

Northwest IA: Maurice, IA Hay Auction (07-16-2002) 18 loads, 207 tons. Alcester, SD Hay Auction closed for the season. Hay prices near steady. Demand fair to good. Alfalfa: Good large square bales 80.00-87.50. Premium to Supreme large round bales 90.00-95.00; Good to Premium 82.50-90.00. Grass: Good to Premium large square bales 80.00-85.00. Brome in large round bales 75.00-80.00.

South-central IA (Private treaty): Hay prices fully steady. Good inquiry. Alfalfa: Good to Premium small square bales horse hay mostly 110.00-120.00; Good 90.00-100.00. Good large round bales 65.00-75.00, Fair to Good 55.00-65.00. Alfalfa/grass mix: Premium small square bales 90.00-110.00; Good to Premium large round bales 65.00-70.00.

Source: http://ams.usda.gov/mnreports/sc_gr310.txt

3.7 Proposed Independent Contractor Agreement

A draft contract between each of the farmers and Prairie Lands Bio-Products (cooperative) is currently being developed; a sample copy is located in Appendix B. This document provides the framework for fuel supply standardization from every farmer. The draft contractual agreement includes stipulations about the following:

- Size, shape, moisture content of baled switchgrass
- Field-by-field harvest plan development
- Collection of harvest and yield-related data
- Fuel supply delivery timeframe
- Amount of fuel to be supplied to OGS
- Timeframe for payment of services
- Agreement of delivered fuel price

Once Prairie Lands and the network of farmers determine the off-site storage locations, they can set a schedule for the farmers to deliver switchgrass to their respective off-site storage facilities.

4.0 THE OTTUMWA GENERATING STATION (OGS)

OGS is located on a 375-acre site adjacent to the Des Moines River and is approximately seven miles northeast of Ottumwa, Iowa (see Exhibit 4-1). Appendix A includes a detailed OGS site plan and an enlarged plan view of the proposed location for the storage barn and processing building. The 726 MW coal-fired power plant, currently operated by Alliant, went into commercial service in May 1981. This chapter describes the existing site and truck traffic conditions at OGS. The traffic section discusses the truck traffic flow used during the first cofiring test campaign. This chapter discusses the options considered for the switchgrass receiving system.

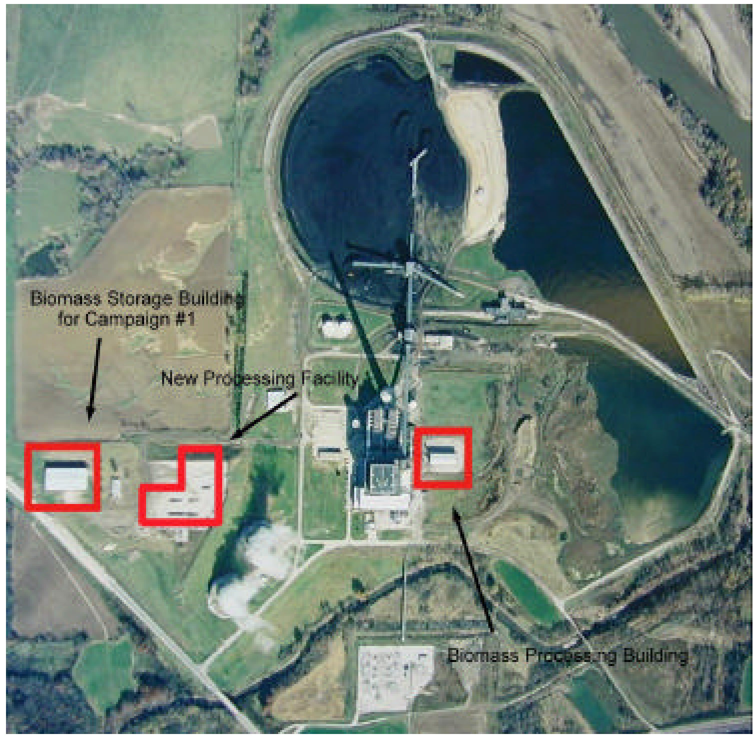


Exhibit 4-1 Aerial View of OGS

Page A-1 in Appendix A shows the existing site plan for OGS. At the time of the first cofiring test campaign, the plant had two available entrances (referred to as the Main and North entrances). However, newly implemented security measures have temporarily closed the North entrance for coal and potential switchgrass deliveries. The Main entrance is used for ash hauling, employees, chemical deliveries, and other miscellaneous transportation needs.

Exhibit 4-2 Ground-Level View of OGS

4.1 Switchgrass Fuel Receiving System

The fuel receiving system will be located within the storage barn and provides three main functions. First, this system unloads the bales from the flatbed trailers. Second, the system will stack these bales within the storage barn. Third, the system will reclaim the bales from these stacks and deliver them to the processing building via a conveyor system. Sometime the stacking process will be bypassed if the process building needs the bales immediately, but otherwise the system will employ a first-in, first-out principle.

This section discusses two proposed fuel receiving system designs using either an automated overhead bridge crane system or a manually-operated forklift system. The current fuel receiving system design for OGS is automated. The automated crane system is based on the Studstrup straw cofiring system, which employs an automated crane system. A manually-operated system was used during the first cofiring test campaign and is evaluated below in comparison to the automated crane system.

4.1.1 Automated Overhead Crane System

An overhead crane system, as shown in Exhibit 4-3, will perform several functions. It can unload the baled switchgrass from the flatbed truck, weigh it, and measure each bale's moisture content. The bales are then carried and stacked within the covered storage bays or directly loaded to the conveyor, as is appropriate.

Studstrup's automated system requires 12 to 15 minutes to unload a truck carrying twenty-four 4' x 4' x 8' bales (Kirkegaard, 2002). The crane can unload twelve bales per trip, so two trips are required to fully unload the flatbed truck. This equates to 6 to 7.5 minutes per trip (or "cycle-time"). However Techwise, the Engineering Firm for both the Chariton Valley Biomass Project and the Studstrup project, believes it is feasible to reduce this cycle time to 5 minutes. The proposed fuel delivery plan for the Iowa project includes the delivery of forty-two 3' x 4' x 8' bales per truck. The 42-bale truck would require three trips, or 15 minutes per truck based on the 5-minute cycle time. In this system, the truck driver will initiate the truck unloading, observe the process, and then clean up the truck and bay. The crane's operating system will print out a copy of the fuel receipt with all pertinent data for payment information.

Exhibit 4-3 Automated Overhead Crane

Each bay within the storage barn will be equipped with an overhead crane that will be able to serve one truck at a time. Two receiving bays are incorporated into the design for cofiring 200,000 tons per year. Two trucks can enter the building simultaneously to be unloaded so any possible traffic problems can be alleviated.

The initial and annual costs of the automated system are listed below in Exhibit 4-4. The initial capital costs include the processing building and all indirect costs assuming the project is constructed using Owner-Engineer instead of an EPC. The system will require a single crane operator during delivery hours. However during non-delivery hours, the crane can automatically reclaim bales from the stacks and send them to be processed. Another two people will be required to drive the trucks into both bays. The maintenance costs for this system are estimated at 2% of the initial capital cost (Easterly, 1994). The annual energy costs are based upon the 3883.5 fully loaded motor hp requirement of the receiving and processing building.

Exhibit 4-4 Automated System Costs

Item	Cost ($)
Initial Capital Cost	$15,308,900
Labor	$225,000
Maintenance	$306,178
Energy	$359,740
Total Annual Costs (not incl. capital charge)	$890,918

4.1.2 Forklift, Manual Process

The manually operated forklift process is similar to the process used in the first cofiring test campaign. After entering the OGS gates, the truck driver has the fuel manually inspected, weighed, and probed for moisture content level. If the fuel is acceptable, the driver is handed a copy of the inspection report for record keeping. Then, the truck is driven into one of the four processing bays for unloading. Once in the bay, the forklift driver unloads the large square bales, three at a time, and either puts them on the conveyor or into the storage area. The truck driver cleans up the area after the truck has been unloaded and drives out of the processing bay.

Test burn data show that a flatbed truck of 24 large square bales took approximately 15 minutes to unload. Based on this information, a flatbed truck with 42 bales will take approximately 22.5 minutes to unload. According to calculations, if the switchgrass feed rate approaches 25 tons/hour, the process would require two forklift drivers to accommodate the truck deliveries. One driver would feed the conveyor with bales from storage, while the other would be unloading the truck and placing the bales into storage. This process would require at least one forklift driver on third-shift and weekends while the plant is operating—feeding the conveyor in order to meet demand. Our analysis assumes that ten full-time forklift drivers will be needed to meet the demand of 25 tons/hour.

The costs for the manual system are listed in Exhibit 4-5. The initial cost is less than the automated system by the cost of the two cranes. The maintenance cost is again estimated at 2% of the initial capital cost. The energy costs are estimated based upon the 3563.5 fully loaded motor hp requirement.

Exhibit 4-5 Manual System Costs

Item	Cost ($)
Initial Capital Cost	$13,846,500
Labor	$750,000
Maintenance	$276,930
Energy	$330,098
Total Annual Costs (not incl. capital charge)	$1,357,028

The maintenance costs for the two systems are relatively close. The automated crane system once properly commissioned is a low maintenance piece of machinery. The automated receiving system is designed to run 8,000 hours per year and to last 20 years.

Exhibit 4-6 Forklift unloading bales during test burn

4.1.3 Results of Life Cycle Cost Analysis

A simple life cycle cost analysis was conducted using data from Exhibit 4-4 and Exhibit 4-5. A life cycle cost (LCC) analysis over a 20-year period was used to determine which system would have a lower present value of future cost streams. A discount rate of 8% was used for both systems. Using the numbers, the automated system has a LCC of $24,755,842 and the manual system has a LCC of $28,235,880. The details on how both present values were calculated are provided in Appendix G.

The automated crane system has a lower life cycle cost due to its lower labor requirement relative to the manual system at the 200,000 tons per year switchgrass processing rate. Although the manual system's initial cost is approximately $1.46 M less than the automated system, the additional seven workers that are required for the labor-intensive manual system adds significant costs to the manual system over time, rendering it unattractive. The discount rate would need to be at least 47% in order for the manual system to be more economical than the automated system.

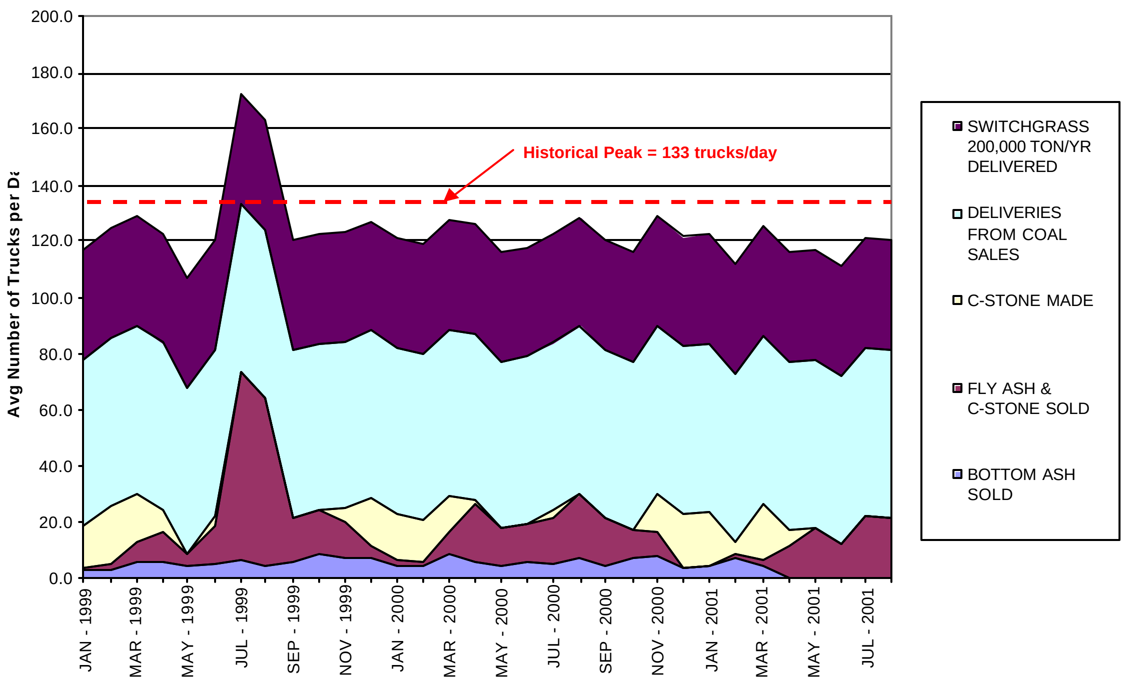
4.2 Existing Traffic Schedules

Currently, coal sales and ash hauling comprise a majority of the existing truck traffic for OGS. OGS receives 3.5 million tons per year of coal, which is delivered via rail. OGS purchases an extra 400,000 to 500,000 tons of coal that is sold to local corporations and is transported outbound via truck from OGS. The additional truck volume due to coal sales equates to about 16,000 to 20,000 trucks annually. Bottom ash is stored on-site until sold. Fly ash is either transported off-site immediately upon unloading from storage hoppers (mostly during the construction season—March through October), or is processed on-site to make C-Stone. The C-Stone is then stockpiled on-site until it is sold. Coal, bottom ash, fly ash, and C-Stone are all shipped via truck to OGS customers. Exhibit 4-7 shows the daily average and peak number of trucks leaving the plant with each material listed.

Exhibit 4-7: Existing Truck Traffic at OGS

Type of Outbound Truck Delivery	Trucks per Day (Average)	Trucks per Day (Peak)
Coal Deliveries	59.5	59.5
Bottom Ash Removal	4.6	8.7
Fly Ash Removal	10.6	22.2
C-Stone Removal	2.8	48.5
Total Trucks per Day	***77.5***	***133.0***

Exhibit 4-8 Historical Truck Traffic at OGS



The average and peak number of coal delivery trucks is based on the assumption that the trucks are all fully loaded with 25 tons of coal and delivering 24 hours a day, 7 days a week, 48 weeks a year. The numbers for ash hauling were calculated from figures obtained from Alliant. Although fly ash and bottom ash sales are somewhat variable, the peak number of trucks leaving OGS for ash removal is small compared to the amount of coal delivery trucks. Currently, C-Stone sales experience feast or famine; the amount of trucks moving the C-Stone varies from zero to a peak amount of almost 50 trucks per day.

The historical truck traffic volume for OGS is shown in Exhibit 4-8, and the anticipated traffic volume for switchgrass traffic is superimposed above the historical levels (in dark blue). The switchgrass deliveries will occur five days a week. Exhibit 4-9 shows the existing traffic patterns for the coal and ash handling trucks.

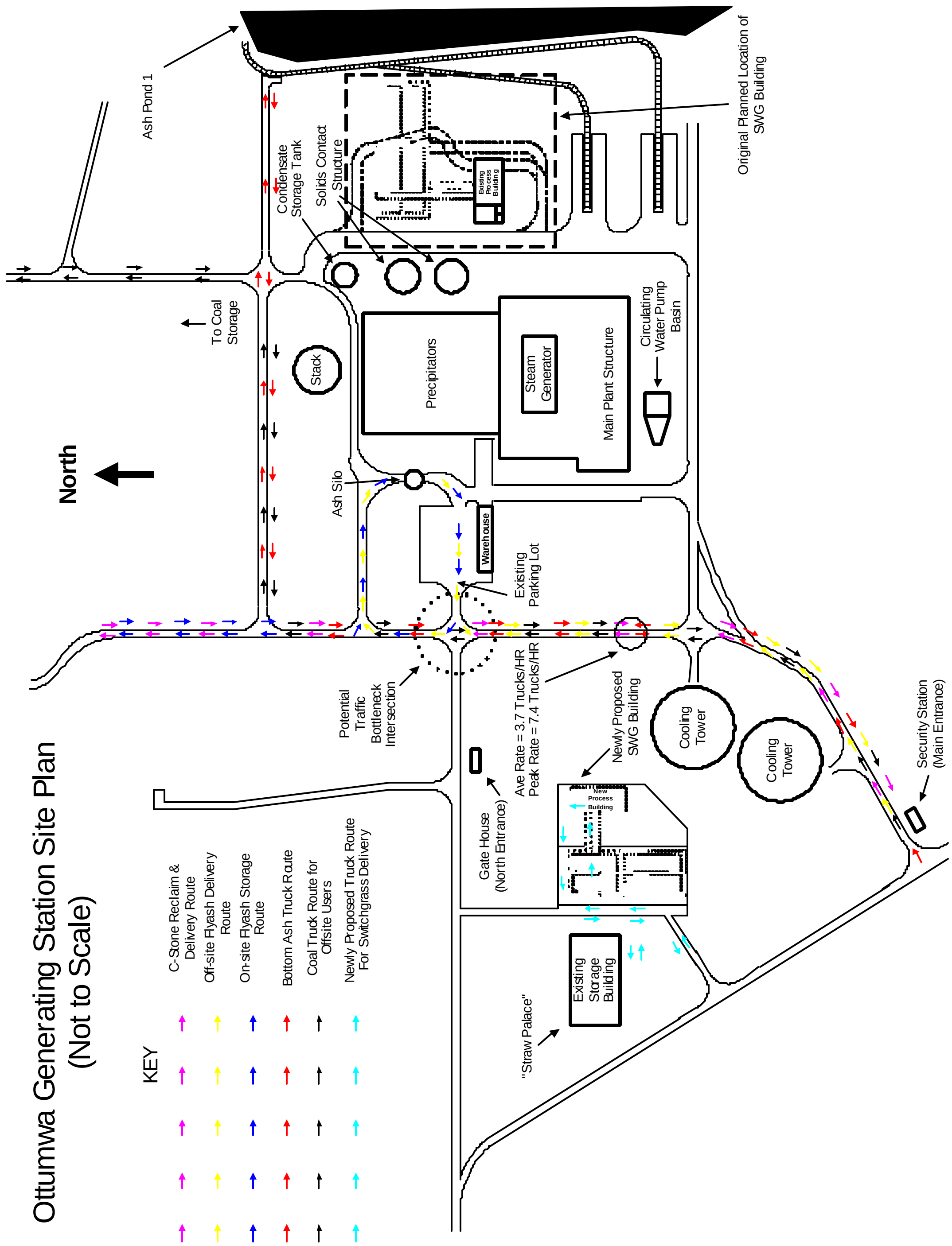


Exhibit 4-9 Existing typical traffic patterns at OGS

The key conclusion is that the historical traffic peak at OGS (represented by the light blue peak in Exhibit 4-8, late summer 1999) is higher than would be expected if switchgrass were supplied to OGS at the maximum rate of 200,000 tons/year. Plant personnel were able to manage traffic flows and volumes during the historical peak without significant reported problems. Therefore, traffic expected for the switchgrass project, even at the maximum supply volume, should be manageable without disrupting other traffic at OGS under most circumstances.

It is noted that short-term traffic volumes could potentially exceed the historical peak if another high fly ash / c-stone selling event were experienced (as in late summer 1999). The fact that switchgrass will be brought in and out of the North entrance would mitigate the congestion effects if a new historical truck traffic peak were experienced.

4.3 Test Campaign Fuel Supply Scenarios

4.3.1 Test Campaign #1

For the initial test burns in December 2000, switchgrass was delivered from the straw palace to OGS in 3’ x 3’ x 8’ and 3’ x 4’ x 8’ large square bales via flatbed trucks. The flatbed trucks entered the power plant from the North entrance and drove into the switchgrass processing building. The flatbed trucks delivered between 24 and 36 bales of switchgrass. The baled product was then unloaded with forklifts, three bales a time, from the truck to a staging area. The forklift operator also loaded the conveyor system to the steam generator. Unloading 24 bales took approximately 15 minutes, taking three bales off the truck simultaneously. Once the switchgrass was completely unloaded, the truck left the area to make room for the next one. (Kelderman, 2001)

The delivery trucks did not conflict with other existing traffic at OGS. The majority of the time, the switchgrass feed rate was around 6 tons/hour (which is equivalent to an annual consumption rate of 50,000 tons). The maximum switchgrass feed rate sustained for the test was around 16.5 tons/hour. Overall, the test burn process consumed approximately 1,269 tons of switchgrass over the 26-day period. (Kelderman, 2001) Exhibit 4-10 shows the traffic pattern of the switchgrass truck traffic during Cofire Test 1, along with the existing traffic patterns for coal and ash hauling.

4.3.2 Test Campaign #2

The final processing system construction is planned for 2003. As planned, the new system would be used during cofiring test #2. The existing processing building that was used during cofire test #1 will probably be torn down and moved (most of the original equipment has been dismantled).

During the second cofiring test campaign, up to 6,000 tons of switchgrass will be cofired in the boiler. The existing process building will be reused for this cofiring test. The traffic patterns will be similar to those used during the first test campaign.

4.3.3 Test Campaign #3

The third test cofiring campaign details are currently being developed. As planned, up to 25,000 tons of switchgrass will be cofired in the boiler. The traffic patterns used for this third test will be similar to those expected during commercial operation (discussed below).

4.4 Traffic Schedule During Proposed Commercial Operation

During commercial cofiring operations, the switchgrass receiving and processing building will be located to the west of the main plant structure. The location where the first cofiring test campaign occurred will be the future location of another coal-fired boiler and power plant. The proposed new location for commercial operations will not present any interference with the existing coal and ash hauling traffic. Exhibit 4-11 shows the location of the new site and displays the proposed traffic pattern for switchgrass traffic.

4.5 Conclusions about Truck Traffic at OGS

The switchgrass project will not present any logistics problems for the truck traffic at OGS associated with coal-only operations. The proposed location for the switchgrass receiving and processing, along with plans to truck switchgrass in through the North entrance, will mitigate any traffic impacts.

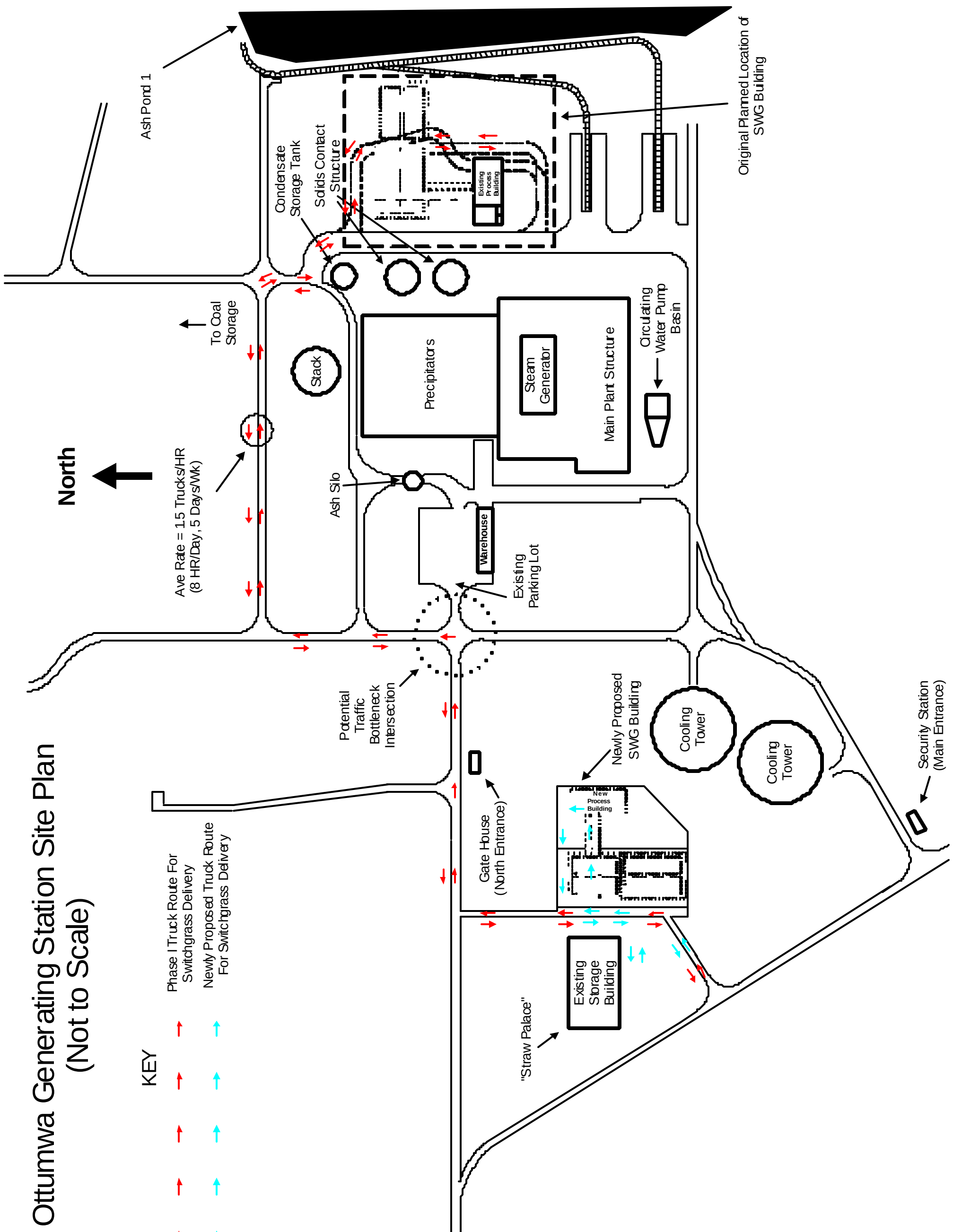


Exhibit 4-10 Switchgrass traffic pattern during cofire test campaign #1

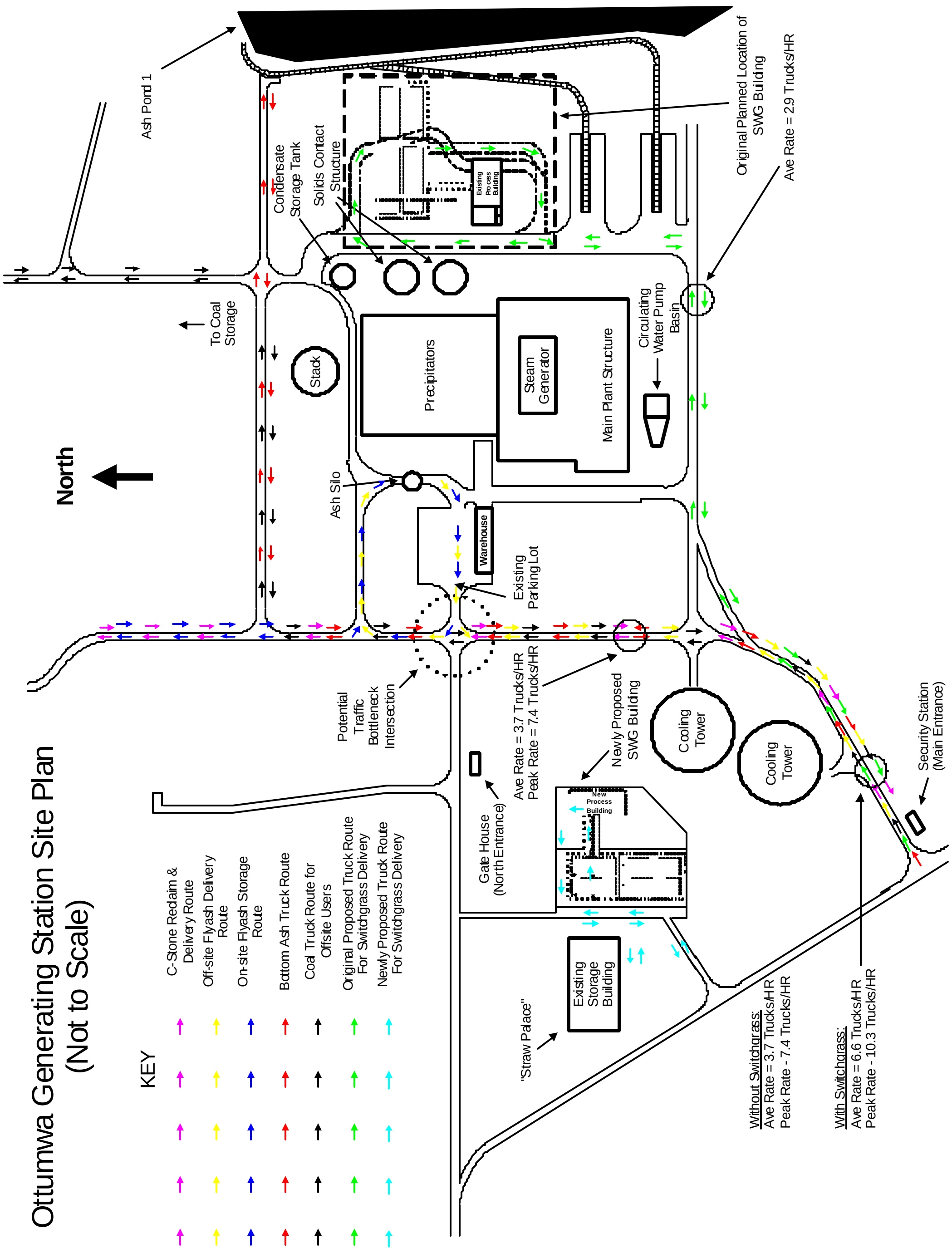


Exhibit 4-11 Traffic patterns during commercial switchgrass operation

5.0 LABOR REQUIREMENTS FOR BIOMASS PROJECT

The biomass project will have annual labor requirements to produce and deliver 200,000 tons of switchgrass to OGS. The following tasks will be required to make this project successful:

1. Acquire sufficient land to grow 200,000 tons of switchgrass per year.
2. Establish the switchgrass stand within the first year. If necessary, reseeding will occur during the second year.
3. Apply the necessary fertilizers, nutrients, and herbicides to nurture the switchgrass (noted as producing switchgrass crops in Exhibit 5-3).
4. Harvest and bale the switchgrass.
5. Store the switchgrass under covered off-site storage, or

5a. Deliver the switchgrass directly to OGS (Labor done by the loaders / unloaders and the contract truckers).

6. Oversee the incoming deliveries at OGS (Labor done by spotter truck drivers and the crane operator).
7. Manage the trucking logistics of switchgrass deliveries (Performed by Prairie Lands Administration).

5.1 Acquiring Land / Farmer Participation (Year 1+)

Based on an average yield of 4 tons per acre (tpa), this project will require approximately 50,000 acres of land to grow 200,000 tons of switchgrass per year. The intent of the project is to involve 500 farmers, with 100 acres each. It would be most ideal from a transportation point of view to have these farms located as close as possible to OGS. This analysis assumes that the average distance between the farm and OGS is 30 miles.

5.2 Establishing the Stand (Year 1)

During year one, switchgrass will need to be established on the 50,000 acres. This analysis assumes that the land will need to be converted from either cropland or grassland to switchgrass. It also assumes that the labor required to establish the stand will take approximately 30 days. The fields can be either frost or spring seeded. The steps required to convert the land from cropland are:

1. Disking
2. Harrowing
3. Spreading seed and fertilizer
4. Spraying herbicides (atrazine and 2,4 D)

The steps required to convert the land from grassland include:

1. Mowing
2. Spreading seed and fertilizer
3. Spraying herbicide (Roundup)
4. Spraying herbicides (atrazine and 2,4 D)

Both of these processes will require about the same number of man-hours to convert the land on a per acre basis. If this work were contracted out on all 50,000 acres, it would require about 70 people to convert the land and establish the stand (calculation included in Appendix F).

5.3 Producing Switchgrass Crops (Year 2+)

During year two, it is assumed that 75% of the switchgrass farmland will be ready to produce switchgrass for OGS. The other 25% will require reseeding and another year to establish the stand. The reseeding effort will repeat steps 3 and 4 performed while converting the land from cropland to switchgrass fields. The processes that need to occur on the fields that have established switchgrass stands are:

1. Spreading liquid nitrogen
2. Applying P&K
3. Spraying chemicals

It is assumed that these processes will need to be completed in 30 working days between mid-April and late May. If this work is contracted to parties other than the landowners, it will require around 18 people to reseed the switchgrass fields and about 33 people to produce switchgrass for a fall harvest in the second year. In the third year, the work would require around 44 people to produce switchgrass (calculations included in Appendix F).

5.4 Harvesting and Baling Switchgrass (Year 2+)

In the fall, the switchgrass will be harvested and baled in preparation for delivery to OGS. The estimated timeframe from the start of the harvest to the end of the baling process is 44 working days. The harvest season would start approximately September 1 and last until mid-November. The processes required during this season include (in chronological order):

1. Mowing after a killing frost
2. Baling (large square bales) the day after mowing

If this work were contracted to other parties other than the landowner, it would require a crew of 71 workers to harvest 50,000 acres and bale 200,000 tons. The mowing process is estimated to take the first 14 days. The final 30 days of the harvest season would be spent baling the switchgrass (calculations included in Appendix F – these calculations discuss the usually unnecessary step of raking).

5.5 Delivering the Switchgrass (Year 2+)

Once the switchgrass is baled, the entire 200,000 tons of switchgrass will be delivered to either OGS or covered storage. All of the 200,000 tons will be need to be delivered within 2 months or approximately 43 working days, starting in about Mid-October and ending around Mid-December. During the harvest season, approximately 18% or 36,200 tons of switchgrass will be delivered direct to OGS. The remaining 163,800 tons will be delivered to covered storage. The following steps will be taken for the deliveries from the fields:

1. The switchgrass is staged and loaded on flatbed trailers.
2. The trailers will be delivered to OGS or covered storage.
3. The trailer will bring back an empty trailer to the field.
4. Repeat steps 1, 2, and 3.

During the non-harvest season when the switchgrass is located in covered storage, the same truck drivers who transported the switchgrass directly to OGS will deliver the switchgrass from covered storage to OGS. The non-harvest season will empty the covered storage slowly until they are refilled with switchgrass during the following harvest.

It is assumed that the average distance between the farm and the covered storage is 10 miles and between the farm or covered storage and OGS is 30 miles. The estimated time for the truck to make a single delivery (i.e., complete delivery steps 1 to 3) to the covered storage is 45 minutes and to OGS is 90 minutes. In addition, it is assumed that the average working day is eight hours and the average truck payload is 21 tons (42 bales) of switchgrass. From these estimates and assumptions, the numbers of truck drivers required during the harvest and non-harvest seasons are calculated in Exhibit 5-1.

Exhibit 5-1 Truck Driver Requirements for Biomass Project

	Harvest Season to Covered Storage	Harvest Season Direct to OGS	Non-Harvest Season to OGS
Tons / Yr	163,800	36,200	163,800
Days / Season (given)	43	43	195
Tons / Day (calculated)	5460	840	840
Tons / Truck	21	21	21
Trucks / Day (calculated)	260	40	40
Time for Single Delivery, hrs	0.75	1.5	1.5
Length of Working Day, hrs	8	8	8
Deliveries / Truck / Day (calculated)	11	5	5
Truck Drivers (calculated)	25	8	8

The truck drivers are not the only people essential for delivering switchgrass to OGS. Forklift operators are required to stage and load the trailers at the fields and in the covered storage facilities. The following assumptions are made about the loading, unloading, and stacking procedures that will be needed:

- The bales have been staged before they are loaded on the trailer.
- Loading the staged bales onto the trailer will require 15 minutes.
- Unloading and stacking the bales in storage will take 45 minutes.
- The truck driver will not load trailers.

From these assumptions, the number of required forklift operators varies from as high as 32 during the harvest season down to two during the non-harvest season. The labor requirements for loading and unloading trailers are broken down for the entire project and are listed in the table below. It is assumed that the forklift operators will also work eight-hour days.

Exhibit 5-2 Forklift Operator Requirements for Biomass Project

	Harvest Season to Covered Storage	Harvest Season Direct to OGS	Non-Harvest Season to OGS
Trucks to Load / Day	260	40	40
Trucks to Unload / Day	260	0	0
Loaders	9	2	2
Un-loaders	25	0	0
Subtotal (Harvest Season only)	34	2	N/A
Totals per Season	36		2

5.6 Overseeing Incoming Deliveries at OGS (Year 2+)

The truck parking lot design outside of the storage barn was developed so that a contracted truck driving fleet would perform these steps (in chronological order):

1. Pick up full trailer at the field or covered storage.
2. Drive full trailers to the lot outside the storage barn.
3. Drop off full trailer, park in the staging area.
4. Pick up empty trailer to take to field or covered storage.
5. Drop off empty trailer at field or covered storage.

At OGS, two spotter truck drivers will to drive the pre-staged trailers into the storage barn for a smooth unloading process. These spotter truck drivers will allow the contract drivers to maximize their time spent by not waiting in-line for prior deliveries to be unloaded by the automated cranes. The parking lot is designed so up to sixteen fully loaded trailers will be waiting in queue for the spotters. In addition, the lot will have a minimum of eight empty trailers waiting for the contract drivers to pick up if they make after hours deliveries. The spotters perform these tasks (in order):

1. Pick up full trailer in staging area.
2. Visually inspect trailer for the number and condition of bales.
3. Drive full trailer to storage barn.
4. Clean off trailer after crane has emptied the trailer.
5. Drive empty trailer to parking lot.
6. Drop off empty trailer for contract drivers.

Three people will be required at OGS for switchgrass deliveries. Two of these people will be the spotters. The third person will assist in the crane operation and coordinate with the spotters. The spotters will also have to perform their tasks on an average 24-minute cycle for eight-hour shift, five days a week.

5.7 Prairie Lands Administration (Year 2+)

Prairie Lands will handle the logistics of delivering the switchgrass from the fields to OGS and delivering payment to the farmers for their crop. If the truck driving fleet is contracted, then they will serve as an intermediary between the farmer and the truck drivers. These administrative tasks will likely require at least two people.

5.8 Summary of Project Labor Requirements

Exhibit 5.3 lists the minimum estimated labor requirements at each stage of the fuel supply plan: production, harvesting/baling, delivery, and fuel receiving at OGS. The table assumes the following about the biomass project:

1. The contract workers who produce the switchgrass also help harvest and bale.
2. The minimum requirement assumes that the landowners will perform the work.
3. The maximum requirement assumes that the landowners will contract out the work.

Exhibit 5-3 Total Participation Required for Biomass Project

Function / Labor Requirement	Min. People Required	Max. People Required
Acquire Land / Farmer Participation	500	500
Establish the stand	-	70
Producing Switchgrass Crops*	-	44
Harvesting and Baling	-	71
Contract Truckers	-	33
Loaders / Unloaders	-	36
Prairie Lands Administration	2	2
Spotter Truck Drivers	-	2
Crane Operator	1	1
Total Number of Participants	503	643

* This also includes the labor required for reseeding in year 2.

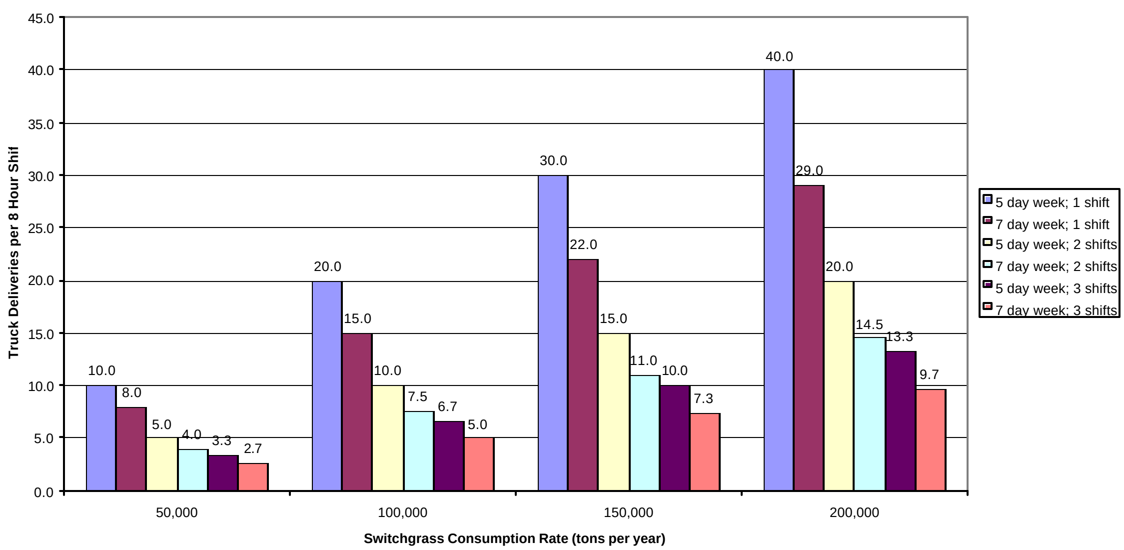
6.0 RESULTS OF PRELIMINARY QUEUE ANALYSIS

The queuing analysis was performed to provide an estimate of the frequency of switchgrass truck and train deliveries needed to supply 200,000 tons of switchgrass to OGS annually. The rail deliveries are not detailed here, but the discussion is located in Appendix E. The rail option would present conflicts with the existing coal deliveries and is not feasible for the new process building location; thus the rail option is not under serious consideration. This section will discuss the delivery frequency and the optimal fuel delivery schedule. It will then discuss some preliminary conclusions.

6.1 Delivery Frequency

Vehicle capacity data was collected to determine the anticipated truck (or rail) volume entering OGS on a daily basis. Once the weight and size restrictions and truck (or rail car) limitations were determined, the frequency of deliveries were calculated based upon the demand of the power plant's steam generator. The graph in Exhibit 6-1 shows the predicted hourly truck volume increase depending on the amount of 8-hour shifts worked per week for various consumption rates. For annual consumption of 200,000 tons per year, 40 flatbed trucks will need to arrive daily for a 5-day week schedule. In this scenario, either 40 trucks could arrive in one shift or 20 trucks could arrive in two shifts.

Exhibit 6-1 Flatbed Truck Switchgrass Delivery Frequency



6.2 Optimal Fuel Delivery Schedule

Knowing the truck delivery frequency for various scenarios, the maximum unloading time required by either the automated or manual system was determined. The unloading time is shown graphically in Exhibit 6-2, assuming that two bays would be in place along with two unloading mechanisms. The unloading mechanism could be either a forklift or an overhead bridge crane. The unloading time decreases as the amount of available delivery hours decreases. These unloading times are based on the 200,000 tons/year (25 ton/hour) consumption rate.

Exhibit 6-2 shows that maximum unload time per crane for a single shift operation, five days a week is 24 minutes. The manual operation requires between 18 to 22.5 minutes while the automatic operation requires 15 minutes to unload the truck and stack the bales in the storage barn. This schedule will be tight for the manual system, since only 1.5 minutes is available to clean off each truck and queue up the next trailer. The automated system will have 9 minutes to queue up the next trailer. For the automated system, a single shift, five-day operation will maximize the use of the labor and equipment while minimizing the amount of time required for switchgrass-carrying trucks to be on the grounds of OGS. The manual system probably would require overtime in order to unload the same amount of bales as the automated system is capable of unloading.

Exhibit 6-2 Maximum Unload Time per Crane / Forklift

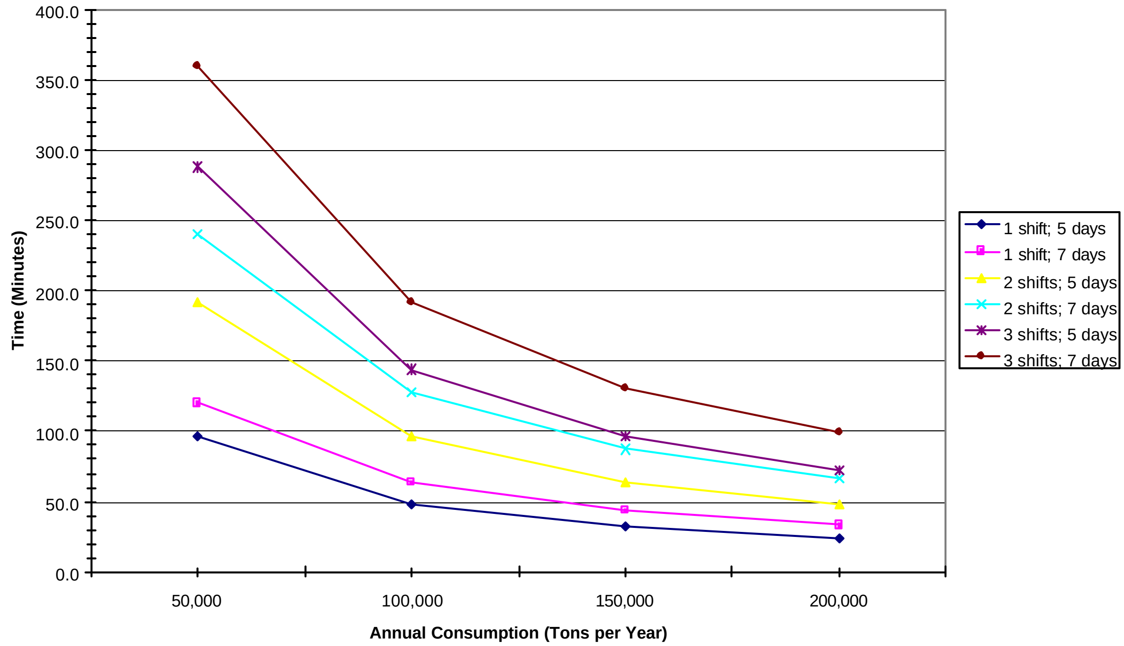
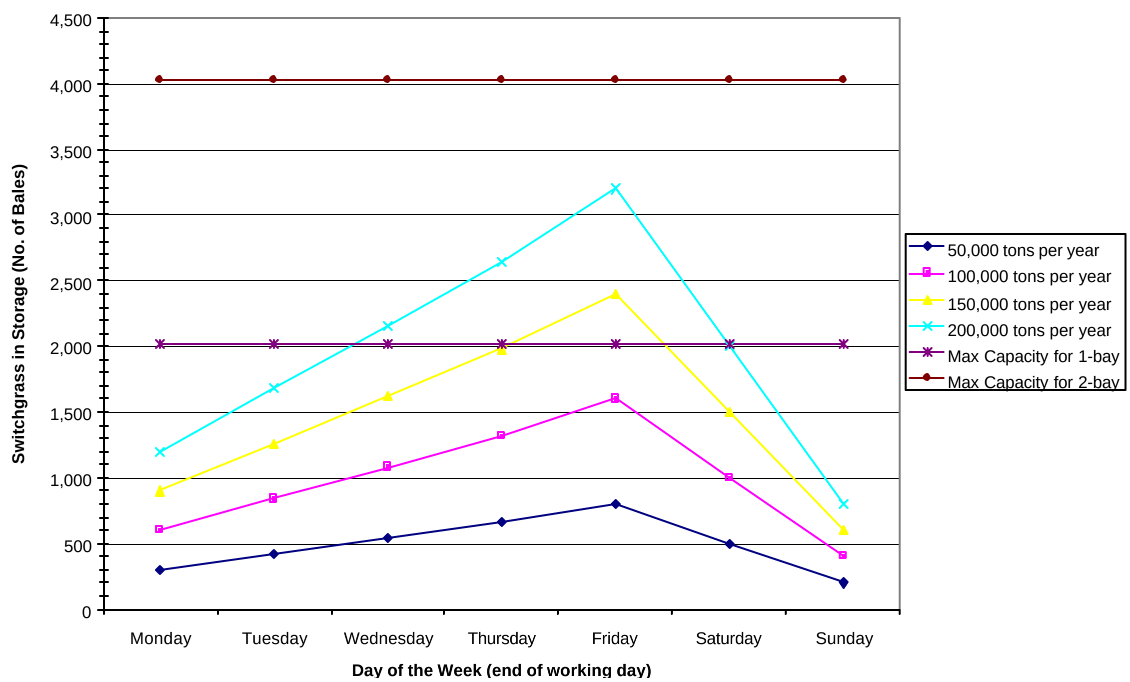


Exhibit 6-3 Minimum Storage Volume Required for 5-day Operation



If Prairie Lands chose a five-day workweek for the workers involved with bale unloading, the daily storage volume for the switchgrass would need to follow a pattern as shown in Exhibit 6-3. The plant would gradually increase its storage capacity throughout the week in order to save up for the weekend. The storage barn would accept 840 tons (1680 bales) per day when deliveries are made, and the plant would consume 600 tons (1200 bales) per day. Then the additional 240 tons (480 bales) per day over five days would result in 1200 tons (2400 bales) of fuel, enough for the weekend operation.

7.0 SUMMARY TABLES

The single most important issue for switchgrass production cost is baling, and whether the farmer should bale using a round or large square baler. Exhibit 7-1 below revisits the pros and cons of both options.

Exhibit 7-1 Round Bales vs. Large Square Bales

Bale Type	Advantages	Disadvantages
Round Bales	• Higher packed density • Higher water resistance • Lower capital costs for farmers	• More difficult to transport • Not compatible with current automatic crane design • Difficult for stacking in storage sheds • Difficult to process due to varying density in the bales
Large Square Bales	• Easier to transport • Easier to stack and reclaim • Can be used with crane system	• Higher capital costs for farmer

This report discussed whether or not the automated bale receiving system is economically superior to the manual system for the cofiring operation proposed at OGS. Exhibit 7-2 lists the characteristics of both receiving systems, supporting the conclusion that the automated system should be the system chosen at the OGS.

Exhibit 7-2 Manual vs Automated Receiving System

System Type	Advantages	Disadvantages
Manual	• Flexible with firing rate • Lower initial cost	• High labor costs • High life cycle cost • Staffing required around the clock
Automatic	• No staffing required during 2nd or 3rd shift or on weekends • Lower life cycle cost	• Higher initial cost

Six off-site storage methods were discussed in chapter 3. Four of the six are listed in Exhibit 7-3 below (pole barns represent two methods – open-sided and enclosed). The two unprotected methods (on-ground and on-crushed-rock) are not included in this table. The table lists the key characteristics of each of the four storage methods.

Exhibit 7-3 Off-Site Storage Methods

Storage Method	Advantages	Disadvantages
Tarping	• Lowest initial cost • Good for short term storage	• Allows condensation to affect switchgrass and tarps blow off from high winter winds
Pole Barns	• Mid-level cost (1/2 to 2/3 cost of steel sheds) • Maintains low moisture level while roof remains intact	• Roof caves in during a heavy wet snowfall • Added cost of reinforcing roof raises cost to comparable level with steel sheds • Wind and rain exposure for open-sided design
Steel Sheds	• Keeps the switchgrass dry for the longest time • Most solid structure	• Highest initial cost

8.0 CONCLUSIONS

The historical traffic peak at OGS is higher than would be expected if switchgrass were supplied to OGS at the maximum rate of 200,000 tons/year. Plant personnel were able to manage traffic flows and volumes during the historical peak without significant reported problems. Therefore, traffic expected for the switchgrass project, even at the maximum supply volume, should be manageable without disrupting other traffic at OGS under most circumstances.

It is noted that short-term traffic volumes could potentially exceed the historical peak if another high fly ash / c-stone selling event were experienced (as in late summer 1999). The proposed location for the switchgrass receiving and processing, along with plans to truck switchgrass in through the North entrance, will mitigate any congestion effects if a new historical truck traffic peak is experienced.

In addition to having a lower life cycle cost than the manual bale receiving system, the automated crane system would be more reliable. The Danish have used cranes on straw-fired combined heat and power systems with a firing rate as low as 2 tons/hour, which is less than 10% of the amount needed at OGS. Automated cranes have worked reliably in various overseas operations, and provide the best bale handling solution for switchgrass at OGS.

Some issues remain unresolved for the fuel supply plan. First, the production costs need to be reduced to make the switchgrass project more economically viable. Second, many farmers are still concerned with baling the switchgrass in large square form as required by the receiving and processing system. The large square baling equipment represents a large capital investment for those farmers without access to the large square balers. "Rebaling" at $5/ton is a potential option for those farmers. Third, the network of off-site storage sheds and locations needs further development. A better-planned and developed network will lower the delivered cost of switchgrass. As a related issue, actual dry matter losses for the six alternative storage options should be evaluated (in the Chariton Valley) to help configure the optimal storage scenario/network. Ultimately, each switchgrass producer will likely choose his optimal storage method.

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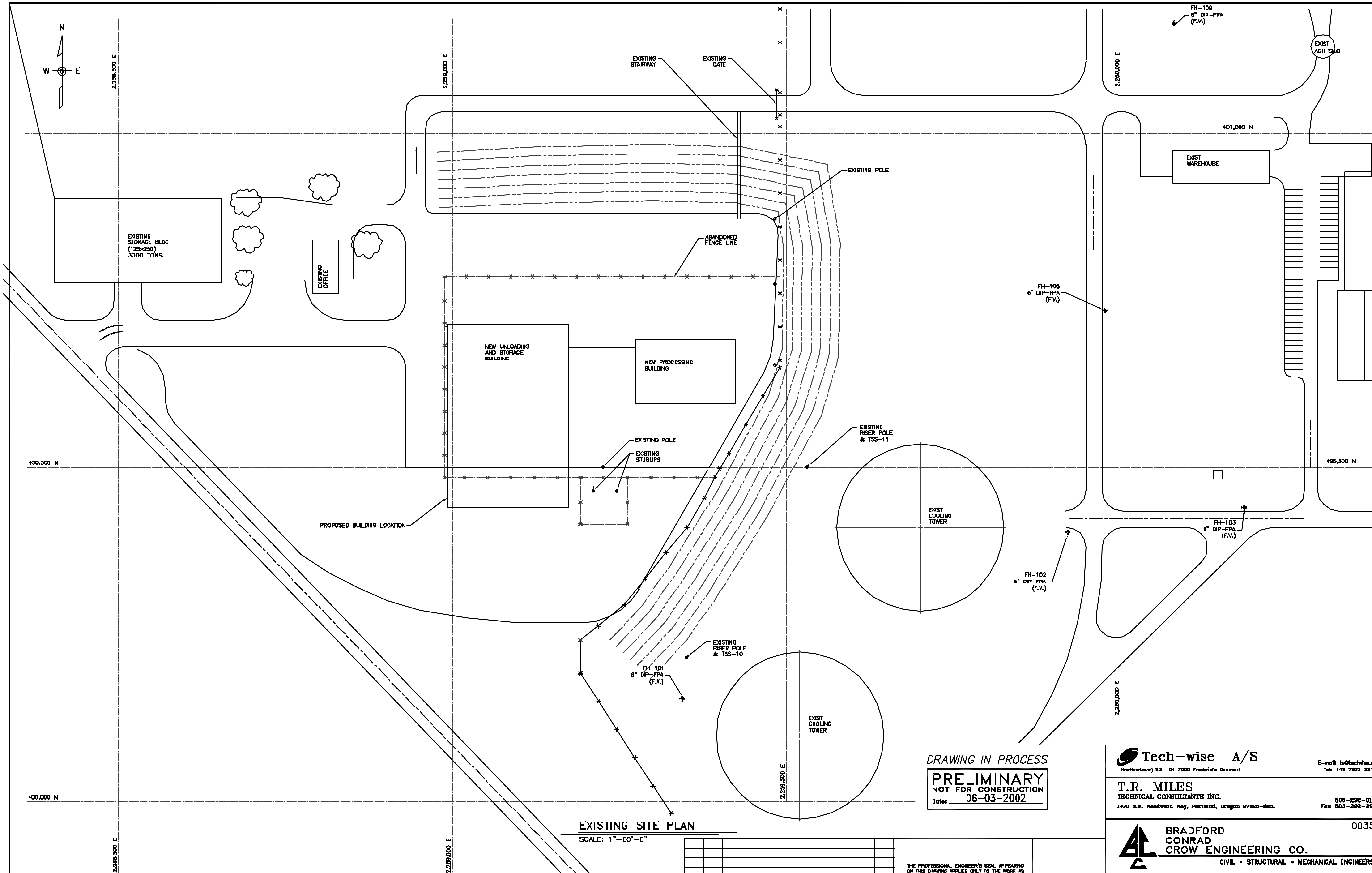
APPENDIX A. OGS Site Plan and Proposed Plant Layout



EXISTING SITE PLAN

SCALE: 1"=60'-0"

DRAWING IN PROCESS

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Date: 06-03-2002

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REV.	DATE	DESCRIPTION	BY
A	4/13/02	UPDATED PER FIELD NOTES 4/13/02	JAC

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DES J. CARR	EXISTING SITE PLAN			
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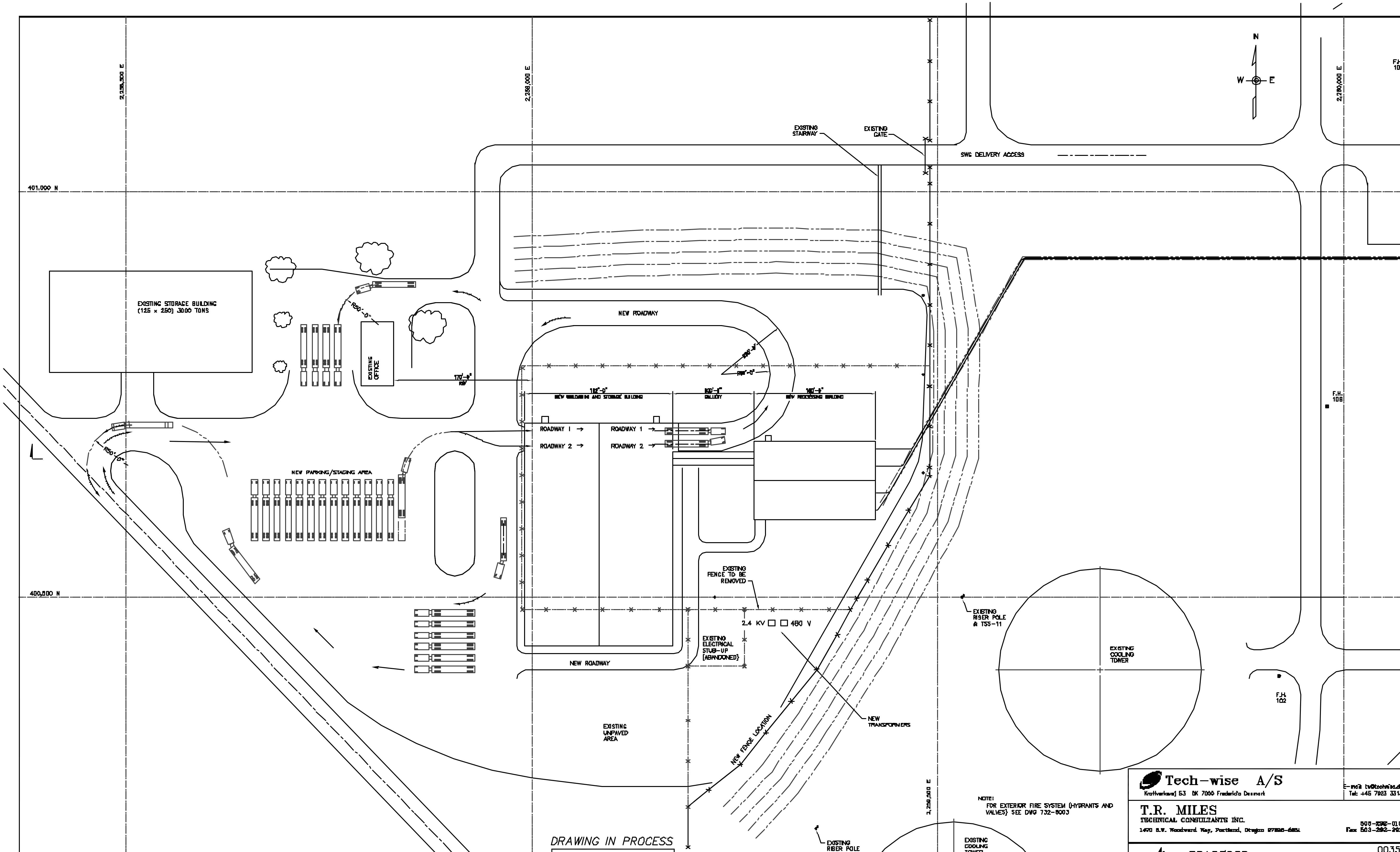

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C	00/00/00	UPDATED	DN
B	00/00/00	REVISED PER 4-30-02 MEETING	PJM
A	00/00/00	UPDATED PER FIELD NOTES 4/13/02	JAC

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DRN J. CARR	AREA PLAN		
CHK	25 TPH AUTOMATED SYSTEM		
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APPENDIX B. Independent Contractor Agreement

INDEPENDENT CONTRACTOR AGREEMENT

THIS AGREEMENT by and between Prairie Lands Bio-Products, Inc. (Prairie Lands) and Mr. _______________________ (Contractor) shall be in full force and effect on and after the date of its final execution.

WITNESSETH:

WHEREAS, Prairie Lands is cooperating with land owners in the Chariton Valley Biomass Project underway in southern Iowa, and the Contractor has agreed to perform services under the terms and conditions set forth herein,

NOW, THEREFORE, IT IS AGREED:

1. Term of Agreement. The Contractor shall complete the duties provided for by this agreement on or before ___________, unless the completion date is modified by agreement of both parties.

2. Scope of Contract. For the consideration set forth herein the Contractor agrees to perform the activities described in the Scope of Work as listed on Attachment A that, by this reference, is made part of this agreement. The Contractor shall provide his own tools and equipment required to perform the Scope of Work activities. Performance of the activities described in the Scope of Work are not assignable without the prior written consent of Prairie Lands.

3. Compensation. If the Contractor performs the duties, responsibilities, and all activities as set forth herein to the satisfaction of Prairie Lands, the Contractor will be compensated according to the rates included in the Scope of Work on Attachment A. The Contractor shall prepare and submit invoices in a format acceptable to Prairie Lands. Prairie Lands will issue payment to the Contractor, based on acceptance of invoices, within __ days of the invoice date.

4. Default. In the event that Prairie Lands determines that the Contractor is unable or fails to perform the duties, responsibilities, and activities set forth herein, Prairie Lands may declare any portion or all of this agreement null and void by providing the Contractor written communication. Upon the sending of such communication, this agreement shall be rendered null and void and of no further force and effect.

5 Independent Contractor. The Contractor shall perform the services rendered hereunder as an independent contractor and not as an employee of Prairie Lands or the federal government; accordingly, Contractor waives any benefits which might otherwise be receivable if he was determined to be an employee of Prairie Lands or the federal government, including but not limited to any worker's compensation benefits, social security contributions, or unemployment compensation benefits.

6. Operations. The Contractor agrees to adequately insure and safely operate, maintain, and repair facilities, supplies, materials, and equipment related to and acquired through this agreement.

7. Assets. The Contractor agrees not to mortgage, use as collateral, or borrow against supplies, materials, facilities, or equipment provided by Prairie Lands through this agreement.

8. Legal. Prairie Lands and the Contractor agree to comply with all applicable local, state, and federal ordinances, regulations, and laws.

9. Liability. The Contractor agrees to assume all risks in connection with the performance of the activities undertaken through this agreement and to be responsible for all claims, demands, actions, or causes of action of whatsoever nature or character arising out of or by reason of the execution or performance of the activities provided herein.

10. Intent to Cooperate. It is the intent of Prairie Lands and the Contractor to fulfill their obligations under this agreement. However, neither Prairie Lands nor the Contractor shall be obligated beyond funds available.

11. Amendment. The terms and conditions of this agreement may be modified by amendment agreed to in writing by both Prairie Lands and Contractor.

12. Certifications: Contractor will complete and submit to Prairie Lands all required and applicable certifications that may include, but are not limited to, the following: Assurance of Compliance Nondiscrimination in Federally Assisted Programs, Disclosure of Lobbying Activities, Certifications Regarding Lobbying; Debarment, Suspension and Other Responsibility Matters; and Drug-Free Workplace Requirements, and W-9 Request for Taxpayer Identification Number and Certification, copies of which are included in Attachment B. Contractor shall ensure the completion and submittal to the RC&D of applicable certifications from any subcontractor(s).

13. Civil Rights Act. The activities conducted under this agreement shall be in compliance with the nondiscrimination provisions contained in the Titles VI and VII of the Civil Rights Act of 1964, as amended, the Civil Rights Restoration Act of 1987 (Public Law 100-259); and other nondiscrimination statutes: namely, Section 504 of the Rehabilitation Act of 1973, Title IX of the Education Amendments of 1972, and the Age Discrimination Act of 1975. They will also be in accordance with regulations of the Secretary of Agriculture (7 CFR-l5, Subparts A and B), which provide that no person in the United States shall on the grounds of race, color, national origin, age, sex, religion, marital status, or handicap be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity receiving federal financial assistance from the Department of Agriculture or any agency thereof.

IN WITNESS WHEREOF, the parties hereto have caused this agreement to be executed:

For:	For:
Prairie Lands Bio-Products, Inc. (Prairie Lands)	_________________________ (Contractor)
_________________________	_________________________
_________________________ Date	_________________________ Date

Attachment A

Scope of Work

1. Perform all operations according to recommendations provided by representatives of Prairie Lands.

2. Perform all activities, including but not limited to, mow, rake, bale, stage, load, transport, unload, store, and reclaim, required to harvest and deliver to an agreed to location, up to ____ tons of biomass with the following specifications:

   - ___% large square bales – plastic twine (dimensions __ ft x __ ft x __ ft)
   - Maximum moisture content: __% by weight
   - Maximum inorganic/trash content: __% by weight
   - Negligible rotten material and wet spots

   Note: Prairie Lands reserves the right to refuse acceptance of any biomass that does not meet these specifications.

3. All biomass will be delivered to, and stored at the Ottumwa Generating Station (OGS) of off-site facilities as directed, that is, <u>at the time and rate requested</u>, by representatives of Prairie Lands.

4. The Contractor will participate in field by field harvest plan development and review with representatives of Prairie Lands.

5. The Contractor will assist with the collection of harvest and yield related data and biomass samples as requested by Prairie Lands.

6. Prairie Lands will compensate the Contractor as described below for the satisfactory completion of the activities set forth in this agreement:

   a. Biomass delivered directly to OGS, that is, biomass that is <u>not</u> stored in off-site facilities, will be compensated at $___ per ton.

   b. Biomass delivered to OGS that has first been stored in off-site facilities will be compensated at $___ per ton. Of this amount, $___ per ton will be paid to the Contractor once biomass is placed in an off-site storage facility. The balance of $___ per ton will be paid to the Contractor once the biomass is delivered to OGS.

APPENDIX C. Queue Analysis Input

	OGS @ 50,000 tpy	OGS @ 100,000 tpy	OGS @ 150,000 tpy	OGS @ 200,000 tpy	Reference
Installed Capacity (MW)	725	725	725	725	line 1
Net Capacity (MW)	675	675	675	675	line 1
Switchgrass Usage (tons/yr)	50,000	100,000	150,000	200,000	input values
Maximum Percent Switchgrass in Co-Fire	1.5%	3.1%	4.6%	6.2%	calculated
Power Generation from Switchgrass (MW)	8.6	17.2	25.8	34.4	calculated
Number of Operating Hours per Year at OGS	8,000	8,000	8,000	8,000	assumption (based on 48 week oper
Average Daily SWG Consumption Rate (tons/day)	150.0	300.0	450.0	600.0	calculated
Average Hourly SWG Consumption Rate (tons/hr)	6.25	12.5	18.75	25.0	calculated
Harvested Acres of Switchgrass per day	37.5	75.0	112.5	150.0	calculated (based on 4 ton/acre)
Harvested Acres of Switchgrass per year	12,500	25,000	37,500	50,000	calculated
Harvested Square Miles of Switchgrass per year	19.5	39.1	58.6	78.1	calculated
Existing Coal Consumption (tons/yr)	2,881,168	2,881,168	2,881,168	2,881,168	calculated
Net Electricity Generation (GWh/yr)	4,470	4,470	4,470	4,470	calculated
Gross Electricity Generation (GWh/yr)	4,801	4,801	4,801	4,801	calculated
Capacity Factor	76%	76%	76%	76%	line 1
Net Plant Heat Rate (Btu/kWh)	10,828	10,828	10,828	10,828	line 1
Average Rectangular Bale Weight (lb)	1,000	1,000	1,000	1,000	line 4
Average Rectangular Bale Volume (ft^3)	96	96	96	96	given
Average Rectangular Bale Fuel Density (lb/ft^3)	10.4	10.4	10.4	10.4	calculated
Heat Input from Coal (MMBtu/yr) - existing rate	48,403,629	48,403,629	48,403,629	48,403,629	calculated
Average Heat Input Rate from Biomass (MMBtu/hr)	93.2	186.5	279.7	372.9	calculated
Average HHV from Coal Displaced (Btu/lb)	8400	8400	8400	8400	given
Average HHV from Switchgrass (Btu/lb)	7458	7458	7458	7458	given
Coal Displaced Due to Cofire (tons/yr)	44,393	88,786	133,179	177,571	calculated
Net Coal Consumption (tons/yr)	2,836,776	2,792,383	2,747,990	2,703,597	calculated
Average Ash Amount in Coal (lb/MMBtu)	7.1	7.1	7.1	7.1	given
Average Coal Ash Generation Rate (lb/hr)	42,237	41,576	40,915	40,254	calculated
Average Ash Amount in Switchgrass (lb/MMBtu)	6.1	6.1	6.1	6.1	given
Average Switchgrass Ash Generation Rate (lb/hr)	569	1,137	1,706	2,275	calculated
Fuel Receiving (for 40 hour work week)					
Switchgrass Usage (tons/yr)	50,000	100,000	150,000	200,000	input values
Delivery days per week	5	5	5	5	variable 5 or 7
Tons delivered per delivery day	210	420	630	840	calculated
Double Trailer Trucks per day (22 tons each)	10	20	29	39	calculated
Daily hauls per double trailer truck	4	4	4	4	given
Number of double trailer trucks required	3	5	7	10	calculated
Flatbed Trucks per day (21 tons each)	10	20	30	40	calculated
Hauls per flatbed truck per shift	5	5	5	5	given
Number of flatbed trucks required	2	4	6	8	calculated
Maximum allowable unloading time (minutes)	48	24	16	12	calculated
Delivery hours per delivery day	8	8	8	8	variable 8, 16, 24
Double Trailer Trucks per delivery hour	1.3	2.5	3.6	4.9	calculated
Flatbed Trucks per delivery hour	1.3	2.5	3.8	5.0	calculated
Covered hopper railroad cars needed per day	7	14	21	28	calculated
Covered hopper railroad cars required per hour	0.9	1.8	2.6	3.5	calculated
Flatbed railroad cars needed per day	7	14	20	27	calculated
Flatbed railroad cars required per hour	0.9	1.8	2.5	3.4	calculated
Unloading rate for railroad cars (tons/hr)	26.3	52.5	78.8	105.0	calculated

	OGS @ 50,000 tpy	OGS @ 100,000 tpy	OGS @ 150,000 tpy	OGS @ 200,000 tpy	Reference
Fuel Receiving (for 56 hour work week)					
Switchgrass Usage (tons/yr)	50,000	100,000	150,000	200,000	input values
Delivery days per week	7	7	7	7	variable 5 or 7
Tons delivered per delivery day	150	300	450	600	calculated
Double Trailer Trucks per day (22 tons each)	7	14	21	28	calculated
Daily hauls per double trailer truck	4	4	4	4	given
Number of double trailer trucks required	2	4	6	7	calculated
Flatbed Trucks per day (21 tons each)	8	15	22	29	calculated
Hauls per flatbed truck per shift	5	5	5	5	given
Number of flatbed trucks required	2	3	5	6	calculated
Maximum allowable unloading time (minutes)	60	32	22	17	calculated
Delivery hours per delivery day	8	8	8	8	variable 8, 16, 24
Double Trailer Trucks per delivery hour	0.9	1.8	2.6	3.5	calculated
Flatbed Trucks per delivery hour	1.0	1.9	2.8	3.6	calculated
Covered hopper railroad cars needed per day	5	10	15	20	calculated
Covered hopper railroad cars needed per hour	0.6	1.3	1.9	2.5	calculated
Flatbed railroad cars needed per day	5	10	15	19	calculated
Flatbed railroad cars required per hour	0.6	1.3	1.9	2.4	calculated
Unloading rate for railroad cars (tons/hr)	18.8	37.5	56.3	75.0	calculated
Fuel Receiving (for 80 hour work week)					
Switchgrass Usage (tons/yr)	50,000	100,000	150,000	200,000	input values
Delivery days per week	5	5	5	5	variable 5 or 7
Tons delivered per delivery day	210	420	630	840	calculated
Double Trailer Trucks per day (22 tons each)	10	20	29	39	calculated
Daily hauls per double trailer truck	4	4	4	4	given
Number of double trailer trucks required	3	5	7	10	calculated
Flatbed Trucks per day (21 tons each)	10	20	30	40	calculated
Hauls per flatbed truck per shift	5	5	5	5	given
Number of flatbed trucks required	1	2	3	4	calculated
Maximum allowable unloading time (minutes)	96	48	32	24	calculated
Delivery hours per delivery day	16	16	16	16	variable 8, 16, 24
Double Trailer Trucks per delivery hour	0.6	1.3	1.8	2.4	calculated
Flatbed trucks per delivery hour	0.6	1.3	1.9	2.5	calculated
Covered hopper railroad cars needed per day	7	14	21	28	calculated
Covered hopper railroad cars required per hour	0.4	0.9	1.3	1.8	calculated
Flatbed railroad cars needed per day	7	14	20	27	calculated
Flatbed railroad cars required per hour	0.4	0.9	1.3	1.7	calculated
Unloading rate for railroad cars (tons/hr)	13.1	26.3	39.4	52.5	calculated
Fuel Receiving (for 112 hour work week)					
Switchgrass Usage (tons/yr)	50,000	100,000	150,000	200,000	input values
Delivery days per week	7	7	7	7	variable 5 or 7
Tons delivered per delivery day	150	300	450	600	calculated
Double Trailer Trucks per day (22 tons each)	7	14	21	28	calculated
Daily hauls per truck	4	4	4	4	given
Number of double trailer trucks required	2	4	5	7	calculated
Flatbed Trucks per day (21 tons each)	8	15	22	29	calculated
Hauls per flatbed truck per shift	5	5	5	5	given
Number of flatbed trucks required	1	2	3	3	calculated
Maximum allowable unloading time (minutes)	120	64	44	33	calculated
Delivery hours per delivery day	16	16	16	16	variable 8, 16, 24
Double Trailer Trucks per delivery hour	0.4	0.9	1.3	1.8	calculated
Flatbed trucks per delivery hour	0.5	0.9	1.4	1.8	calculated
Covered hopper railroad cars needed per day	5	10	15	20	calculated
Covered hopper railroad cars required per hour	0.3	0.6	0.9	1.3	calculated
Flatbed railroad cars needed per day	5	10	15	19	calculated
Flatbed railroad cars required per hour	0.3	0.6	0.9	1.2	calculated
Unloading rate for railroad cars (tons/hr)	9.4	18.8	28.1	37.5	calculated
Fuel Receiving (for 120 hour work week)					
Switchgrass Usage (tons/yr)	50,000	100,000	150,000	200,000	input values

	OGS @ 50,000 tpy	OGS @ 100,000 tpy	OGS @ 150,000 tpy	OGS @ 200,000 tpy	Reference
Delivery days per week	5	5	5	5	variable 5 or 7
Tons delivered per delivery day	210	420	630	840	calculated
Double Trailer Trucks per day (22 tons each)	10	20	29	39	calculated
Daily hauls per truck	4	4	4	4	given
Number of double trailer trucks required	3	5	7	10	calculated
Flatbed Trucks per day (21 tons each)	10	20	30	40	calculated
Hauls per flatbed truck per shift	5	5	5	5	given
Number of flatbed trucks required	1	2	2	3	calculated
Maximum allowable unloading time (minutes)	144	72	48	36	calculated
Delivery hours per delivery day	24	24	24	24	variable 8, 16, 24
Double Trailer Trucks per delivery hour	0.4	0.8	1.2	1.6	calculated
Flatbed trucks per delivery hour	0.4	0.8	1.3	1.7	calculated
Covered hopper railroad cars needed per day	7	14	21	28	calculated
Covered hopper railroad cars required per hour	0.3	0.6	0.9	1.2	calculated
Flatbed railroad cars needed per day	7	14	20	27	calculated
Flatbed railroad cars required per hour	0.3	0.6	0.8	1.1	calculated
Unloading rate for railroad cars (tons/hr)	8.8	17.5	26.3	35.0	calculated
Fuel Receiving (for 168 hour work week)					
Switchgrass Usage (tons/yr)	50,000	100,000	150,000	200,000	input values
Delivery days per week	7	7	7	7	variable 5 or 7
Tons delivered per delivery day	150	300	450	600	calculated
Double Trailer Trucks per day (22 tons each)	7	14	21	28	calculated
Daily hauls per truck	4	4	4	4	given
Number of double trailer trucks required	2	4	5	7	calculated
Flatbed Trucks per day (21 tons each)	8	15	22	29	calculated
Hauls per flatbed truck per shift	5	5	5	5	given
Number of flatbed trucks required	1	1	2	2	calculated
Maximum allowable unloading time (minutes)	180	96	65	50	calculated
Delivery hours per delivery day	24	24	24	24	variable 8, 16, 24
Double Trailer Trucks per delivery hour	0.3	0.6	0.9	1.2	calculated
Flatbed trucks per delivery hour	0.3	0.6	0.9	1.2	calculated
Covered hopper railroad cars needed per day	5	10	15	20	calculated
Covered hopper railroad cars required per hour	0.2	0.4	0.6	0.8	calculated
Flatbed railroad cars needed per day	5	10	15	19	calculated
Flatbed railroad cars required per hour	0.2	0.4	0.6	0.8	calculated
Unloading rate for railroad cars (tons/hr)	6.3	12.5	18.8	25.0	calculated
Fuel Storage					
Minimum storage time before use (hours)	16	16	16	16	estimated for 40 hr week
Maximum non-delivery capacity (hours)	48	48	48	48	estimated for 40 hr week
Maximum storage capacity before use (hours)	64	64	64	64	calculated
Max. storage qty (tons of switchgrass)	400	800	1200	1600	calculated
Max. storage qty (bales of switchgrass)	800	1600	2400	3200	calculated
Design storage qty for 25 tph fuel hall (bales)	4256	4256	4256	4256	design for 152 - 28 bale courses
Maximum number of rectangular bales	800	1600	2400	3200	calculated
Percent of design storage qty utilized	19%	38%	56%	75%	calculated
Safety Factor Available (extra hours if filled)	276	106	49	21	calculated
Ash Hauling					
Switchgrass Ash Generated (tons/yr)	2,275	4,549	6,824	9,099	calculated
Total Ash Generated (tons/yr)	171,222	170,853	170,483	170,114	calculated
Percent Biomass Ash for OGS	1.3%	2.7%	4.0%	5.3%	calculated
Pick-up days per week	5	5	5	5	variable 5 or 7
Number of working hours for ash hauling	24	24	24	24	variable 8, 16, or 24
Tons hauled per pick-up day	713	712	710	709	calculated
Avg Ash Volume per haul (ft^3)	1,375	1,375	1,375	1,375	calculated
Fraction of hauling volume occupied	33%	33%	33%	33%	calculated
Tons hauled per truck	22	22	22	22	given
Trucks per day	32	32	32	32	calculated
Pick-up hours per pick-up day	8	8	8	8	assumption
Trucks per pick-up hour	4	4	4	4	calculated

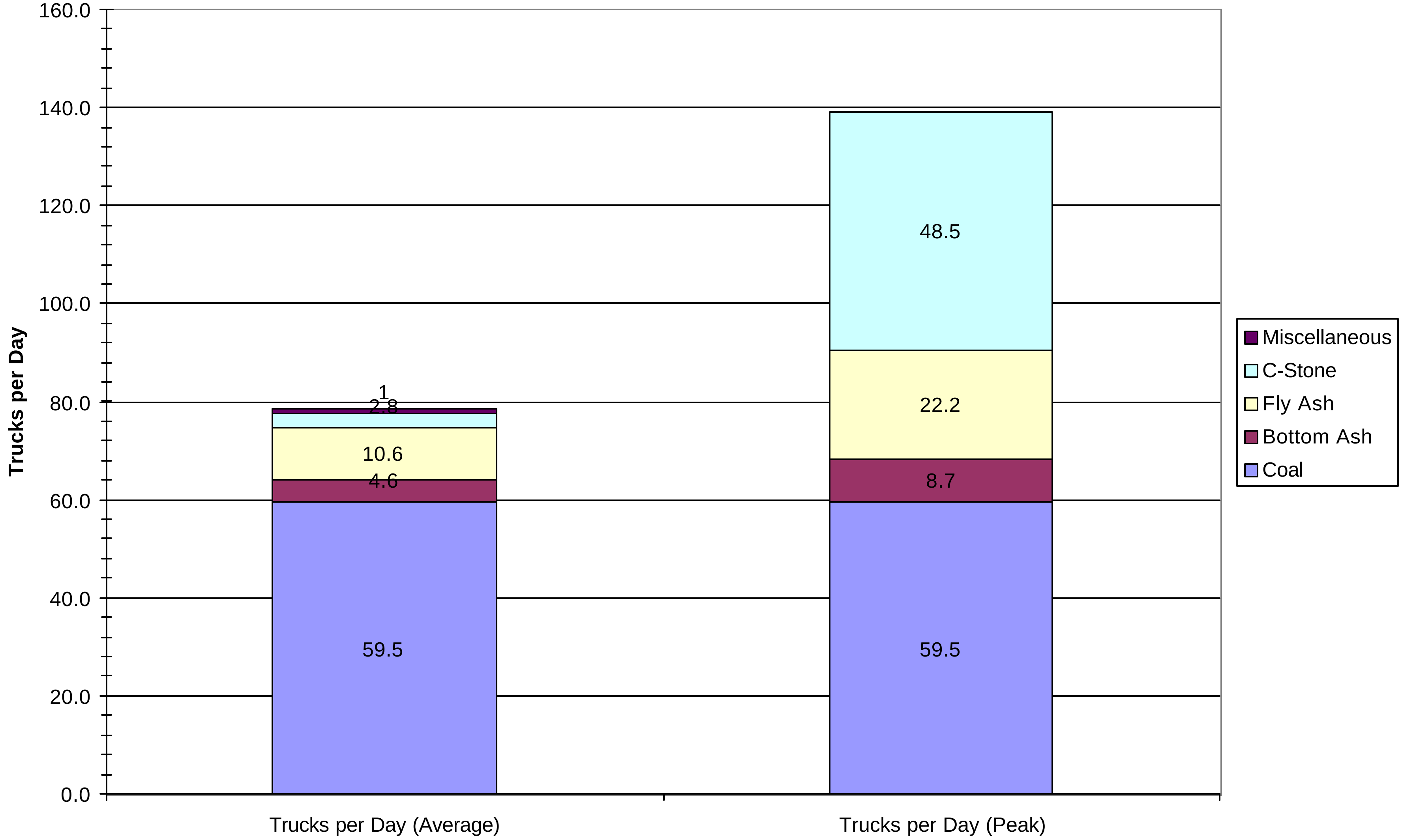
	OGS @ 50,000 tpy	OGS @ 100,000 tpy	OGS @ 150,000 tpy	OGS @ 200,000 tpy	Reference
Ash Storage					
Maximum storage capacity (days)	3.0	3.0	3.0	3.0	calculated
Maximum storage quantity (tons)	2140	2136	2131	2126	calculated
Avg Ash Density (lb/ft^3)	32.0	32.0	32.0	32.0	Muse, John K. and Charles C. Mitch
Maximum required buffer storage (ft^3)	133,767	133,479	133,190	132,902	calculated
Number of ash storage silos	3	3	3	3	Fibro-thetford brochure
Diameter of ash silo (ft)	14.0	14.0	14.0	14.0	Standard Handbook of Powerplant E
Height of ash silo (ft)	72.4	72.3	72.1	71.9	
Double Trailer Details - Baled Switchgrass					
Max. legal trailer length (ft)	48	48	48	48	line 3
Usable trailer length (ft) 11 bales long	44	44	44	44	line 3
Max. legal trailer width (ft.)	8.2	8.2	8.2	8.2	line 3
Usable trailer width (ft) 1 bale wide	8	8	8	8	line 3
Max. legal trailer height (ft)	13.5	13.5	13.5	13.5	line 3
Useable trailer height (ft) 4 bales high	12.0	12.0	12.0	12.0	line 3
Max. useable trailer volume (ft^3)	4,224	4,224	4,224	4,224	calculated
Max. tonnage of switchgrass @ 10 lb/ft3	22	22	22	22	calculated
Assumed avg switchgrass payload (tons)	22	22	22	22	line 3
Flatbed Truck Details - Baled Switchgrass					
Max. legal trailer length (ft)	53	53	53	53	line 3
Assumed actual trailer length (ft) 7 bales long	56	56	56	56	line 3
Usable trailer width (in.) 2 bales wide	96	96	96	96	line 3
Max. legal trailer width (in.) 1 bales wide	96	96	96	96	line 3
Max. legal trailer height (ft)	13.5	13.5	13.5	13.5	line 3
Max. useable trailer height (ft) 3 bales high	9.0	9.0	9.0	9.0	line 3
Max. useable trailer volume (ft^3)	4,032	4,032	4,032	4,032	calculated
Max. tonnage of switchgrass @ 10 lb/ft3	21.0	21.0	21.0	21.0	calculated
Assumed avg switchgrass payload (tons)	21.0	21.0	21.0	21.0	line 3
Railroad Flat Car Details - Baled Switchgrass					
Railroad car usable length (ft.) 8 bales long	64	64	64	64	line 2
Railroad car usable width (ft.) 2 bales wide	8	8	8	8	line 2
Railroad car maximum height (ft) 4 bales high	13.5	13.5	13.5	13.5	line 2
Max. useable railroad car height (ft)	12.0	12.0	12.0	12.0	line 2
Max. useable railroad car volume (ft^3)	6,144	6,144	6,144	6,144	calculated
Max. tonnage of switchgrass @ 10 lb/ft3	32.0	32.0	32.0	32.0	calculated
Assumed avg switchgrass payload (tons)	32.0	32.0	32.0	32.0	line 2
Railroad Covered Hopper Car Details - Loose Switchgrass					
Railroad car usable length (ft.)	60	60	60	60	line 2
Railroad car usable width (ft.)	9	9	9	9	line 2
Railroad car maximum height (ft)	15.5	15.5	15.5	15.5	line 2
Max. useable railroad car height (ft)	10.8	10.8	10.8	10.8	line 2
Max. useable railroad car volume (ft^3)	5,805	5,805	5,805	5,805	calculated
Max. tonnage of switchgrass @ 10 lb/ft3	30.2	30.2	30.2	30.2	calculated
Assumed avg switchgrass payload (tons)	30.2	30.2	30.2	30.2	line 2

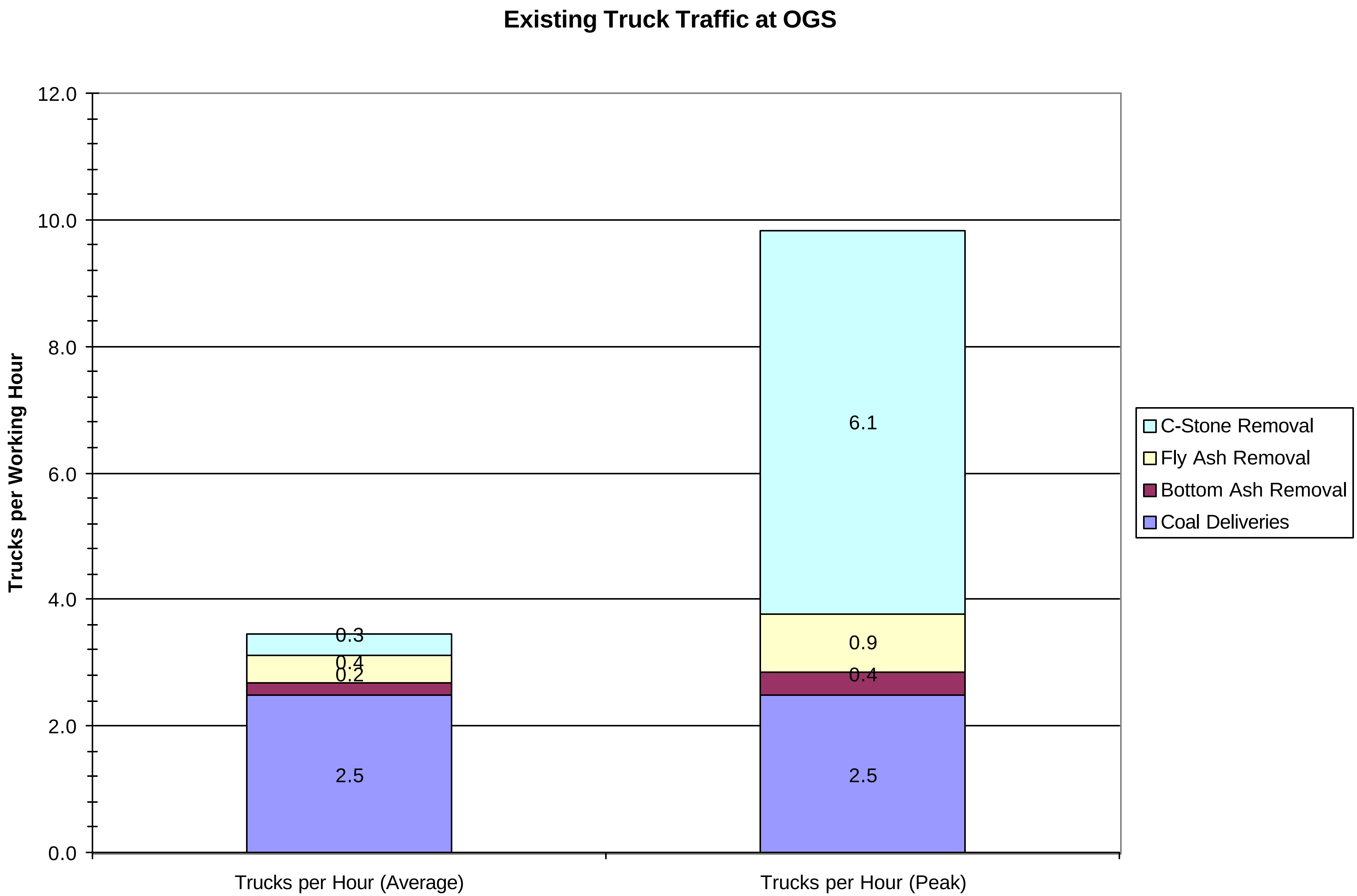
References / Notes:

1. World Electric Power Plants Database, Utility Data Institute, McGraw Hill Companies, June 1999
2. Railroad Car Dimensions from http://www.freightcar.com
3. Trailer Dimensions from http://www.tiptrailers.com/fleet
4. Fuel density based on a dry weight 1000 lb. Rectangular bale (3'x4'x8')
5. Amos, Wade, National Renewable Energy Laboratory, Data from December 2000 Test Burn, February 2002

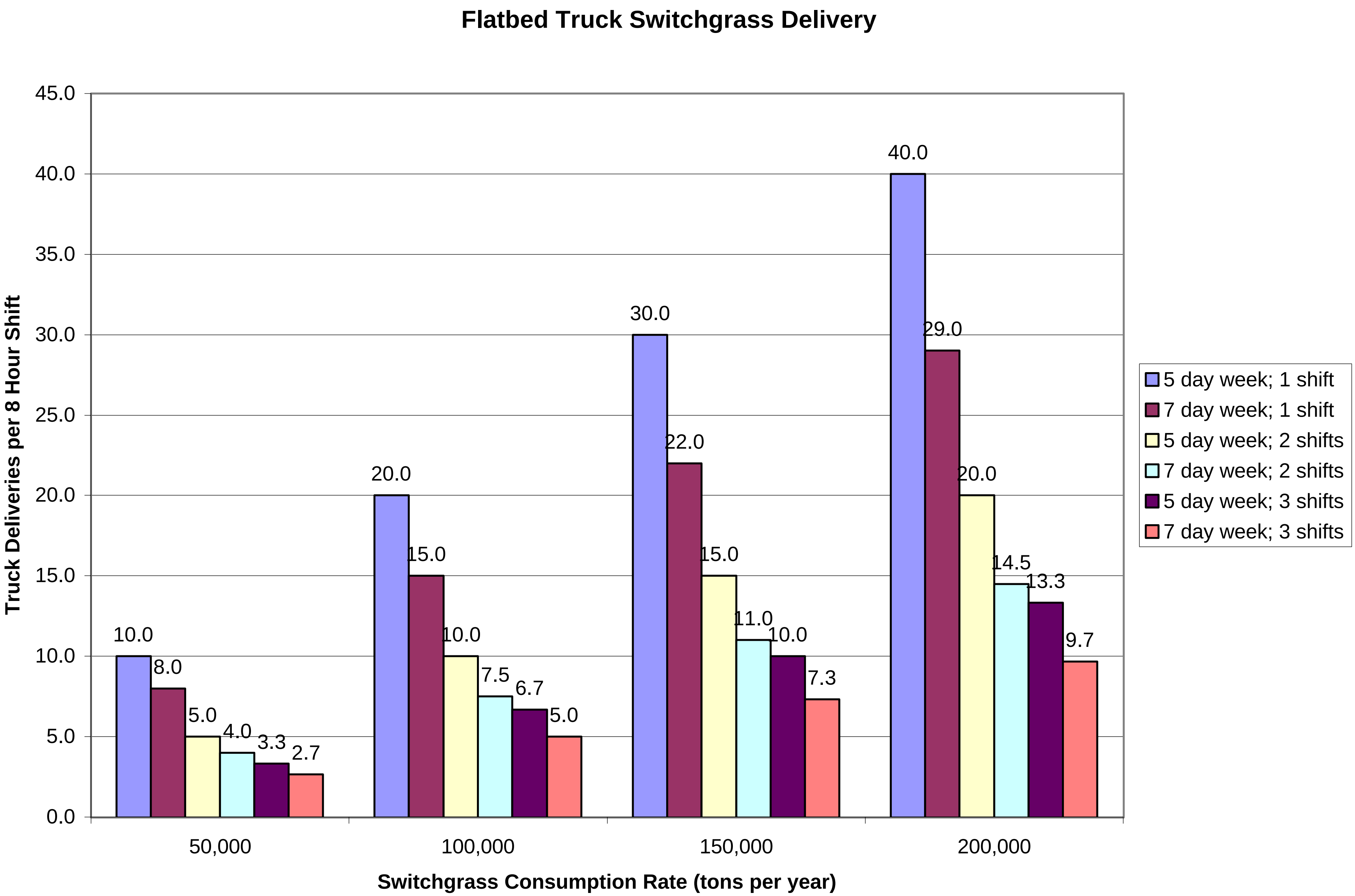
APPENDIX D. Queue Analysis Results

Existing Truck Traffic at OGS





Existing Truck Traffic at OGS
Trucks per Working Hour
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.3
0.4
0.2
2.5
6.1
0.9
0.4
2.5
Trucks per Hour (Average)
Trucks per Hour (Peak)
C-Stone Removal
Fly Ash Removal
Bottom Ash Removal
Coal Deliveries


Flatbed Truck Switchgrass Delivery
Truck Deliveries per 8 Hour Shift
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10.0
8.0
5.0
4.0
3.3
2.7
20.0
15.0
10.0
7.5
6.7
5.0
30.0
22.0
15.0
11.0
10.0
7.3
40.0
29.0
20.0
14.5
13.3
9.7
50,000
100,000
150,000
200,000
Switchgrass Consumption Rate (tons per year)
5 day week; 1 shift
7 day week; 1 shift
5 day week; 2 shifts
7 day week; 2 shifts
5 day week; 3 shifts
7 day week; 3 shifts

Existing Truck Delivery Conditions at OGS

Type of Truck Delivery	Trucks per Day (Average)	Trucks per Day (Peak)
Coal Deliveries	59.5	59.5
Bottom Ash Removal	4.6	8.7
Fly Ash Removal	10.6	22.2
C-Stone Removal	2.8	48.5
Total Trucks per Day	77.5	139.0

Type of Truck Delivery	Trucks per Hour (Average)	Trucks per Hour (Peak)
Coal Deliveries	2.5	2.5
Bottom Ash Removal	0.2	0.4
Fly Ash Removal	0.4	0.9
C-Stone Removal	0.3	6.1
Total Trucks per Working Hour	3.5	9.8

Existing Rail Delivery Conditions at OGS

Type of Rail Delivery	Rail Cars per Day (Average)	Rail Cars per Day (Peak)
Coal Deliveries	62.4	110.0
Anticipated SWG @ 200ktpy	19	133

Exhibit 1 - Existing Truck Delivery Conditions at OGS

Type of Truck Delivery	Trucks per Day (Average)	Trucks per Day (Peak)
Coal Deliveries	59.5	59.5
Bottom Ash Removal	4.6	8.7
Fly Ash Removal	10.6	22.2
C-Stone Removal	2.8	48.5
Total Trucks per Day	77.5	139.0

Exhibit 2 - Flatbed Truck Deliveries Per Shift

	Tons/Year			
Working Hours	50,000	100,000	150,000	200,000
1 shift; 5 days	10.0	20.0	30.0	40.0
1 shift; 7 days	8.0	15.0	22.0	29.0
2 shifts; 5 days	5.0	10.0	15.0	20.0
2 shifts; 7 days	4.0	7.5	11.0	14.5
3 shifts; 5 days	3.3	6.7	10.0	13.3
3 shifts; 7 days	2.7	5.0	7.3	9.7

Exhibit 3 - Covered Hopper Railroad Car Deliveries Per Day

	Tons/Year			
No. of Work Days	50,000	100,000	150,000	200,000
5	7.0	14.0	21.0	28.0
7	5.0	10.0	15.0	20.0

Exhibit 4 - Flatbed Trailer Maximum Unload Time (Minutes) (For One Processing Bay)

	Tons/Year			
Working Hours	50,000	100,000	150,000	200,000
1 shift; 5 days	48.0	24.0	16.0	12.0
1 shift; 7 days	60.0	32.0	21.8	16.6
2 shifts; 5 days	96.0	48.0	32.0	24.0
2 shifts; 7 days	120.0	64.0	43.6	33.1
3 shifts; 5 days	144.0	72.0	48.0	36.0
3 shifts; 7 days	180.0	96.0	65.5	49.7

Exhibit 4a - Flatbed Trailer Maximum Unload Time (Minutes) (For Two Processing Bays)

	Tons/Year			
Working Hours	50,000	100,000	150,000	200,000
1 shift; 5 days	96.0	48.0	32.0	24.0
1 shift; 7 days	120.0	64.0	43.6	33.1
2 shifts; 5 days	192.0	96.0	64.0	48.0
2 shifts; 7 days	240.0	128.0	87.3	66.2
3 shifts; 5 days	288.0	144.0	96.0	72.0
3 shifts; 7 days	360.0	192.0	130.9	99.3

Exhibit 4b - Flatbed Trailer Maximum Unload Time (Minutes) (For Four Processing Bays)

	Tons/Year			
Working Hours	50,000	100,000	150,000	200,000
1 shift; 5 days	192.0	96.0	64.0	48.0
1 shift; 7 days	240.0	128.0	87.3	66.2
2 shifts; 5 days	384.0	192.0	128.0	96.0
2 shifts; 7 days	480.0	256.0	174.5	132.4
3 shifts; 5 days	576.0	288.0	192.0	144.0
3 shifts; 7 days	720.0	384.0	261.8	198.6

Exhibit 5 - Maximum Off-Site Sheltered Switchgrass Storage Supply (days)

Switchgrass Firing Rate (tons/yr)	Number of Days
50,000	44
100,000	22
150,000	15
200,000	11

Note: The amount of off-site storage hold approximately 6,500 tons. The amount of days is calculated by the following equation:

Number of Days = (6500 tons x 336 days/yr) / (firing rate in tons/yr)

Double Trailer Truck Deliveries Per Shift

	Tons/Hr			
Working Hours	50,000	100,000	150,000	200,000
1 shift; 5 days	10.0	20.0	29.0	39.0
1 shift; 7 days	7.0	14.0	21.0	28.0
2 shifts; 5 days	5.0	10.0	14.5	19.5
2 shifts; 7 days	3.5	7.0	10.5	14.0
3 shifts; 5 days	3.3	6.7	9.7	13.0
3 shifts; 7 days	2.3	4.7	7.0	9.3

Flatbed Truck Deliveries Per Shift

	Tons/Hr			
Working Hours	50,000	100,000	150,000	200,000
1 shift; 5 days	10.0	20.0	30.0	40.0
1 shift; 7 days	8.0	15.0	22.0	29.0
2 shifts; 5 days	5.0	10.0	15.0	20.0
2 shifts; 7 days	4.0	7.5	11.0	14.5
3 shifts; 5 days	3.3	6.7	10.0	13.3
3 shifts; 7 days	2.7	5.0	7.3	9.7

Covered Hopper Railroad Car Deliveries Per Day

	Tons/Hr			
No. of Work Days	50,000	100,000	150,000	200,000
5	7.0	14.0	21.0	28.0
7	5.0	10.0	15.0	20.0

Flatbed Railroad Car Deliveries Per Shift

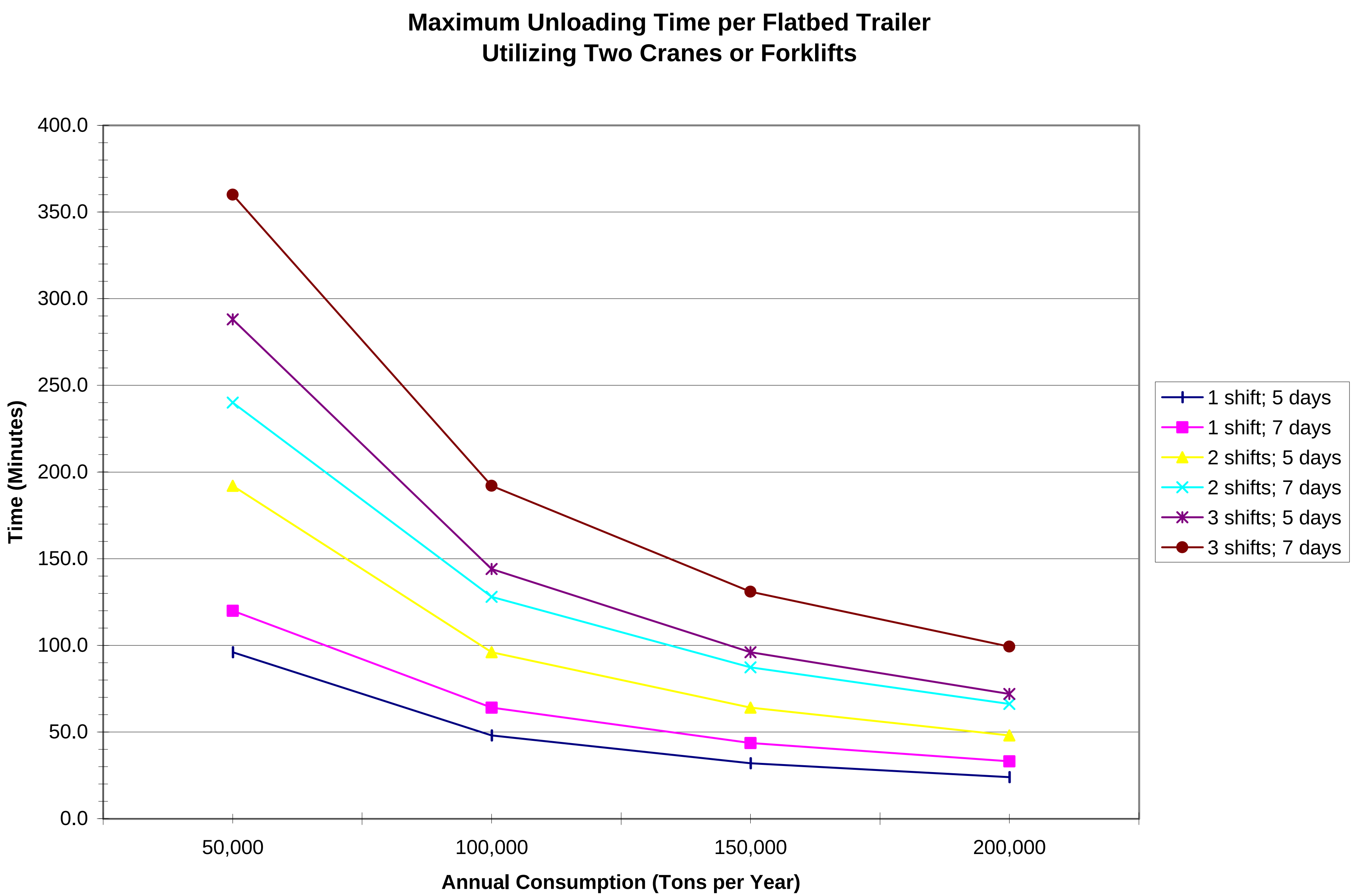
	Tons/Hr			
No. of Work Days	50,000	100,000	150,000	200,000
5	7.0	14.0	20.0	27.0
7	5.0	10.0	15.0	19.0

Storage Needs - 5 days a week (in tons of switchgrass)

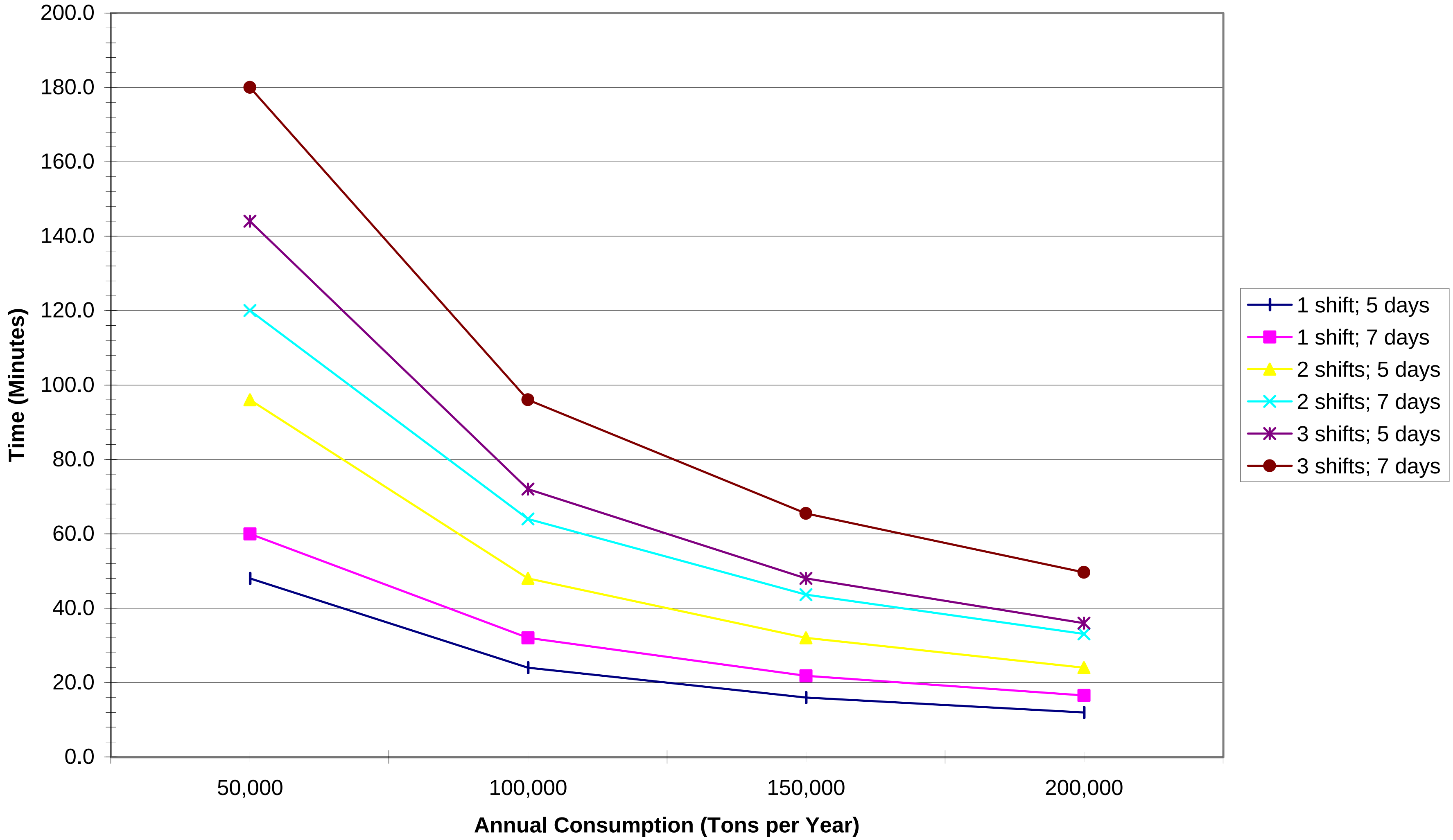
	Tons/Hr					
Day of Week	50,000	100,000	150,000	200,000		
Monday	150	300	450	600	1,036	2072
Tuesday	210	420	630	840	1,036	2072
Wednesday	270	540	810	1,080	1,036	2072
Thursday	330	660	990	1,320	1,036	2072
Friday	400	800	1,200	1,600	1,036	2072
Saturday	250	500	750	1,000	1,036	2072
Sunday	100	200	300	400	1,036	2072

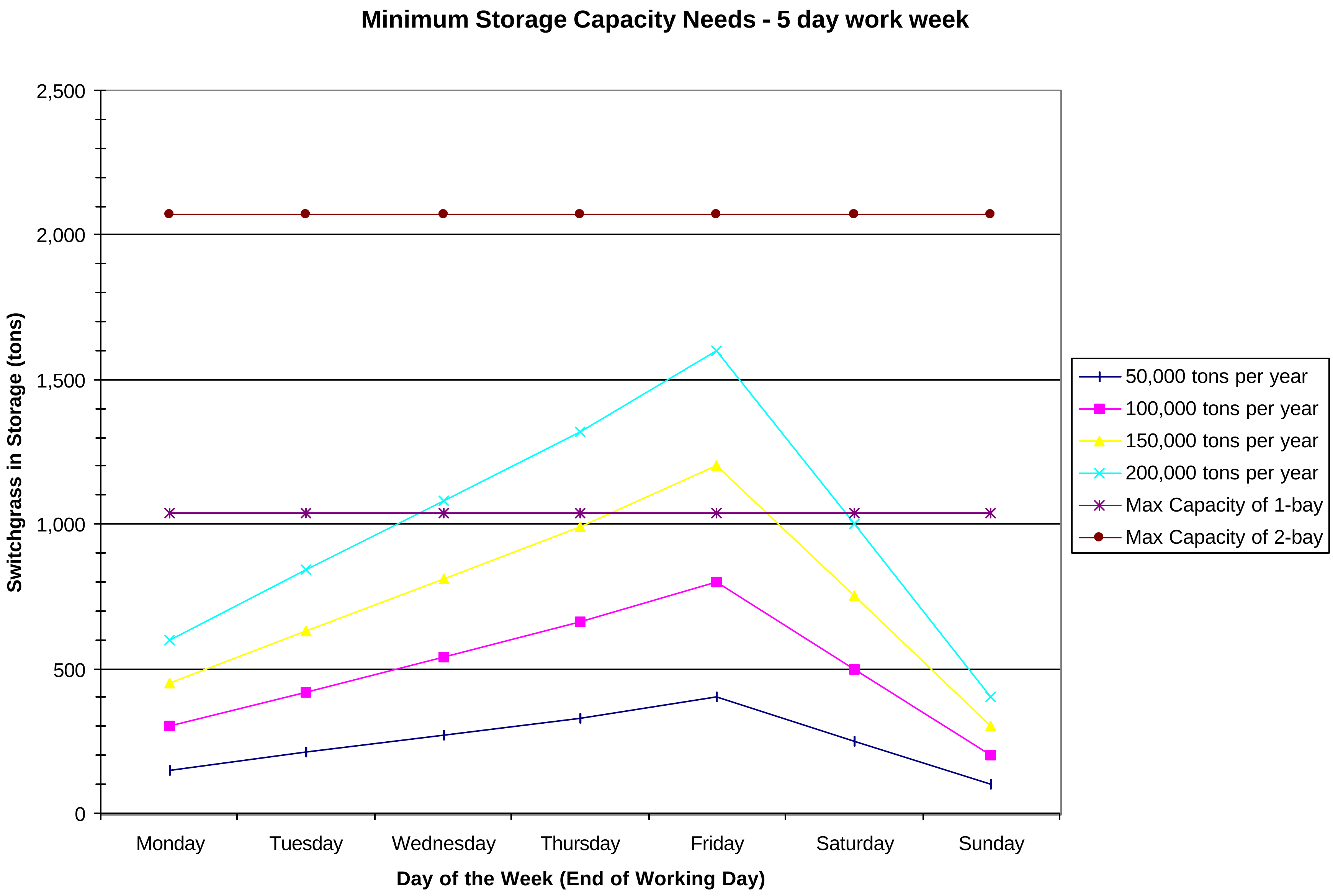
Storage Needs - 5 days a week (in bales of switchgrass)

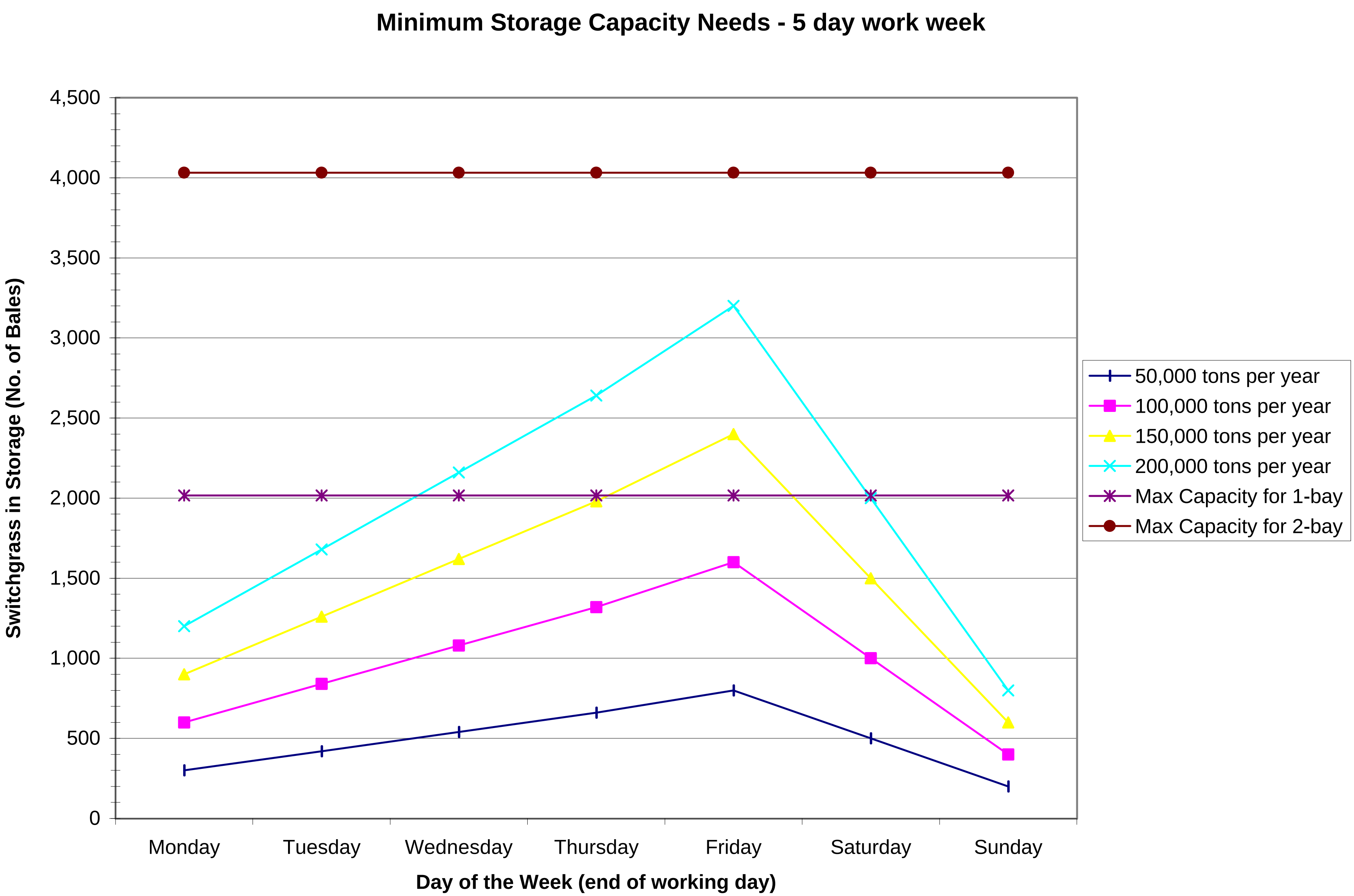
	Tons/Hr					
Day of Week	50,000	100,000	150,000	200,000		
Monday	300	600	900	1,200	2016	4032
Tuesday	420	840	1,260	1,680	2016	4032
Wednesday	540	1,080	1,620	2,160	2016	4032
Thursday	660	1,320	1,980	2,640	2016	4032
Friday	800	1,600	2,400	3,200	2016	4032
Saturday	500	1,000	1,500	2,000	2016	4032
Sunday	200	400	600	800	2016	4032

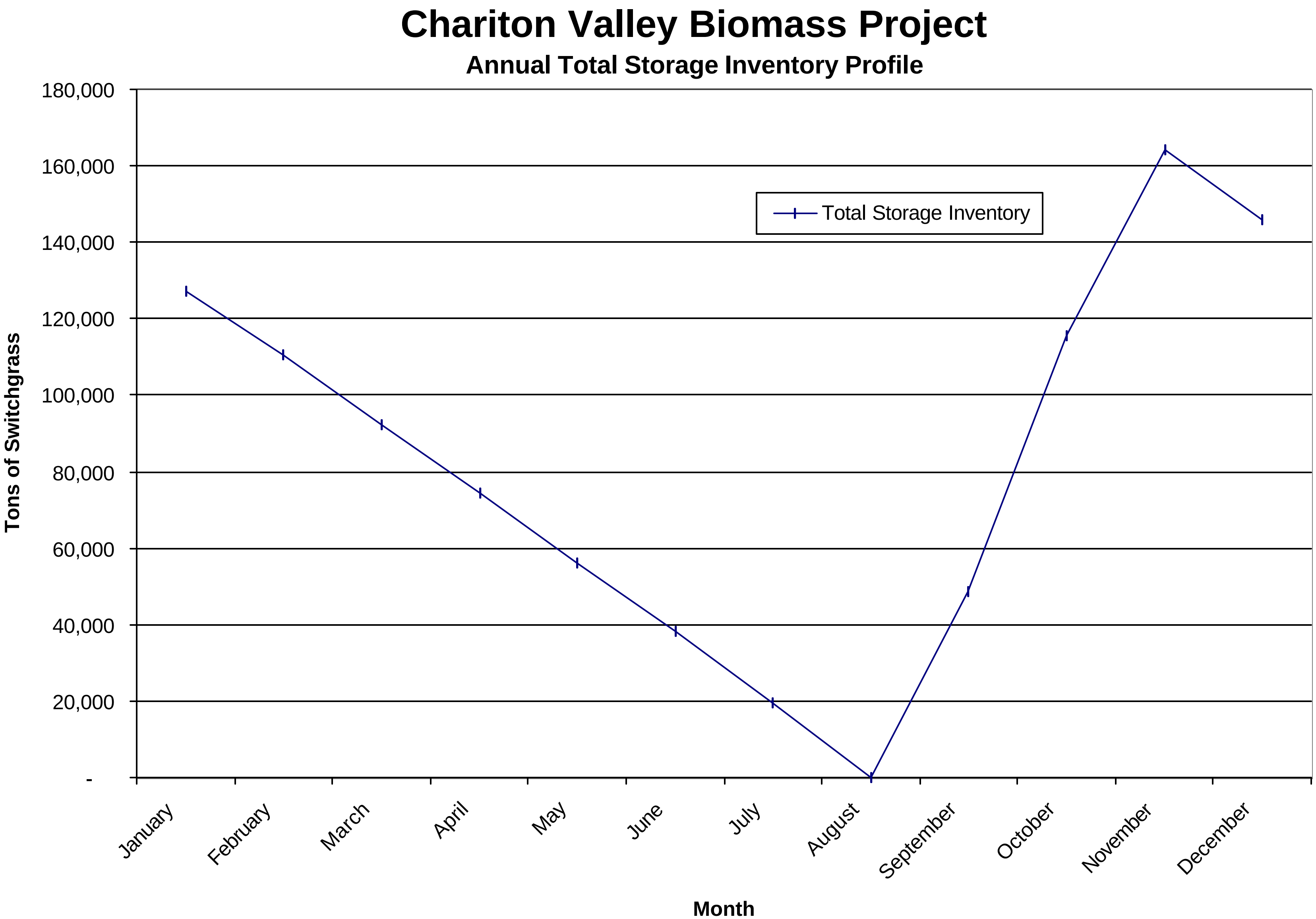

Maximum Unloading Time per Flatbed Trailer
Utilizing Two Cranes or Forklifts
Time (Minutes)
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
50,000
100,000
150,000
200,000
Annual Consumption (Tons per Year)
1 shift; 5 days
1 shift; 7 days
2 shifts; 5 days
2 shifts; 7 days
3 shifts; 5 days
3 shifts; 7 days

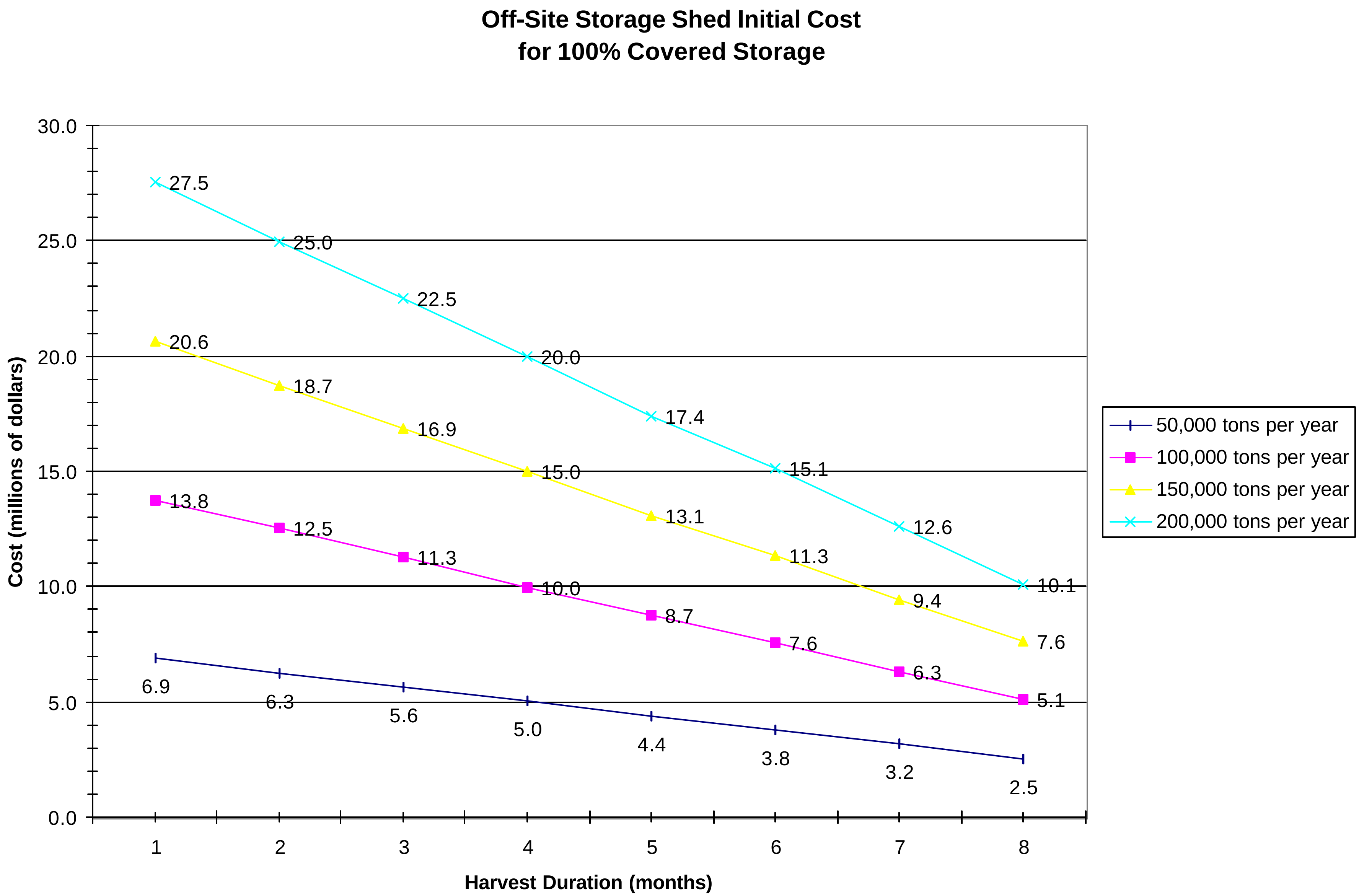
Maximum Unloading Time per Flatbed Trailer Utilizing a Single Crane or Forklift



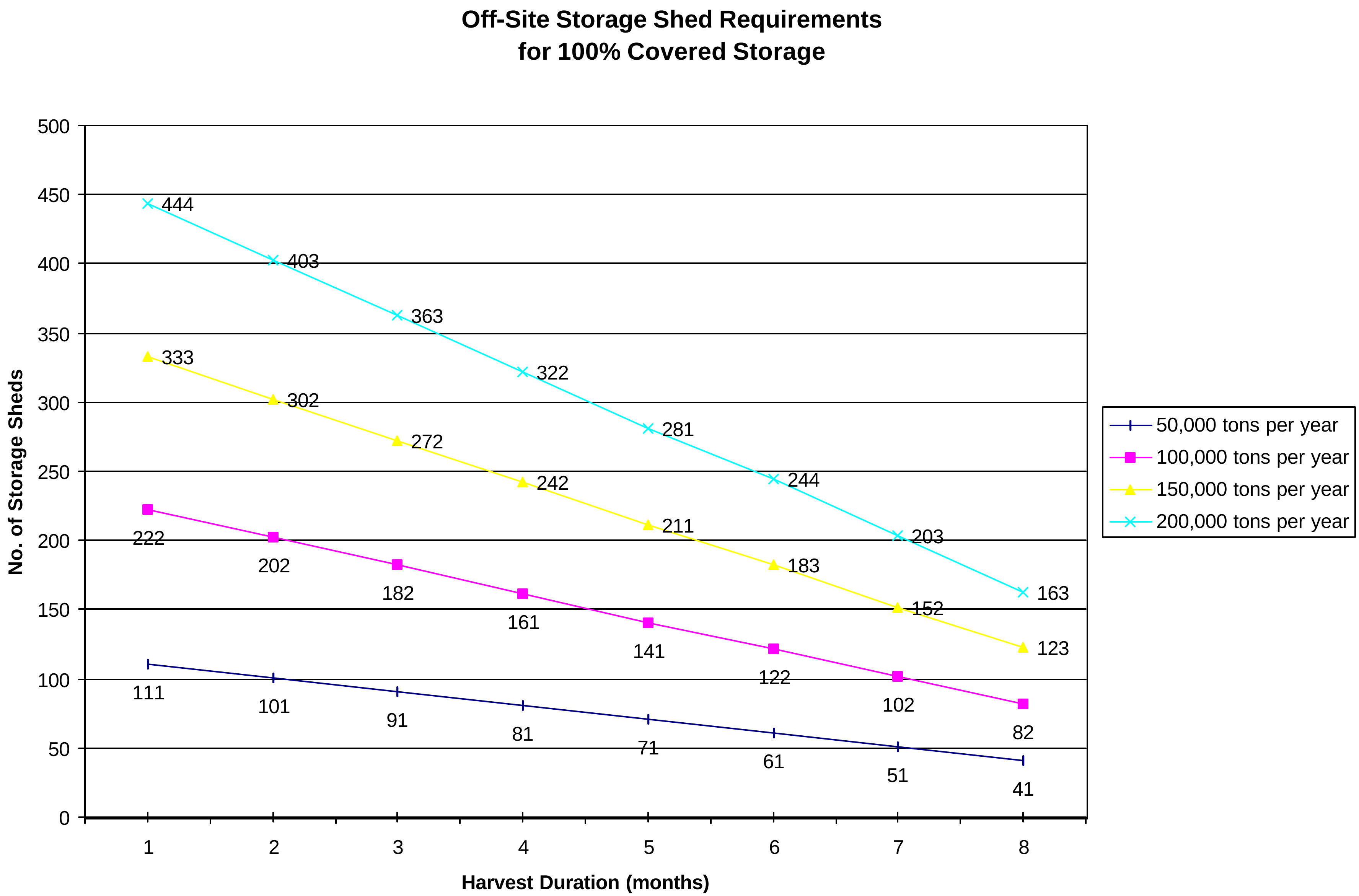

Minimum Storage Capacity Needs - 5 day work week
Switchgrass in Storage (tons)
2,500
2,000
1,500
1,000
500
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of the Week (End of Working Day)
50,000 tons per year
100,000 tons per year
150,000 tons per year
200,000 tons per year
Max Capacity of 1-bay
Max Capacity of 2-bay

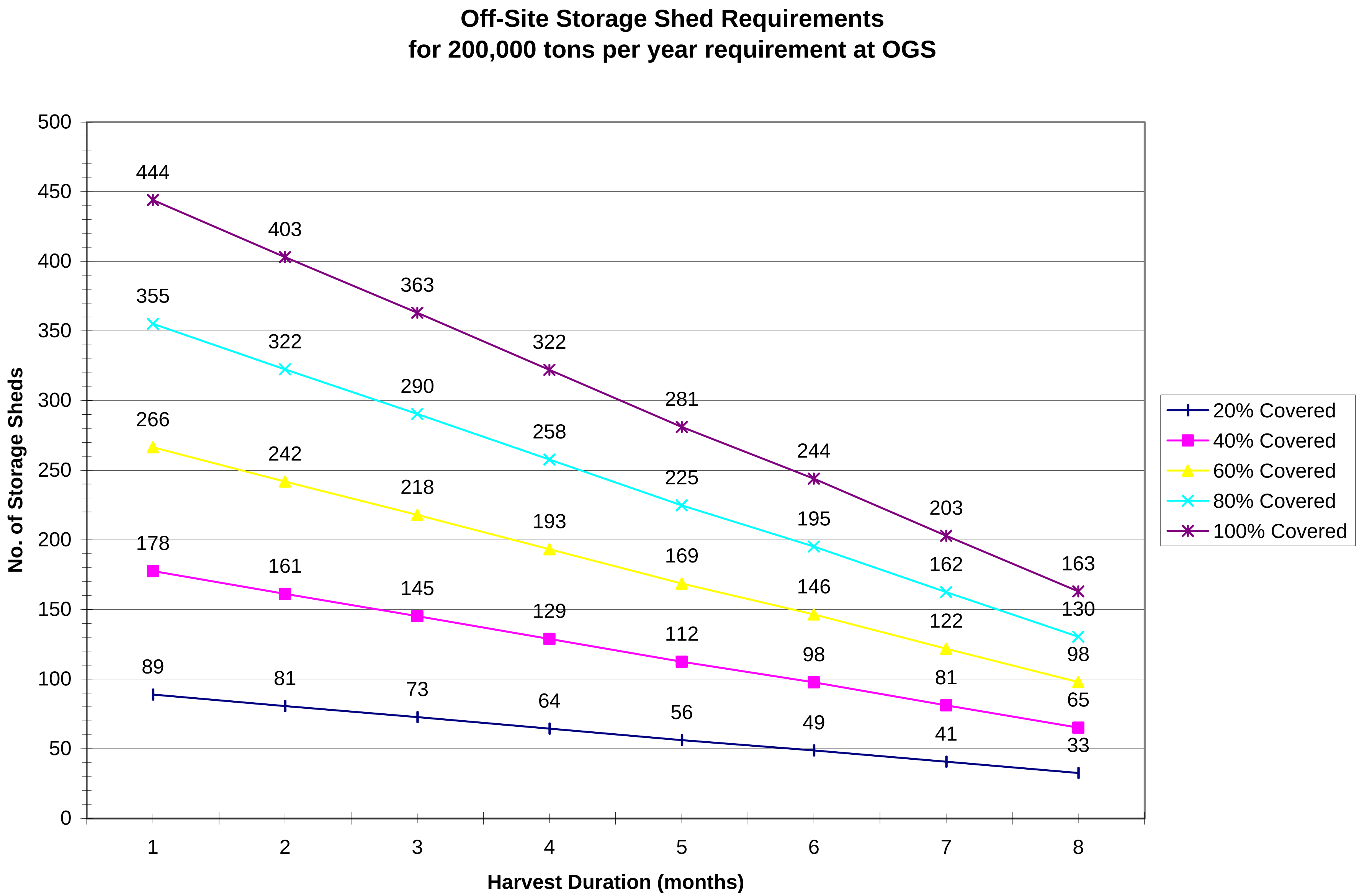

Minimum Storage Capacity Needs - 5 day work week
Switchgrass in Storage (No. of Bales)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of the Week (end of working day)
50,000 tons per year
100,000 tons per year
150,000 tons per year
200,000 tons per year
Max Capacity for 1-bay
Max Capacity for 2-bay


Chariton Valley Biomass Project
Annual Total Storage Inventory Profile
Total Storage Inventory
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
-
Tons of Switchgrass
January
February
March
April
May
June
July
August
September
October
November
December
Month



Off-Site Storage Shed Initial Cost
for 100% Covered Storage
Cost (millions of dollars)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Harvest Duration (months)
1
2
3
4
5
6
7
8
27.5
25.0
22.5
20.0
17.4
15.1
12.6
10.1
20.6
18.7
16.9
15.0
13.1
11.3
9.4
7.6
13.8
12.5
11.3
10.0
8.7
7.6
6.3
5.1
6.9
6.3
5.6
5.0
4.4
3.8
3.2
2.5
50,000 tons per year
100,000 tons per year
150,000 tons per year
200,000 tons per year


Off-Site Storage Shed Requirements
for 100% Covered Storage
No. of Storage Sheds
Harvest Duration (months)
50,000 tons per year
100,000 tons per year
150,000 tons per year
200,000 tons per year
0
50
100
150
200
250
300
350
400
450
500
1
2
3
4
5
6
7
8
444
403
363
322
281
244
203
163
333
302
272
242
211
183
152
123
222
202
182
161
141
122
102
82
111
101
91
81
71
61
51
41


Off-Site Storage Shed Requirements
for 200,000 tons per year requirement at OGS
No. of Storage Sheds
Harvest Duration (months)
20% Covered
40% Covered
60% Covered
80% Covered
100% Covered
0
50
100
150
200
250
300
350
400
450
500
1
2
3
4
5
6
7
8
444
403
363
322
281
244
203
163
355
322
290
258
225
195
162
130
266
242
218
193
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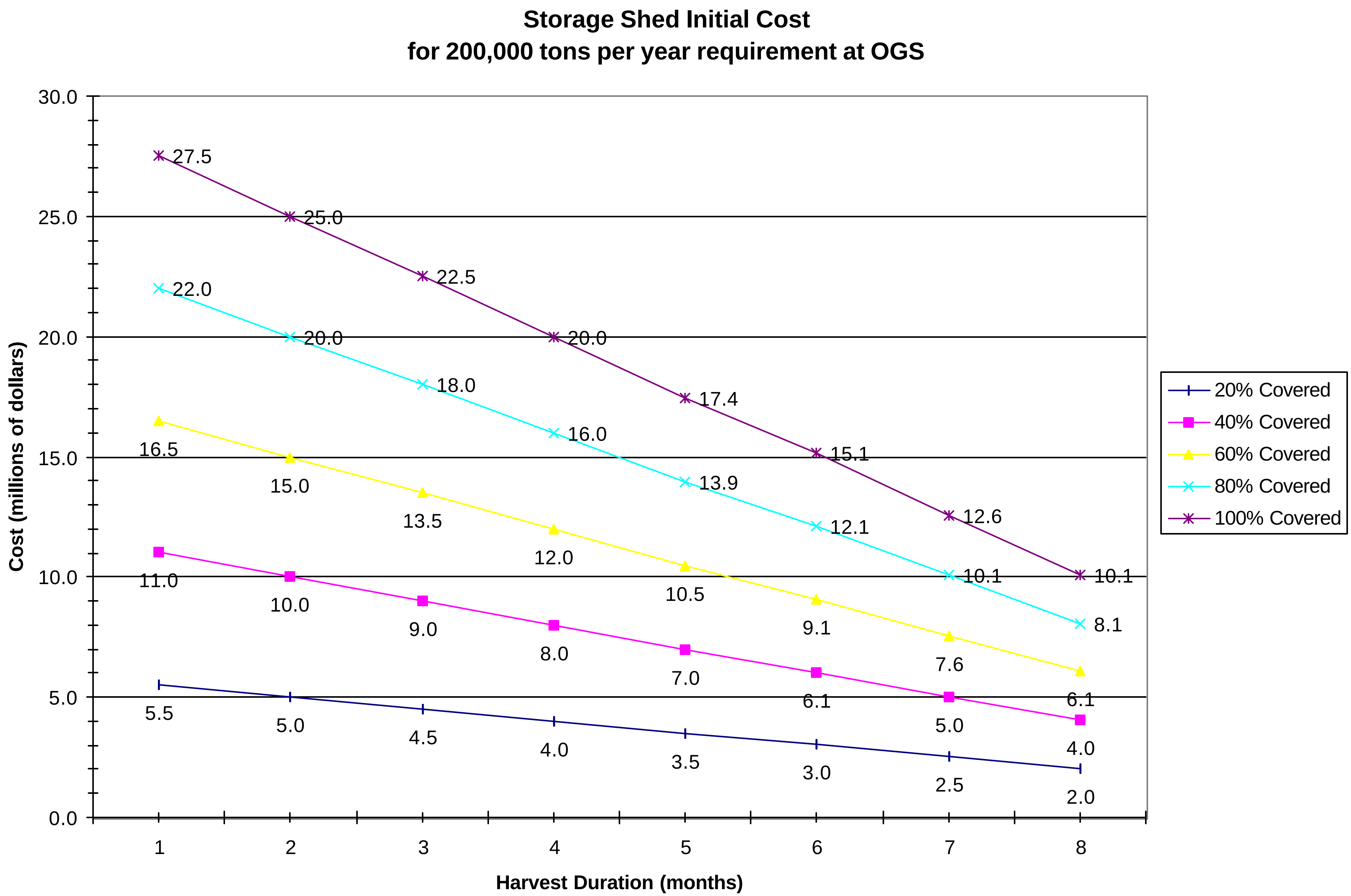
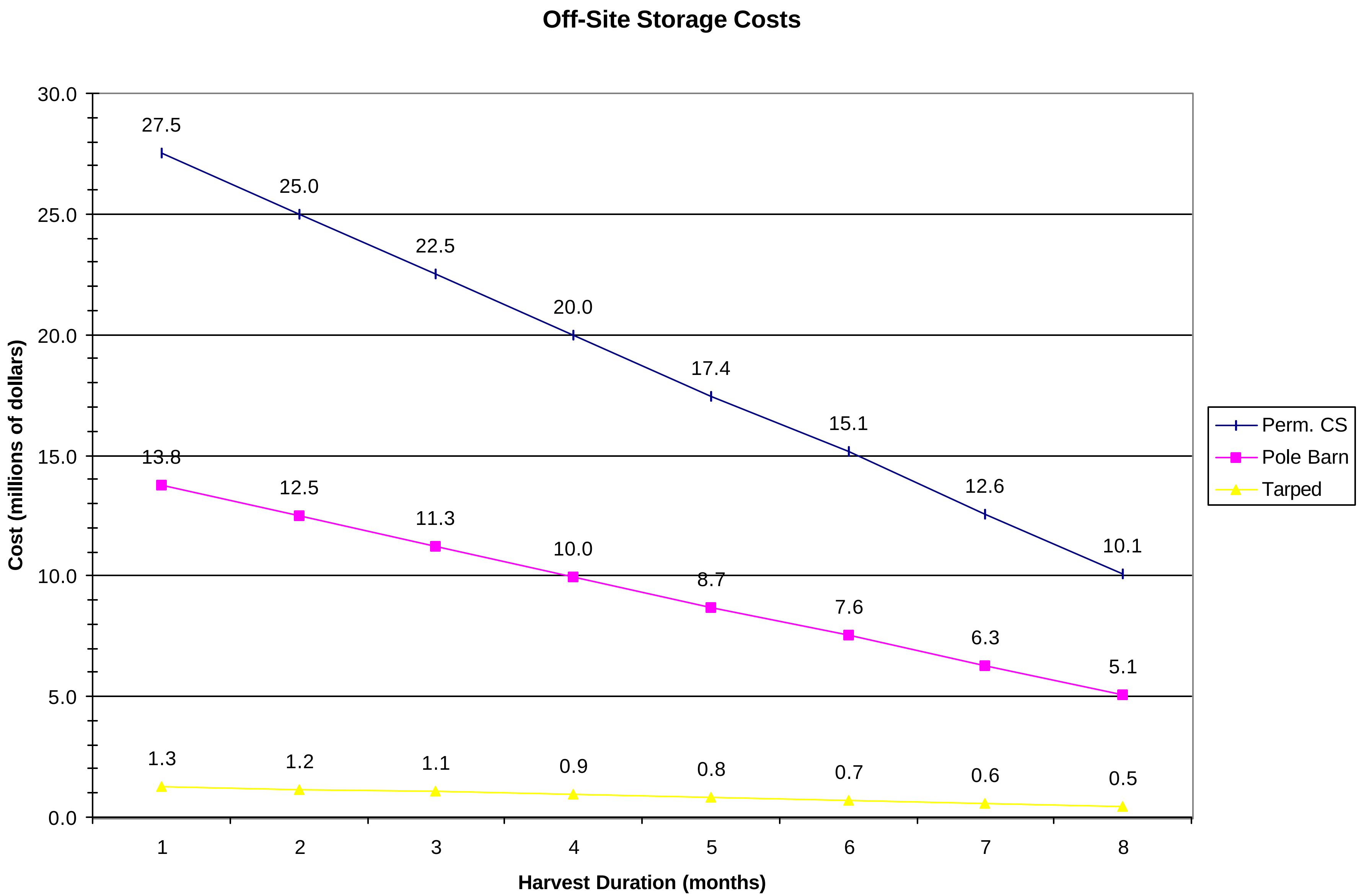
73
64
56
49
41
33


Storage Shed Initial Cost
for 200,000 tons per year requirement at OGS
Cost (millions of dollars)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
27.5
25.0
22.5
20.0
17.4
15.1
12.6
10.1
22.0
20.0
18.0
16.0
13.9
12.1
10.1
8.1
16.5
15.0
13.5
12.0
10.5
9.1
7.6
6.1
11.0
10.0
9.0
8.0
7.0
6.1
5.0
4.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1
2
3
4
5
6
7
8
Harvest Duration (months)
20% Covered
40% Covered
60% Covered
80% Covered
100% Covered



Off-Site Storage Costs
Cost (millions of dollars)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
27.5
25.0
22.5
20.0
17.4
15.1
12.6
10.1
13.8
12.5
11.3
10.0
8.7
7.6
6.3
5.1
1.3
1.2
1.1
0.9
0.8
0.7
0.6
0.5
1
2
3
4
5
6
7
8
Harvest Duration (months)
Perm. CS
Pole Barn
Tarped

Input Items:

Annual Switchgrass Supply: 200,000 tons/yr
Safety Margin: - weeks
Harvest Duration: 3 months
Average Yield: 4 tons/acre/yr
Number of Growers: 500
Harvest Frequency: 0.3 harvest/acre/yr
Fraction of Covered Storage at Peak Storage Volume: 100%
Storage Capacity per Field Shed: 450 tons/shed
Storage Volume of Straw Palace: 4,000 tons
Average Bale Weight: 1,000 lbs. (3' x 4' x 8' bale)
Average Truck Payload: 18.0 tons (2 x 6 x 3 bales)
Harvest Days per Week: 5 days/week
Annual Weeks of OGS Downtime: 4 weeks/yr
Payment to Landowner: $ 18.75 /acre/yr = $ 4.69 /ton
Cost to Owner for Building: $ 20,000
Total Cost of Storage Building: $ 62,000

Acres/mi.^2= 640
Mile Radius = 5 = total of 50,265 acres
70 = total of 9,852,035 acres
0.51%
22.6349206

Calculated Items:

Average Weekly Firing Rate: 4,167 tons/week
Maximum Storage Inventory Required: 164,286 tons
Minimum Number of Field Sheds Required: 365
Number of Sheds per Grower: 0.73
Number of Growers per Shed: 1.37
Total Acres Harvested per Year: 50,000
Average Acres per Grower: 100
Total Cost to Growers for Storage Buildings: $ 7,301,587
Total Cost for Storage Buildings: $ 22,634,921

		Harvest Month	Firing Month	Total Amount of Switchgrass Harvested				Amount of Switchgrass Harvested per Grower					Total Storage Inventory *		Storage Inventory per Grower			
	Month	**(Y/N)**	**(Y/N)**	Acres	Bales	Tons	Truckloads	Acres	Acres/day	Bales	Tons	Truckloads	Tons	Weeks	Bales	Tons	Truckloads	Days/montl
1	January	N	Y	-	-	-	-	-	-	-	-	-	127,381	30.6	510	254.8	14.2	31
2	February	N	Y	-	-	-	-	-	-	-	-	-	110,714	26.6	443	221.4	12.3	28
3	March	N	Y	-	-	-	-	-	-	-	-	-	92,262	22.1	369	184.5	10.3	31
4	April	N	Y	-	-	-	-	-	-	-	-	-	74,405	17.9	298	148.8	8.3	30
5	May	N	Y	-	-	-	-	-	-	-	-	-	55,952	13.4	224	111.9	6.2	31
6	June	N	Y	-	-	-	-	-	-	-	-	-	38,095	9.1	152	76.2	4.2	30
7	July	N	Y	-	-	-	-	-	-	-	-	-	19,643	4.7	79	39.3	2.2	31
8	August	N	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31
9	September	Y	Y	16,667	133,333	66,667	3,704	33	1.6	267	133	7	48,810	11.7	195	97.6	5.4	30
10	October	Y	N	16,667	133,333	66,667	3,704	33	1.5	267	133	7	115,476	27.7	462	231.0	12.8	31
11	November	Y	Y	16,667	133,333	66,667	3,704	33	1.6	267	133	7	164,286	39.4	657	328.6	18.3	30
12	December	N	Y	-	-	-	-	-	-	-	-	-	145,833	35.0	583	291.7	16.2	31
	Totals			**50,000**	**400,000**	**200,000**	**11,111**	**100**		**800**	**400**	**22**						**365**

* End of month inventory

Possible Graphs/Charts

1 harvesting duration vs. storage shed $$ (plot lines for 50, 100, 150, and 200 kton/yr)
2 harvesting duration vs. # storage sheds (plot lines for 50, 100, 150, & 200 kton/yr)
3 same as 1 plot only 200 kton /yr, vary fraction covered storage
4 same as 2 plot only 200 kton /yr, vary fraction covered storage
5 same as 1 plot only 200 kton /yr (plot lines for covered storage, pole barns, tarped storage)

Assuming 100% Harvested Switchgrass in Covered Storage

Harvest Duration (Months)	Storage Shed Cost (dollars in millions)			
	50,000	100,000	150,000	200,000
1	6.9	13.8	20.6	27.5
2	6.3	12.5	18.7	25.0
3	5.6	11.3	16.9	22.5
4	5.0	10.0	15.0	20.0
5	4.4	8.7	13.1	17.4
6	3.8	7.6	11.3	15.1
7	3.2	6.3	9.4	12.6
8	2.5	5.1	7.6	10.1

Assuming 100% Harvested Switchgrass in Covered Storage

Harvest Duration (Months)	No. of Storage Sheds				Growing Days
	50000	100000	150000	200000	
1	111	222	333	444	335
2	101	202	302	403	304
3	91	182	272	363	274
4	81	161	242	322	243
5	71	141	211	281	212
6	61	122	183	244	184
7	51	102	152	203	153
8	41	82	123	163	123

Assuming 200,000 tons/yr Consumption Rate

Harvest Duration (Months)	Storage Shed Cost (dollars in millions)				
	20%	40%	60%	80%	100%
1	5.5	11.0	16.5	22.0	27.5
2	5.0	10.0	15.0	20.0	25.0
3	4.5	9.0	13.5	18.0	22.5
4	4.0	8.0	12.0	16.0	20.0
5	3.5	7.0	10.5	13.9	17.4
6	3.0	6.1	9.1	12.1	15.1
7	2.5	5.0	7.6	10.1	12.6
8	2.0	4.0	6.1	8.1	10.1

Assuming 200,000 tons/yr Consumption Rate

Harvest Duration (Months)	No. of Storage Sheds				
	20%	40%	60%	80%	100%
1	89	178	266	355	444
2	81	161	242	322	403
3	73	145	218	290	363
4	64	129	193	258	322
5	56	112	169	225	281
6	49	98	146	195	244
7	41	81	122	162	203
8	33	65	98	130	163

Assuming 200,000 tons/yr Consumption Rate

Harvest Duration (Months)	Storage Shed Cost (dollars in millions)			
	Perm. CS	Pole Barn	Pole Barn w/ Reinforce	Tarped
1	27.5	13.8	22.2	1.3
2	25.0	12.5	20.2	1.2
3	22.5	11.3	18.2	1.1
4	20.0	10.0	16.1	0.9
5	17.4	8.7	14.1	0.8
6	15.1	7.6	12.2	0.7
7	12.6	6.3	10.2	0.6
8	10.1	5.1	8.2	0.5

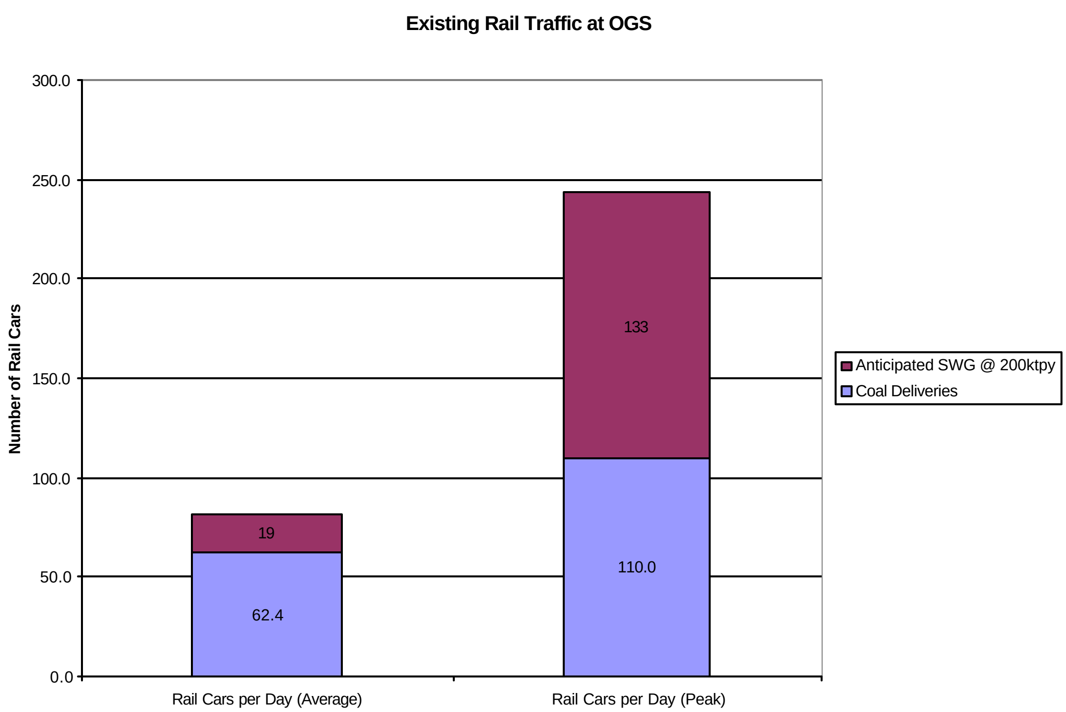
APPENDIX E. Railcar Delivery Comparison

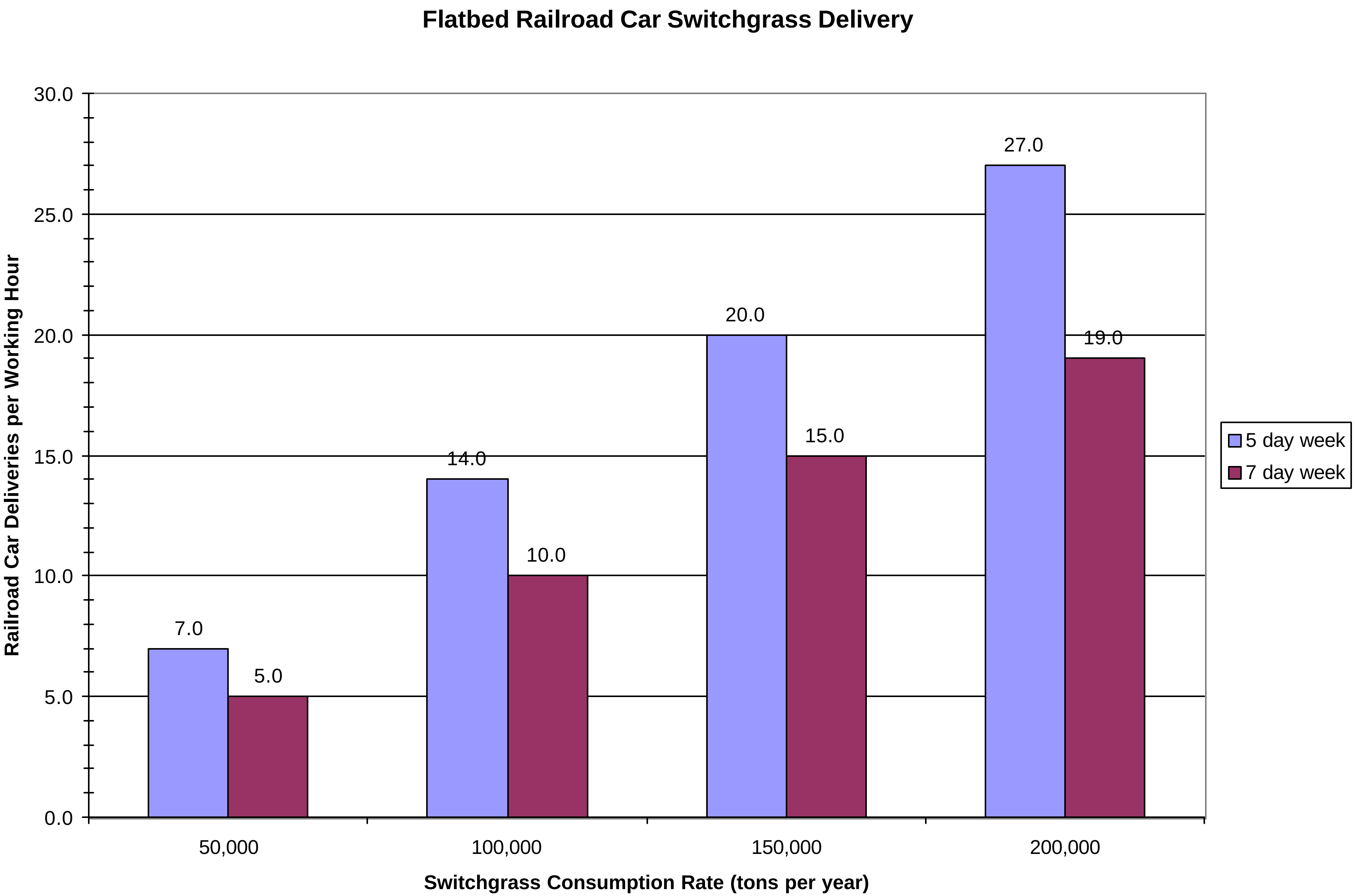
As noted in section 3.2, coal is delivered to OGS via rail. The low sulfur bituminous coal is delivered to OGS four times a week by rail in 110-car unit trains. The only rail spur at the present time into OGS is utilized for coal deliveries. The end of the rail line ends near the rotary dump facility, which is the staging area for coal processing and close to the point where coal is loaded for truck deliveries.

If switchgrass were to be delivered by rail, rail alterations at OGS would need to be performed in order not to cause any delays with coal deliveries or problems with the existing operation. A rail spur would need to be installed for switchgrass deliveries. The final destination would likely be the Straw Palace or another large storage facility because the train might impede traffic on-site if the cars went directly towards the proposed processing facility.

Railroad cars are capable of delivering large square baled switchgrass. Flatbed rail cars can handle 14 more tons of switchgrass per rail car than a single flatbed truck (FreightCar.com, 2001). The typical bale arrangement would be eight bales long (8' dimension), two bales wide (4' dimension), and four bales high (3' dimension). The deliveries of switchgrass by rail cars would not have to be as frequent as the truck deliveries from the farmers, but another large storage facility sized at least as large as the Straw Palace will need to be constructed to unload all the cars within the train.

The bar chart below shows the level of existing train traffic at OGS and the anticipated rise in traffic if switchgrass was delivered on rail. The peak traffic for switchgrass deliveries is the amount of rail cars required for a single train weekly delivery. The peak traffic for coal is the 110-car train that is delivered four times per week. The average traffic is calculated by totaling the sum of the volume for the week and dividing the total by the number of days per week.




Flatbed Railroad Car Switchgrass Delivery
Railroad Car Deliveries per Working Hour
Switchgrass Consumption Rate (tons per year)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
50,000
100,000
150,000
200,000
7.0
5.0
14.0
10.0
20.0
15.0
27.0
19.0
5 day week
7 day week

APPENDIX F. Labor Requirement Calculations

Determination of the number of contract workers required to establish SWG stand

Assumptions	Value	Notes:
SWG consumption (tons / yr)	200000	
DM loss in storage (%)	0	
SWG yield (tons / acre)	4	
Length of planting season (number of days)	30	(6 - 5 day weeks from 10/15 to 11/30)
Average time of working day (hours)	8	
Size of Disk (feet)	21	
Size of Seeder (feet)	20	
Size of Sprayer	30	
Given		
Effective Field Capacity for Disk (acres / hour)	12.7	
Effective Field Capacity for Harrowing (acres / hour)	15.1	
Effective Field Capacity for Sprayer (acres / hour)	14.2	
Effective Field Capacity for Seeder (tons / hour)	8.5	
Calculated Results		
No. of manhours required for disking	3,937	
No. of manhours required for harrowing	3,311	
No. of manhours required to spray pesticide, herbicide	3,521	
No. of manhours required to seed (and apply fertilizer)	5,882	
Total No. of manhours required for establish SWG stand	16,652	
Min. No. of people required to establish SWG stand	70	
Max. no. of days required to disk w/ min. crew size	7.0	
Max. no. of days required to harrow w/ min. crew size	5.9	
Max. no. of days required to spray w/ min. crew size	6.3	
Max. no. of days required to seed w/ min. crew size	10.5	

References:

Hanna, Mark, George Ayres, and David Williams; "Machinery Management: Estimating Field Capacity of Farm Machines"; Iowa State University Extension PM 696, April 2001.

Determination of the number of contract laborers required to produce SWG annually

Assumptions	Value	Notes:
SWG consumption (tons / yr)	200000	
DM loss in storage (%)	0	
SWG yield (tons / acre)	4	
Length of planting season (number of days)	30	(6 - 5 day weeks from 4/1 to 5/15)
Average time of working day (hours)	8	
Size of Sprayer	30	
Given		
Effective Field Capacity for Liquid N2 Spreader (acres / hour)	14.2	
Effective Field Capacity for Applying P&K (acres / hour)	15.1	
Effective Field Capacity for Sprayer (acres / hour)	14.2	
Calculated Results		
No. of manhours required for spreading liquid N	3,521	
No. of manhours required for applying P&K	3,311	
No. of manhours required to spray pesticide, herbicide	3,521	
Total No. of manhours required for establish SWG stand	10,354	
Min. No. of people required to establish SWG stand	44	
Max. no. of days required to disk w/ min. crew size	10.0	
Max. no. of days required to harrow w/ min. crew size	9.4	
Max. no. of days required to spray w/ min. crew size	10.0	

References:

Hanna, Mark, George Ayres, and David Williams; "Machinery Management: Estimating Field Capacity of Farm Machines";
Iowa State University Extension PM 696, April 2001.

Determination of the number of contract harvesters required

Assumptions	Value	Notes:
SWG consumption (tons / yr)	200000	
DM loss in storage (%)	0	
SWG yield (tons / acre)	4	
Length of harvest season (number of days)	60	(12 - 5 day weeks from 9/1 to 11/30)
Average time of working day (hours)	8	
Size of Rotary Mower-Conditioner (feet)	9	
Size of Rake (feet)	9	
Type of Baler	Lg. Rect.	
Given		
Effective Field Capacity for Mower-Conditioner (acres / hour)	6.3	
Effective Field Capacity for Rake (acres / hour)	5.4	
Effective Field Capacity for Baler (tons / hour)	12	
Calculated Results		
No. of manhours required to mow SWG	7,937	
No. of manhours required to rake SWG	9,259	
No. of manhours required to bale SWG	16,667	
Total No. of manhours required for harvesting SWG	33,862	
Min. No. of people required to harvest SWG	71	
Max. no. of days required to mow w/ min. crew size	14.0	
Max. no. of days required to rake w/ min. crew size	16.3	
Max. no. of days required to bale w/ min. crew size	29.3	

References:

Hanna, Mark, George Ayres, and David Williams; "Machinery Management: Estimating Field Capacity of Farm Machines"; Iowa State University Extension PM 696, April 2001.

Estimate the number of trucks / drivers to transport SWG from fields to storage

Time frame	30	days
Tons / truck	21	
Tons / yr	200,000	
% to Storage	81.8%	
Tons to Storage / yr	163,636	
Truck to Storage / yr	7,792	
Trucks / day to Storage	260	
Time req'd per delivery	0.75	hours
Delivery Time / day	8	hours
Deliveries / day	10.7	
Truck Drivers required	24	
Non-Harvest Season Operations		
Tons / day to OGS	840	
Time req'd per delivery	1.5	hours
Trucks / day to OGS	40	
Deliveries / day	5	
Truck Drivers required	8	
Time Required to unload Truck	0.75	hours
Time Required to load Trailer	0.25	hours
Loaders required during harvest	9.0	
Loaders required during non-harvest	2.0	
Unloaders Required during harvest	25.0	

APPENDIX G. Life Cycle Cost Calculations

LIFE CYCLE COST WORKSHEET

PROJECT DESCRIPTION:

Agency Name: Antares Group
Project Title: Iowa Switchgrass
Project Code: 8016

ALTERNATIVE DESCRIPTION

Alternative Number: Base System
Alternative Description: Manual Unloading System - 25 tph

	a	b	c	d	e	f	f	h	i= gxh
	Escalated Costs, By Category, By Year						g= (a+b+c+d+e)-	PRESENT WORTH DISCOUNT	
	Specify annual escalation rates used for each cost category below.	0.0%	0.0%	0.0%	0.0%	0.0%			
YEAR	INITIAL CAPITAL COST	REPLACEMENT COST	FUEL / ENERGY COST	LABOR OPERATING COST	MAINT. & REPAIR COST	SALVAGE VALUE	TOTAL ESCALATED COST	FACTOR AT 8% PER ANNUM	TOTAL PRESENT VALUE
1	$ 13,846,500	$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 15,203,528	1.000	$ 15,203,528
2		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.926	$ 1,256,507
3		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.857	$ 1,163,433
4		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.794	$ 1,077,253
5		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.735	$ 997,456
6		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.681	$ 923,570
7		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.630	$ 855,158
8		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.583	$ 791,813
9		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.540	$ 733,160
10		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.500	$ 678,852
11		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.463	$ 628,566
12		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.429	$ 582,006
13		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.397	$ 538,894
14		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.368	$ 498,976
15		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.340	$ 462,015
16		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.315	$ 427,792
17		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.292	$ 396,104
18		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.270	$ 366,763
19		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.250	$ 339,595
20		$ -	$ 330,098	$ 750,000	$ 276,930	$ -	$ 1,357,028	0.232	$ 314,440
Total Present Value Life Cycle Cost (sum of column "i")									$ 28,235,880

LIFE CYCLE COST WORKSHEET

PROJECT DESCRIPTION:

Agency Name: Antares Group
Project Title: Iowa Switchgrass
Project Code: 8016

ALTERNATIVE DESCRIPTION

Alternative Number: Alternate #1
Alternative Description: Automated Crane System - 25 tph

	a	b	c	d	e	f	f	h	i= gxh
	Escalated Costs, By Category, By Year						g= (a+b+c+d+e)-	PRESENT WORTH DISCOUNT	
	Specify annual escalation rates used for each cost category below.	0.0%	0.0%	0.0%	0.0%	0.0%			
YEAR	INITIAL CAPITAL COST	REPLACEMENT COST	FUEL / ENERGY COST	LABOR OPERATING COST	MAINT. & REPAIR COST	SALVAGE VALUE	TOTAL ESCALATED COST	FACTOR AT 10% PER ANNUM	TOTAL PRESENT VALUE
1	$ 15,308,900	$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 16,199,818	1.000	$ 16,199,818
2		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.926	$ 824,925
3		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.857	$ 763,819
4		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.794	$ 707,240
5		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.735	$ 654,852
6		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.681	$ 606,344
7		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.630	$ 561,430
8		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.583	$ 519,842
9		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.540	$ 481,336
10		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.500	$ 445,681
11		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.463	$ 412,668
12		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.429	$ 382,100
13		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.397	$ 353,796
14		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.368	$ 327,589
15		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.340	$ 303,323
16		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.315	$ 280,855
17		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.292	$ 260,051
18		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.270	$ 240,788
19		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.250	$ 222,951
20		$ -	$ 359,740	$ 225,000	$ 306,178	$ -	$ 890,918	0.232	$ 206,437
Total Present Value Life Cycle Cost (sum of column "i")									$ 24,755,842