

Duluth Energy Systems Biomass-Fired Thermal Energy Preliminary Design

Attachments: (1) Sawdust Test Burn Report
(2) Biomass Fuel Type Feasibility Study
(3) Sawdust – Hammer Mill Test Results
(4) Preliminary Hot Gas Generator Concept Description
(5) Baghouse Soil Boring Report
(6) Pulverizer Soil Boring Report

1. INTRODUCTION & OBJECTIVES

Duluth Energy Systems (DES) is a municipal district heating system, owned by the City of Duluth and operated by Ever-Green Energy, Inc. Thermal energy production is accomplished at the DES plant located at the intersection of Interstate I-35 and Lake Ave in the Canal Park area of the city. Additional system information may be found at:

<http://www.duluthenergysystems.com/wp-content/uploads/2015/02/Duluth-Energy-Transformation.pdf>

Four identical 1932 Edge Moore water tube pulverized coal boilers are operated at 225 psig to provide steam for the plant's machinery turbines (coal pulverizers, forced draft fans, induced draft fans and feed pumps). The majority (80 percent) of this "main steam" is reduced to 130-150 psig for distribution to the system's 175 customers through eleven miles of direct-buried pipe. Turbine exhaust steam at a pressure of 4 psi is used by the plant's feed water heaters and by steam-to-water heat exchangers for the closed-loop hot water district heating system serving customers on the South side of I-35 (Canal Park and the Duluth Entertainments & Convention Center – DECC).

Steam demand varies from over 225,000 lbs steam / hour (225 klbs/hr = 269 million Btu/hour) in the winter to less than 30 klbs/hr (36 mmBtu/hr) during the summer months (including the plant's parasitic load).

Approximately one third of the system (on an annual thermal energy consumption basis) is to be retrofitted from single-pipe steam distribution to closed-loop hot water distribution over the next three years.

The plant consumes approximately 50,000 (short) tons of sub-bituminous coal annually. Two of the four boilers are configured to burn either natural gas or coal. On average, approximately 700 lbs of steam is generated per mmBtu fuel input.

The objective of this project is:

- a. Replace 25 percent (on an annual Btu basis) of the plant's annual coal consumption with renewable, biomass-derived fuel.**

The method for meeting this objective has not been pre-determined and is left to the Offeror to determine. Determination of the most promising biomass-fueled steam generation solution is the goal of the preliminary design task solicited herein. Acceptable solutions may include, but are not limited to:

- a. Installation of efficient stand-alone biomass boiler(s).
- b. Modification of existing boiler(s) to efficiently fire biomass.
- c. Installation of a biomass gasification system which can be used to fire or co-fire new or existing boiler(s).
- d. Installation of biomass-fired hot gas generator(s) to be used as the heat source in existing boiler(s) to efficiently generate steam.

- e. Identification of an affordable source of a biomass-based fuel with coal-like properties which could be fired or co-fired in existing boilers with minor modifications to the solid fuel handling systems.

2. DELIVERABLES

The deliverables for this project are:

- a. A report describing the recommended solution which satisfies the objective of replacing 25% of coal fuel with biomass fuel.
- b. Preliminary design of the required modifications or new installations at the DES plant to include renderings of any significant modifications to the existing boilers, exterior of the DES plant and surrounding property.
- c. An estimate (plus or minus 25%) of the total project capital costs (exclusive of additional design costs) and an explanation of the data and assumptions used in development of this estimate.
- d. An estimate (plus or minus 25%) of annual operating costs over a 20-year system lifecycle and an explanation of the data and assumptions used in to development of this estimate.
- e. An estimate (plus or minus 10%) of the additional design costs to complete detailed design and to produce bid specifications for the construction of the proposed solution.
- f. A presentation to Ever-Green Energy and City of Duluth staff providing a case for the follow-on detailed design and construction of the offeror's proposed solution.

3. SCHEDULE

Solicitation	July 19, 2016
Optional Site Tour for Potential Offerors	July 25, 2016
Written Proposals Due	August 19, 2016
Offerors' Presentations (by invitation)	Week of August 29, 2016
Contract Award	September 15, 2016
Deliverables Due	October 7, 2016
Design Presentation(s).....	Week of October 10, 2016

4. REQUIRED PROPOSAL CONTENT

Proposals shall consist of:

- a. A brief description of the proposed solution on which the Offeror's Preliminary Design will be based. This section of the proposal shall include a summary of all options considered and the rational for selection of the proposed solution. This section of the proposal is limited to ten (10) pages of text and up to five (5) additional pages for figures, photographs, etc.
- b. A five (5) page (maximum) summary of projects the Offeror has been involved – and the specific experiences, knowledge and lessons-learned from those past projects which will be brought to bear on this project.
- c. A two (2) page (maximum) summary of the qualifications of the specific individuals who comprising the Offeror's project team and the respective roles of each individual assigned to the team.
- d. The Offeror's total proposed "Not to Exceed" price for the deliverables described in Section 3.

Note: Although not encouraged, Offerors may submit multiple proposals, (one solution per proposal) if unable to identify a clearly superior alternative during the proposal preparation process.

5. SELECTION CRITERIA

Proposals will be evaluated using the following criteria:

- a. The project objective identified in Section 1 is satisfied. (Pass / Fail)
- b. The Offeror's proposed solution adequately addresses design constraints as presented herein; as well as additional constraints or considerations identified by the Offeror. (30%)
- c. The level of innovation and creativity demonstrated by the Offeror in minimizing the estimated lifecycle cost of the proposed solution. The lower-cost, 20-year, functional, safe, no-frills solution will trump the more costly, 40-year, bells and whistles solution. (30%)
- d. Technical expertise and experience of the Offeror's project team as related to the proposed solution. (15%)
- e. Proposed cost for Preliminary Design deliverables. (25%)

Based on the evaluation of written proposals, Offeror(s) may be invited to present their proposal(s) to Ever-Green Energy and City of Duluth staff.

More than one Offeror may be selected to complete preliminary design of its proposed solution.

6. DESIGN ASSUMPTIONS, CONSTRAINTS and BACKGROUND INFORMATION

- a. Assumptions. The following assumptions shall be used by all Offeror's (as applicable to the proposed solution):
 - i. Existing boilers generate 700 lbs of steam per million Btu fuel input.
 - ii. Plant efficiency is 60% when boiler(s) are fired on coal at a boiler steam generation rate of 45 klbs/hr (the maximum practical firing rate on sub-bituminous coal). Plant efficiency decreases by 0.5% for each 5 klbs/hr decrease in boiler load below 45 klbs/hr per boiler. This loss of total plant efficiency increases boiler fuel consumption only; electricity consumption is not impacted.

For example: Firing two existing boilers at 30 klbs / hour to meet a total steam demand of 60 klbs/hr would result in a plant efficiency decrease of 3% to 57%.

- iii. Average total steam demand (klbs/hr):

MONTH	AVERAGE (klbs/hr)	MONTH	AVERAGE (klbs/hr)
JAN	165	JUL	40
FEB	170	AUG	40
MAR	135	SEP	45
APR	80	OCT	60
MAY	60	NOV	95
JUN	45	DEC	130

- iv. Biomass system useful service life: 20 years
- v. The biomass system will be operated year-round in all typical Duluth weather conditions.

- vi. Coal Cost: \$50 per ton (9,000 Btu/lb)
 - vii. Natural Gas Cost: \$4.15 / mmBtu
 - viii. Electricity Cost: \$0.08 / kWh
 - ix. Coal Ash Disposal Cost: \$45 per ton (coal ash content = 6% by weight)
 - x. Biomass Ash Disposal Cost: \$20 per ton
 - xi. DES plant operations labor rate: \$70 per hour (fully-burdened)
 - xii. Local skilled trades hourly labor rates (journeyman, union shop, fully burdened):

Pipefitters	\$95
Electricians	\$100
Boiler Maker	\$100
Outside Machinists	\$85
Sheet Metal Workers	\$80
Insulators	\$115
Asbestos Abatement	\$115
 - xiii. Annual cost escalation rates (adjusted for inflation):

Maintenance, Labor and Materials (fixed costs)	1.0%
Fuel, Energy, Water, chemical (variable costs)	0.5%
 - xiv. Soil and geotechnical conditions in and around the DES plant are assumed to be similar to the conditions described in Attachments (5) and (6).
 - xv. All thermal insulation within the DES plant is assumed to contain asbestos.
- b. Constraints. The proposed solution will be bounded by the following constraints:
- i. Fuel Delivery, Handling and Storage.
 - 1) Biomass shall be delivered to the plant in pre-weighed quantities by truck (i.e. proposed solutions need not include an on-site truck scale).
 - 2) The biomass receiving area shall be located on the West side of the plant.
 - 3) The coal receiving (and coal ash loading) areas shall remain at their current location on the East side of the plant.
 - 4) Fuel storage capacity shall be sufficient to support 24 hours of steam generation at the rate of 30 klbs steam per hour.
 - 5) Fugitive dust containment, explosive dust hazard and fire hazard mitigation shall be addressed by the proposed solution.
 - ii. Ash Handling.
 - 1) If advantageous for any reason, the solution may incorporate use of the existing pneumatic ash transfer system and the existing steel ash silo for biomass ash conveyance and storage (provided coal and biomass ash remain segregated for disposal).

iii. Plant Property Arrangement.

- 1) The plant is located at 1 Lake Place Drive, Duluth, MN. The legal description of the property is:

PARCEL ID: 010-2480-00774

TITLE HOLDER: CITY OF DULUTH MUNIC CORP

PLAT: INDUSTRIAL DIV OF DULUTH BLKS 1 & 2

LOTS 16 18 AND 20 EX HWY RT OF WAY INC PT OF VAC RAILROAD ST ADJ LOT 20

- 2) The arrangement of the site is as shown in Figures 1 and 2. Any proposed biomass receiving, storage, combustion and emission control equipment shall be contained inside the existing plant or in the area currently used for parking on the West side of the plant (within the yellow bordered area).

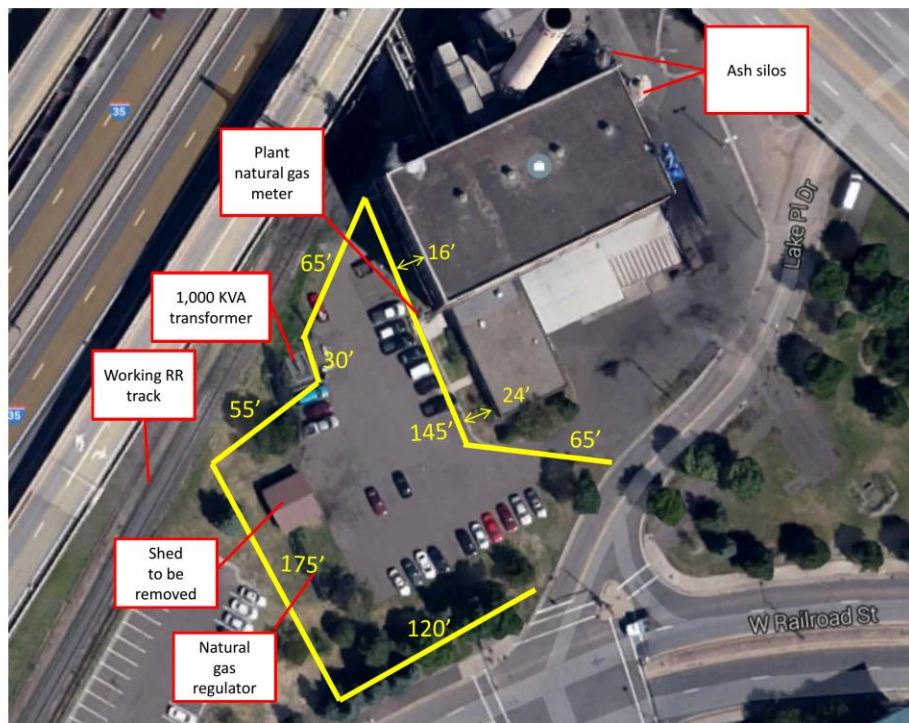


Figure 1 – Aerial view of plant property



Figure 2 – View from West looking East

- 3) The arrangement of the lower (ground) floor of the existing plant is shown in Figure 3 below. The general location of the existing ash collection system is shown with a vacuum pump located in the Northeast corner of the baghouse drawing bottom ash from the boiler fireboxes, fly ash from the boiler multi-clone hoppers and particulate from the baghouse hoppers. The only area on the ground floor of the plant which has space available for the installation of additional equipment is a 10 ft by 30 ft area to the West of Boiler #1. See Figures 3 and 4.

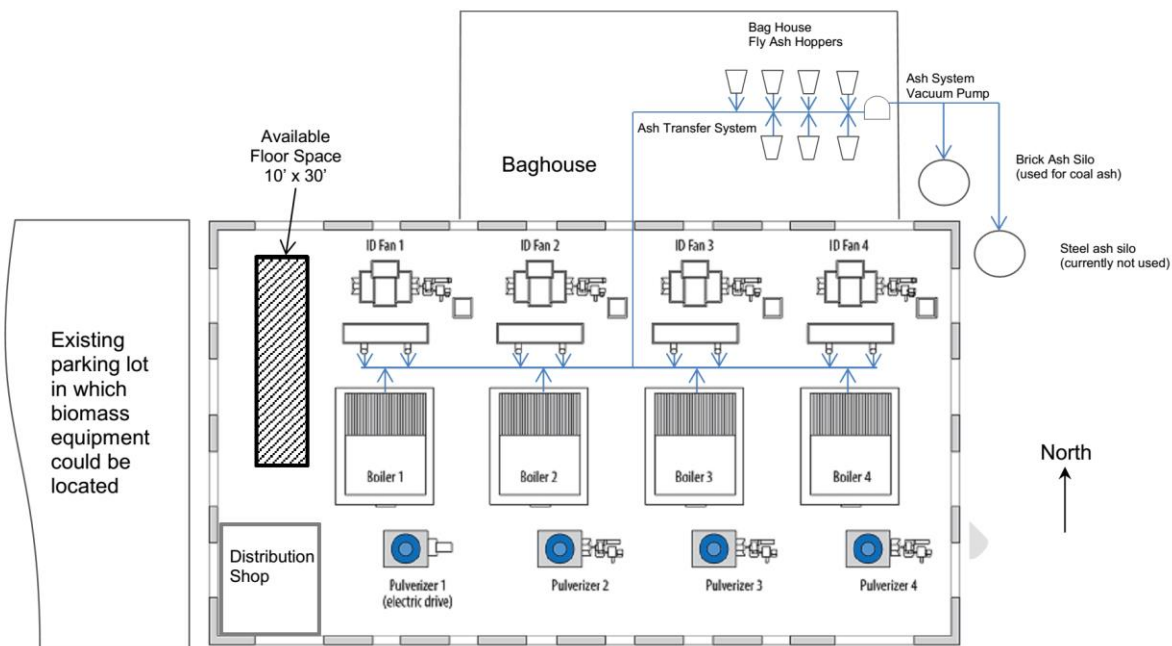


Figure 3 – Plant ground floor



Figure 4 – Empty floor area on ground floor of plant. Photo taken from North wall looking to the South.

- 4) The arrangement of the upper (Operating) floor of the existing plant is shown in Figure 5. The only area on the Operating Floor with space available for the installation of additional equipment is a 40 ft by 15 ft area to the West of Boiler #1. See Figures 5 and 6.

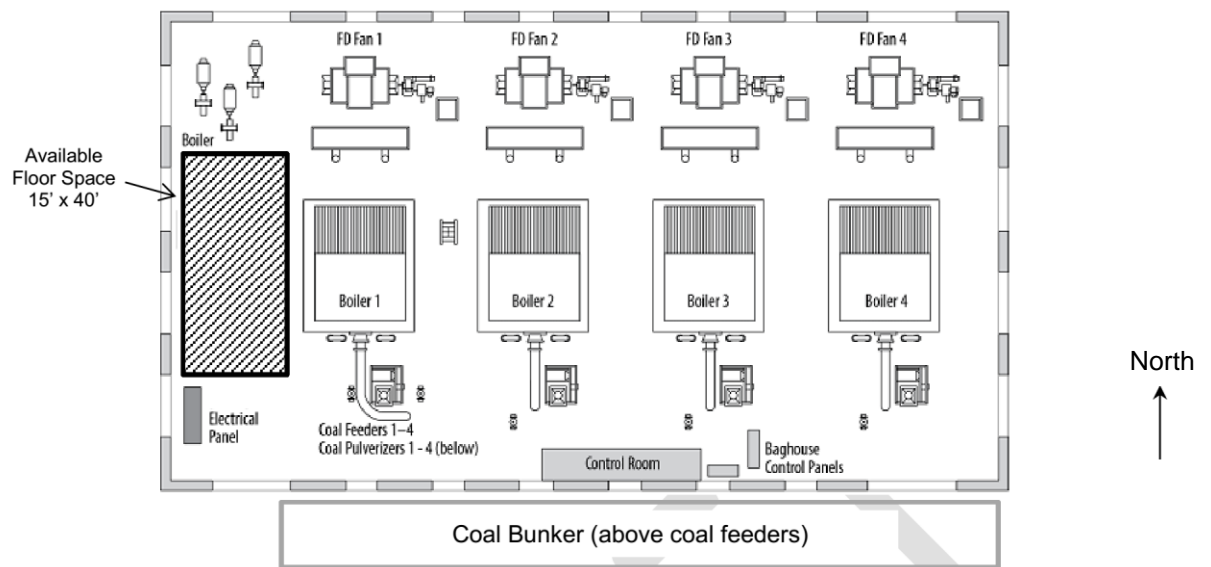
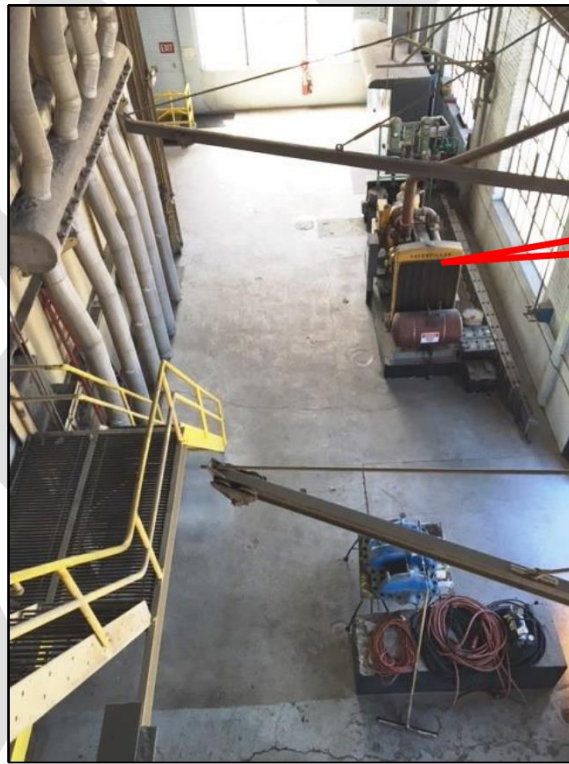


Figure 5 – Operating Floor



Emergency
Generator
(to be removed)

Figure 6 – Empty floor area operating floor. Photo taken from North wall looking to the South from the feedwater heater platform.

c. Background Information.

- i. The Duluth Energy Systems plant produces steam in four (4) Edge Moore Iron Company 4-drum, water tube, saturated steam, pulverized coal-fired boilers originally rated for 90,000 lb/hr at 235 psi. The boilers each have a heating surface of 8,505 ft² and a Maximum Allowable Working Pressure of 425 psi. Each boiler has a dedicated coal pulverizer, Induced Draft Fan and Forced Draft Fan. The boilers are numbered 1-4 from West to East.
- ii. Originally designed to burn bituminous coal, the boilers have been fired with subbituminous (Powder River Basin) coal since the late 1980s. The maximum output of each boiler is 45,000 lbs / hr when fired with subbituminous coal (induced draft limited). As detailed in Section 6.a.ii. of this solicitation, overall plant efficiency could be improved by the addition of efficient steam generation capability at firing rates less than 45,000 lbs/hr; thereby allowing existing boilers to be operated exclusively at higher, more efficient coal-firing rates.
- iii. Each boiler has two coal burners. The boilers operate at a slightly negative pressure (0.1" water column) with respect to atmospheric pressure. Bottom ash collects on a hinged false firebox floor and is then "dumped" to the ash collection area at the bottom of the firebox. Bottom ash is manually "pulled" from the boiler to the ash conveyance system at least once per day. The boilers are equipped with air preheaters but do not have feed water economizers. The boiler fireboxes are protected with water wall tubes on the side and rear walls. Figure 7 shows the boiler cross-section and the combustion gas flow path through the boiler. The 1930 boiler construction drawings can be made available to offerors upon request.

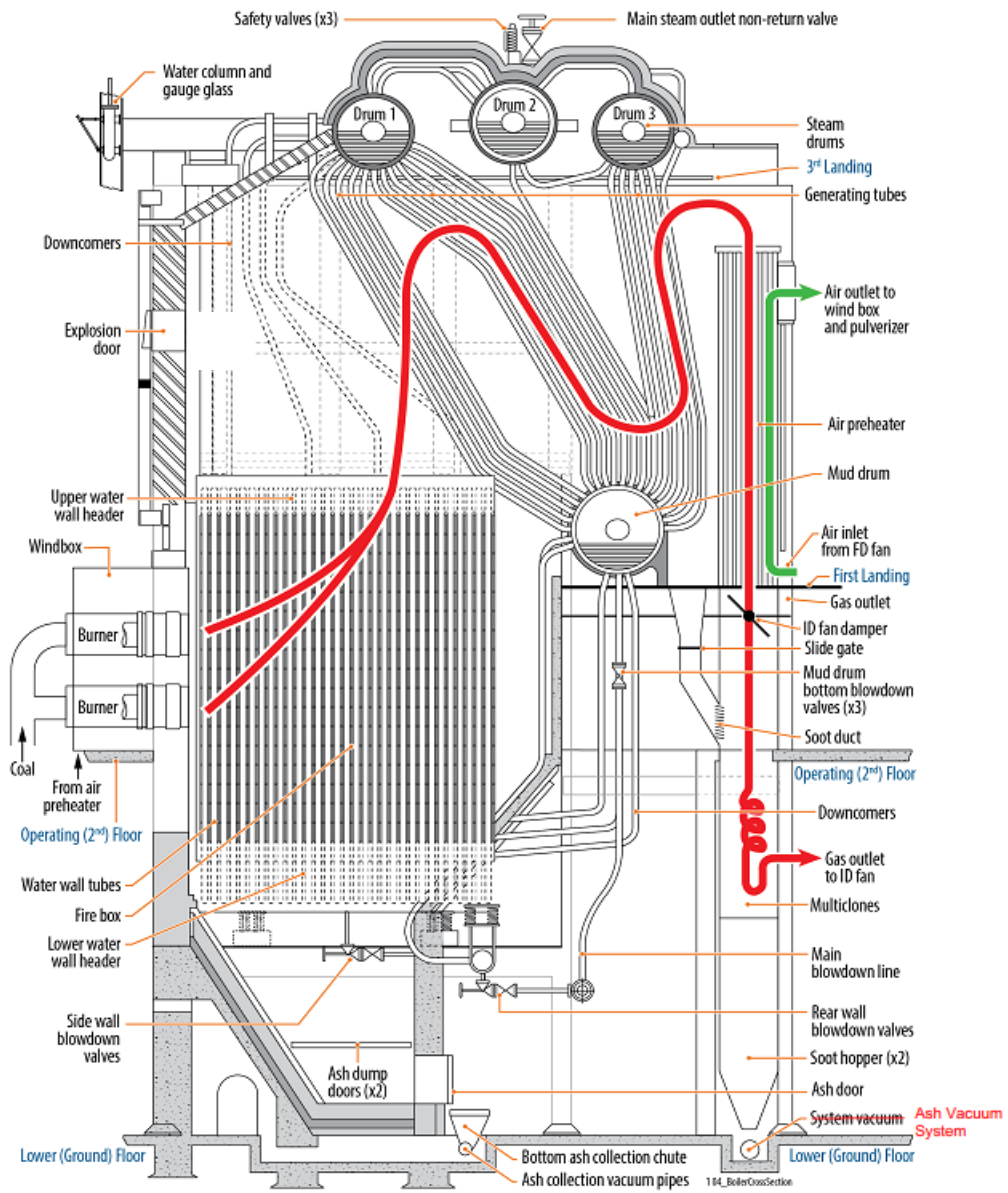


Figure 7 – Boiler cross-section.

- iv. Coal is delivered by 42 ft end-dump trucks to a receiving hopper on the East side of the plant and is then transferred into a bucket elevator for delivery to the bunker (see Figure 8). A conveyor and tripper car system distributes coal to eight separate bins within the bunker.

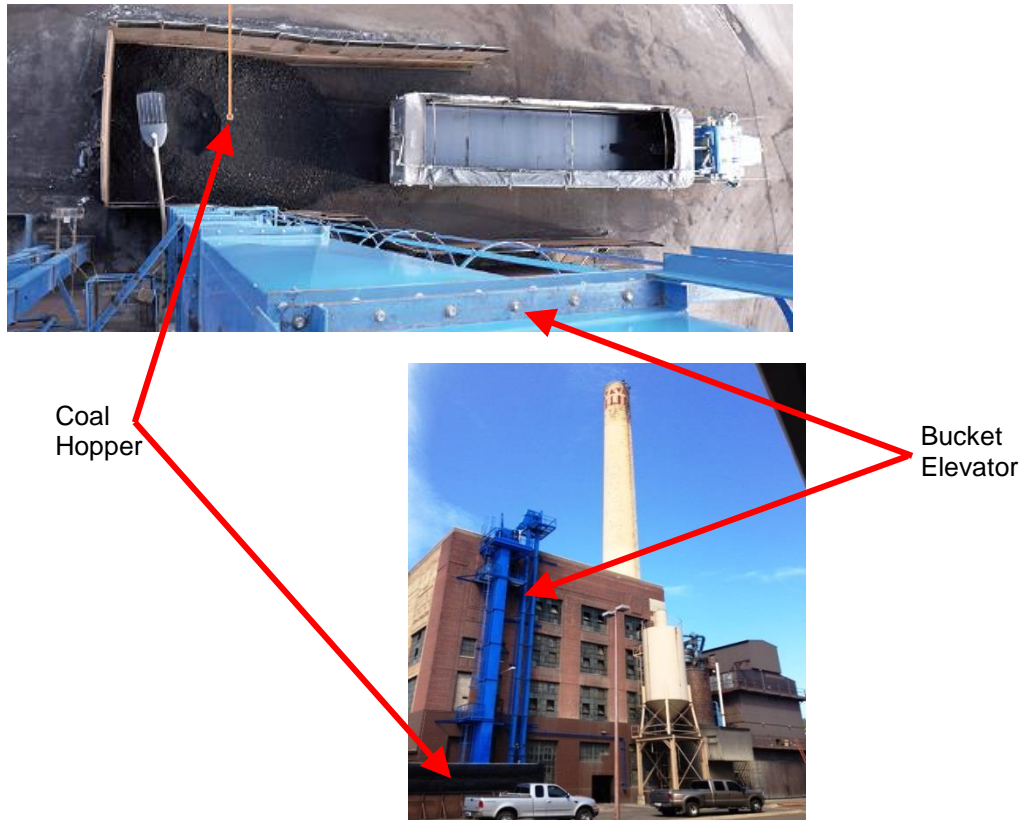


Figure 8 – Coal receiving hopper and bucket elevator.

- v. The rate at which raw coal from the bunker is supplied to each pulverizer is controlled by a rotary feeder. Each boiler is served by a dedicated Combustion Engineering – Raymond Model RB-473 steep-sided bowl mill. The integral pulverizer exhausters are straight blade radial fans which blow the hot air and pulverized coal mixture up to the boiler burners through the coal pipe. A riffle box is installed in the coal pipe to evenly distribute the fuel flow to each of the two burners (see Figure 9).

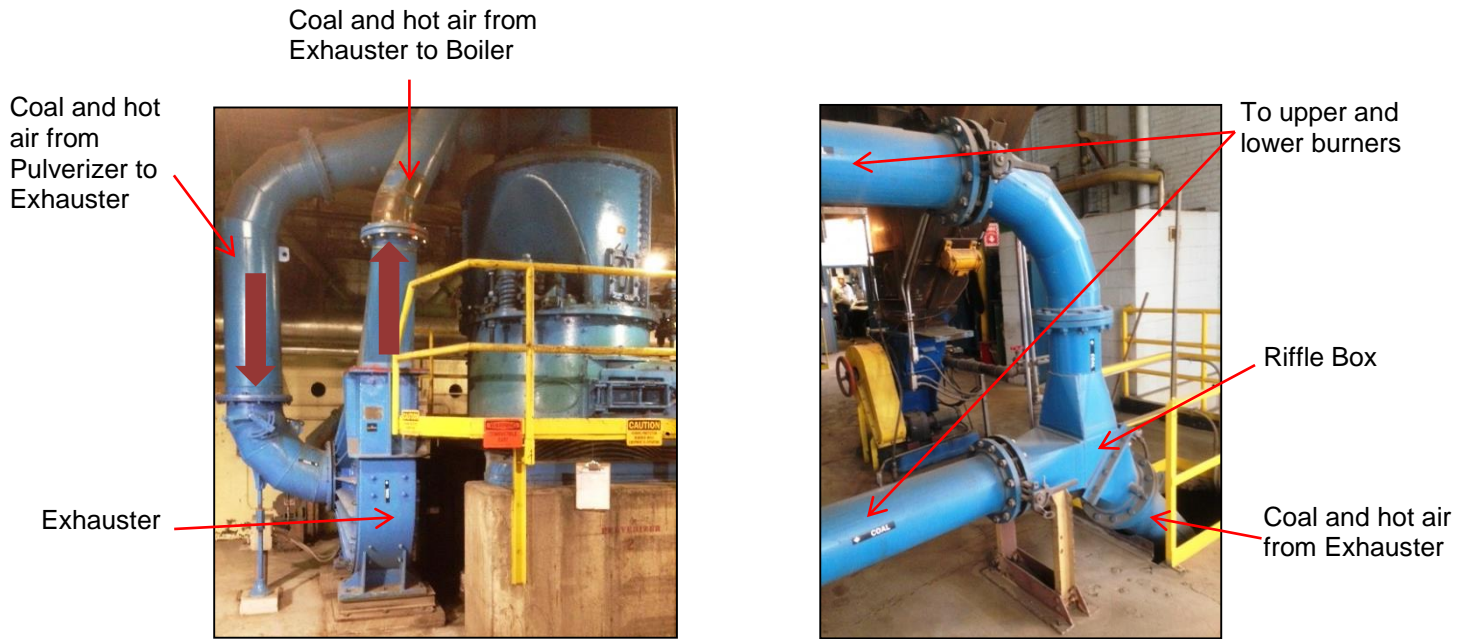


Figure 9 – Pulverized coal flow through Exhauster and to Boiler

vi. Existing Utility Service.

- 1) A 1,000 kVA transformer located on the West edge of the property (see Figure 1) provides 60 Hz, 480V, 3-phase electrical service. The plant's peak electrical demand in 2015 was approximately 775 kVA. A 1,000 kW diesel emergency generator is installed.
- 2) Natural Gas is supplied to the plant at 30 psig from a pressure regulator located on the Western edge of the property, (see Figure 1).
- 3) City water is supplied at 100 psig from a supply main which runs outside and parallel to the west side of the plant. An ion exchange system is used to soften the water before it is introduced into the boiler feedwater system. Sufficient capacity exists to provide either softened 45° F city water or 260 psig, 250° F feed water to an additional boiler.
- 4) A schematic representation of known underground public and private utilities is provided as Figure 10. \

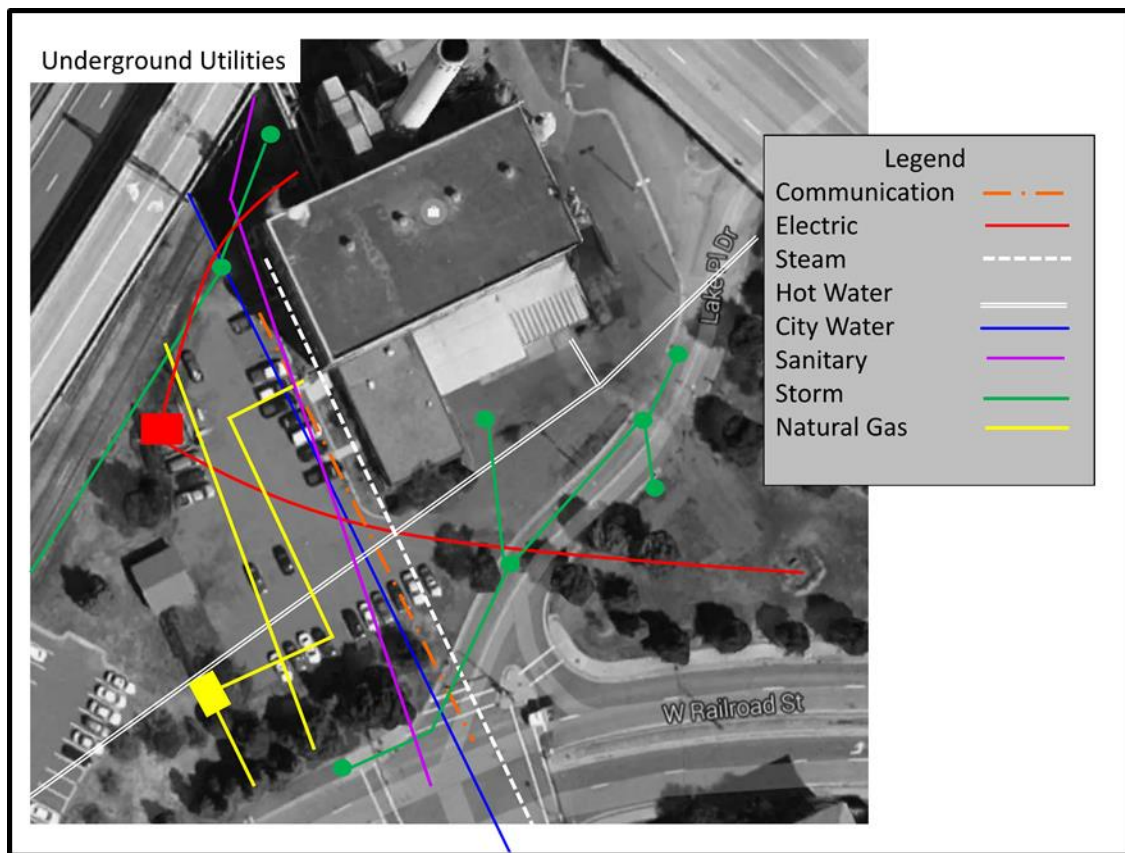


Figure 10 - Underground Utilities in the area of the Duluth Energy Systems plant

vii. Existing Emission Control System

- 1) A fabric filter baghouse is installed to remove airborne particles from boiler flue gas before it enters the smokestack. The baghouse is designed for a maximum flowrate of 160,200 cfm (three of the existing coal boilers at full load) at a maximum operating temperature of 460° F (340° F / 550° F min / max). A reverse gas flow system and sonic horns are used to clean the fabric filter bags.
- 2) A solution which safely and efficiently utilizes the existing baghouse and stack for the filtering of biomass flue gas is acceptable.

viii. Existing Ash Conveyance, Storage and Unloading Systems

- 1) A vacuum pump-powered pneumatic ash conveyance system is used to convey coal bottom and fly ash from the boiler fireboxes, multi-clone hoppers and baghouse hoppers to an ash storage silo.
- 2) Offerors may evaluate the feasibility of using the existing coal ash conveyance system for biomass ash handling.
- 3) The steel ash silo on the East side of the plant is currently not in use and is available for biomass ash storage.

ix. Local Contractors familiar with the Duluth Energy Systems plant.

The following contractors have worked in the Duluth Energy Systems plant in and are aware of this project and RFP. Offerors may choose (but are not required) to communicate with these or other contractors and suppliers in order to develop construction cost estimates.

- ACCT (asbestos abatement)
- A.W. Kettle (pipefitting, sheet metal, roofing electrical)
- Belknap Electric (electrical)
- JAMAR Company (mechanical, sheet metal, inside / outside machine shop, boiler pressure vessel and refractory)
- Power Products (boiler controls and appurtenances)
- Northern Engineering Company (inside / outside machine shop)
- Northern Industrial Insulation (thermal insulation)
- Stack Bros (mechanical, pipefitting)

x. Preliminary Biomass Investigations and Findings.

- 1) Sawdust was test fired in one of the plants existing boilers in 2010. The test report is provided as Attachment (1).
- 2) DES hired WSP Global, Inc. to study the feasibility of processing and burning various types of biomass in the existing boilers (green wood chips, sawdust, and pellets). Deliverables from that study are included as Attachment (2).
- 3) The most significant conclusions reached through these studies are:

- The successful “sawdust” test burn was accomplished using a spec fuel – an extremely dry wood flour manufactured expressly for the test burn. This fuel was selected to mitigate the risk of burning wood embers reaching the fabric filter baghouse. This will continue to be a design consideration for any proposed solution which incorporates the existing boilers or baghouse. Waste stream sawdust from a local pallet manufacturing facility was shipped to the Schutte-Buffalo factory where testing was performed to determine the minimum particle size that could be produced using hammer mills. The results of that testing are provided as Attachment (3). In general, the sawdust required drying before milling in order to obtain a particle size (1/16” hammer mill screen) anticipated (but not proven) to be small enough completely burn in suspension within the boiler before the flue gas reaches the baghouse. The capital and ongoing operating costs associated with the on-site processing of “green” sawdust for combustion in the existing boilers were deemed to be prohibitive.
- The existing bowl type coal pulverizers are not effective in processing traditional biomass fuel types (e.g. sawdust, chips, pellets). The pulverizers are designed for coal with a Hardgrove Grindability Index > 55. Although not actually confirmed at the DES plant, anecdotal evidence and published research suggests traditional biomass fuel types (including white wood pellets) will deform (but not be significantly reduced in size) and will then accumulate and clog this type of pulverizer. Again, the capital and ongoing operating costs associated with the on-site processing of standard woody biomass fuel for combustion in the existing boilers were deemed to be cost prohibitive at that time.
- The concept of ducting hot biomass combustion-generated flue gas into the existing boilers to generate steam was briefly explored but tabled due to concerns about potentially disrupting boiler water and steam circulation within the boiler. This may or may not actually be a problem; an Offeror proposing such a solution will be required to verify that existing boilers could be safely and efficiently operated in this configuration. Attachment (4) provides a description of the ducted hot gas concept as envisioned, but not fully studied by DES.

xi. Geotechnical and Plant Structural Considerations.

- 1) The existing plant was constructed in 1932. Historical photographs and drawings indicate wooden pilings were used under the ground floor slab.
- 2) The plant's baghouse and steel ash silo were installed in 1979. Soil test borings on these areas of the property were drilled and analyzed as part of the engineering effort for that project. The test report is provided as Attachment (5).
- 3) The coal pulverizers along the South wall of the ground floor were replaced in 1994. Soil test borings in this area of the plant were drilled and analyzed as part of the engineering effort for that project. The test report is provided as Attachment (6).
- 4) The plant's original structural construction drawings and related specifications can be made available to Offerors upon request.

xii. Air Emission Permitting

- 1) The Duluth Energy Systems plant is considered to be a major source under the Federal New Source Review Program and Federal Part 70 Program. Limits on the amount of coal burned have been accepted in order to maintain Hazardous Air Pollutants (HAP) emissions below the Major Source thresholds under the National Emission Standards for Hazardous Air Pollutants (NESHAP) program. The Minnesota Pollution Control Agency Air Emission Permit No. 13700022-005 allows biomass to be burned in existing boilers provided stated permit limits are met. The Air Emission Permit can be found at:

<http://www.pca.state.mn.us/index.php/view-document.html?gid=23434>

- 2) The following is a summary of selected existing air permit limits and 2015 Actual emissions:

LIMIT		2015 ACTUAL
Total Facility SO ₂	<1,039 tons/year (12-month rolling average)	248 tons
Total Facility NO _x	<594 tons/year (12-month rolling sum)	217 tons
Total Facility PM ₁₀	<19.9 tons/year (12-month rolling sum)	2 tons
Total Facility CO	<235 tons/year from wood (12-month rolling sum)	NA

Trial Results

Cofiring Wood Sawdust with Coal

By:

Tim Hagen
Coordinator

Kyle Bartholomew
Chemical Engineer

Brian Brashaw
Program Director

August 2010

Project Number: 1026 10417 20109 1000004091

Report Number: NRRI/TR-2010/17

Natural Resources Research Institute
University of Minnesota Duluth
5013 Miller Trunk Highway
Duluth, MN 55811

OBJECTIVE

To measure carbon monoxide (CO), carbon dioxide (CO₂), sulfur dioxide (SO₂), nitrogen oxide (NO), nitrogen dioxide (NO₂), oxygen (O₂) and mercury (Hg) during a cofire of approximately 25 percent dried, pulverized sawdust with coal. A secondary objective was to verify and monitor the nature and extent of sparklers within the combustion zone of the boiler.

BACKGROUND

The Natural Resources Research Institute (NRRI), in cooperation with SYLVA Corporation partnered together to explore biomass cofiring. Test facility pulverizes 56,000 tons per year of Powder River Coal to nominal 80 percent minus 200 mesh which is burned for energy in conventional suspension, coal-fired boilers.

SYLVA Corporation and its affiliate, Wood Chip of Princeton have been in the forest products business for over 11 years. In addition to landscape mulches, they produce bedding for the dairy and poultry industry, engineered wood fiber for playground surfacing, and prepared wood fuel

for alternative energy markets. SYLVA operates a 10 ton per hour (tph) wood chip dryer which provides premium dry wood chips to the biomass energy sector. Currently, SYLVA provides 40-50 truckloads per week of dry (<10% moisture content, dry weight basis) wood chips to the biomass energy sector. 70 percent of the capacity of their wood chip dryer has current markets, leaving potential opportunities for up to 12-15 truckloads/week for additional bioenergy markets.

An interest was expressed in cofiring dried, pulverized sawdust in boilers as an approximate 25% replacement for coal. The purpose of the project was:

- To gain a better understanding of how this biomass fuel performs in their conventional, coal fired combustion system, and
- To monitor and track CO, CO₂, SO_x, NO, NO₂, O₂ and Hg during the trial, comparing the coal only and coal/biomass results.

SYLVA provided a truckload of dried, pulverized sawdust equipped with its own feed and metering device. This greatly simplified the injection of this fuel into the system. The air assisted metering device was calibrated to inject approximately 1,500 lbs/hr of dry sawdust into the system. No information was provided by Sylva on the particular wood species. NRRI staff helped to facilitate the trial and were contracted to monitor and report emissions from the trial. The resulting emission results from a coal only and a coal/sawdust cofire trial are presented in this report.

RESULTS

NRRI set up monitoring and testing equipment for stack gases (Testo Inc. - Model 350S) and for mercury (Ohio Lumex - Model IRM-95) on August 19th, 2010 to measure and track CO, CO₂, SO_x, NO, NO₂, O₂ and Hg. The monitoring probes were set into the hot air stream just down stream of boiler A. A four hour sampling period was conducted to gain baseline emission data with coal only, followed by a 4 hour period in which 25 to 30 percent dry sawdust was cofired with the coal.

System Equilibration

The mercury analyzer was hooked up in a hot gas port just downstream of the boiler at 6:00 AM the morning of the trial. Data was continuously monitored from 7:00 AM to 3:45 PM. From 6:00 AM to 8:00 AM, the boiler was allowed to respond to the morning heating load, resulting in a steady-state operating condition as noted by staff. The gas stream temperature data showed this information as it took approximately 2 hours for the boiler to respond to the morning heating load. The time period from 8:00 - 10:00 AM was used to assess the emissions from coal only firing. Biomass was used to cofire the boiler starting at 10:00 AM. The time period from 10:30 AM - 3:15 PM was used to assess the emissions resulting from the cofiring with approximately 25 percent wood sawdust at a rate of 1,500 lbs/hr of sawdust addition.

Sulfur Dioxide (SO₂)

The SO₂ trend line for the cofiring trial is depicted in Figure 1. The results show a significant downward trend in SO₂ emissions for the biomass section of the cofiring trial. The 8:00 - 10:00 AM time period showed a mean SO₂ concentration of 137 ppm while firing coal only. The 10:30 AM - 3:15 PM time period with 25% sawdust showed mean SO₂ levels of 78 parts per million

(ppm) This corresponds to a nominal 43% reduction in SO₂. A single factor analysis of variance (ANOVA) was completed on the testing data for the two time periods and showed that the reduction in SO₂ was statistically significant (P = 0.05 level) for the biomass cofire.

Mercury (Hg)

An ANOVA showed that there was a statistically significant (P = 0.05 level) reduction in mercury concentration during the biomass cofire. The average Hg concentration recorded during the coal only firing was 4,292 nanograms per cubic meter (ng/m³) and 3,286 ng/m³ during the 25% biomass cofiring. This corresponds to a nominal 23% reduction in mercury concentration. The Hg results for the cofiring trial are depicted in Figure 2.

Nitrogen Oxide (NO_x)

The NO_x concentration varied sporadically throughout the testing period with no particular downward or upward trend evident. The NO_x concentration mean for the 8:00 - 10:00 AM period was 242.9 ppm and 232.9 ppm for the 10:30 AM - 3:15 PM period. An ANOVA was conducted on the testing data and showed that there was a statistically significant difference (P = 0.05 level) in NO_x during the cofiring trial. The NO_x results for the cofiring trial are depicted in Figure 3.

Oxygen (O₂)

The O₂ concentration fluxuated between 8 and 10 percent during the trial. The mean for the 8:00 - 10:00 AM period was 9.0% and 9.2% for the 10:30 AM - 3:15 PM period. An ANOVA showed that a statistically significant difference existed between the two time periods. The O₂ results for the cofiring trial are depicted in Figure 4.

Gas Stream Temperature

The gas stream temperature was slightly more sporadic during the cofiring period. The average was 487°F with coal only, and 468°F with cofiring. The slight differences are likely the result of the systems response to the load combined with minor variations in the feed rate of sawdust into the system. An ANOVA showed that the temperatures during the two trial periods were statistically different at the P=0.05 level. The temperature results for the cofiring trial are depicted in Figure 5.

Carbon Dioxide (CO₂)

Carbon dioxide varied between 10 and 14 percent throughout the trial with coal the 8:00 - 10:00 AM average 12.46 and the 10:30 AM - 3:15 PM average of 12.42. An ANOVA showed that the CO₂ during the two trial periods were not statistically different at the P=0.05 level. The CO₂ results for the cofiring trial are depicted in Figure 6.

Carbon Monoxide (CO)

Carbon monoxide appeared to be slightly more sporadic during the cofiring period. The differences are likely the result of the systems response to the load combined with variations in the feed rate of sawdust into the system. The 8:00 - 10:00 AM average was 19.6 ppm and the 10:30 AM - 3:15 PM average was 65.3 ppm. An ANOVA showed that the CO during the two trial periods were statistically different at the P=0.05 level. The CO results for the cofiring trial are depicted in Figure 7.

DISCUSSION

Two spikes were noted in the Hg emission data at approximately 11:00 AM and 1:00 PM. It was determined that there were slight sawdust plugging issues that took place at that time. These occurred in the feed line for the sawdust injection system and were quickly corrected. It is interesting to note the sensitivity of the mercury recording instrument, as spikes in the data coincide exactly where sawdust plugging issues surfaced.

Evidence of sparklers was noted in the combustion zone of the boiler as the result of injecting dry sawdust into the system. Sparklers are defined as glowing embers floating around in the combustion zone. The sparklers were approximately $\frac{1}{8}$ th to $\frac{1}{4}$ inch size and were observed floating in the combustion space, hitting the back wall of the boiler and rolling down to the bottom of the ash pit. Inspection of the bottom ash revealed very slight agglomerates that were quite frail and easily broken apart. However, the intensity of the sparklers and their frequency in the combustion zone appeared manageable as visual inspection downstream of the combustion zone revealed no evidence of sparklers prior to entering the emission collection equipment.

Three possible scenarios are presented for the reason sparklers were detected in the combustion zone. These included:

1. Some of the sawdust particles were too large and did not burn completely across the combustion zone.
2. Static electrification may have caused some of the sawdust particles to stick together.
3. The sawdust may have caused the temperature profile surrounding the micro environment of coal ash particles to fuse together slightly.

CONCLUSIONS

Completion of a firing trial with a 25 percent replacement of coal with sawdust biomass was completed at 3:15 p.m. on August 19, 2010. The data collected during emission monitoring was analyzed and the following conclusions were drawn from this study:

- Cofiring dry sawdust at nominal 1,500 lb/hr into conventional pulverized coal fired boiler is technically feasible.
- A reduction in mercury concentration on the order of 23% was recorded throughout this trial. The reduction closely parallels the proportion of injected sawdust. The average coal only and biomass cofiring were 4,292 ng/m³ and 3,286 ng/m³, respectively. An ANOVA showed that this was a statistically significant reduction.
- The SO₂ concentration in the gas stream decreased significantly as a result of cofiring with sawdust. The average coal only and biomass cofiring concentrations were 137 ppm and 78 ppm, respectively. An ANOVA showed that this was a statistically significant reduction.

- An ANOVA showed that there were also statistically significant differences noted for the NO_x , O_2 , gas stream temperatures and CO emissions results during the coal and biomass cofiring time periods. There was no statistical difference noted for the CO_2 .
- According to staff present during the trial, sparklers in the combustion zone appeared to be manageable. Sparklers were not observed beyond the boiler.

The results clearly demonstrate significant reductions in both Hg and SO_2 can be expected when cofiring dry sawdust into a conventional pulverized coal fired boiler and small reductions in NO_x . Cofiring appears to provide a logical pathway to meet evolving and more stringent future emission standards. A cofiring option may give utilities an additional tool to overcome the costs associated with expensive pollution control equipment.

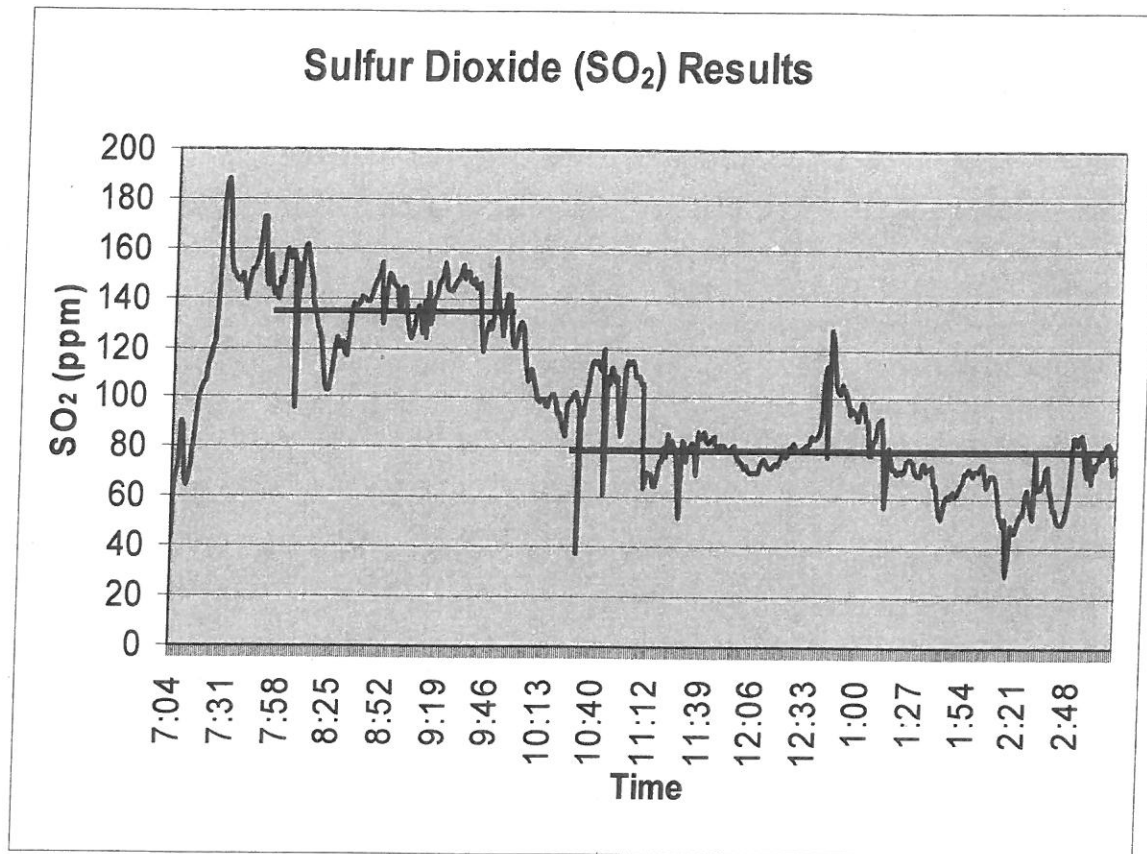


Figure 1.--Sulfur dioxide emissions during the August 19, 2010 biomass cofiring trial.

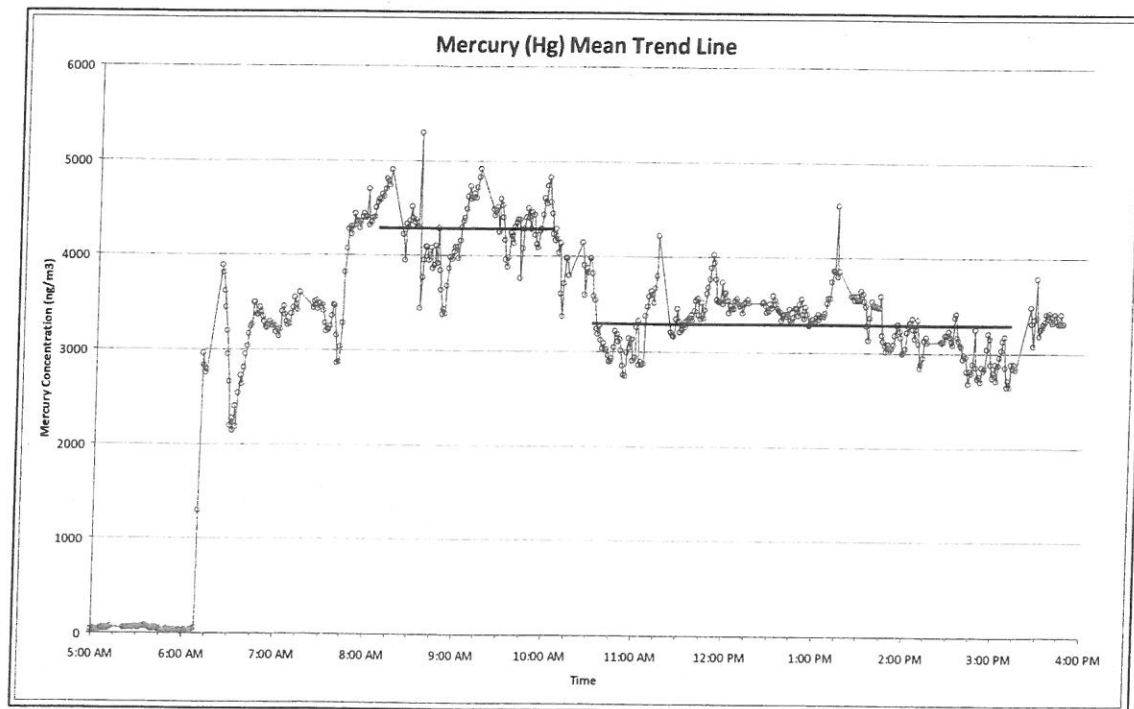


Figure 2.--Mercury emissions during the August 19, 2010 biomass cofiring trial.

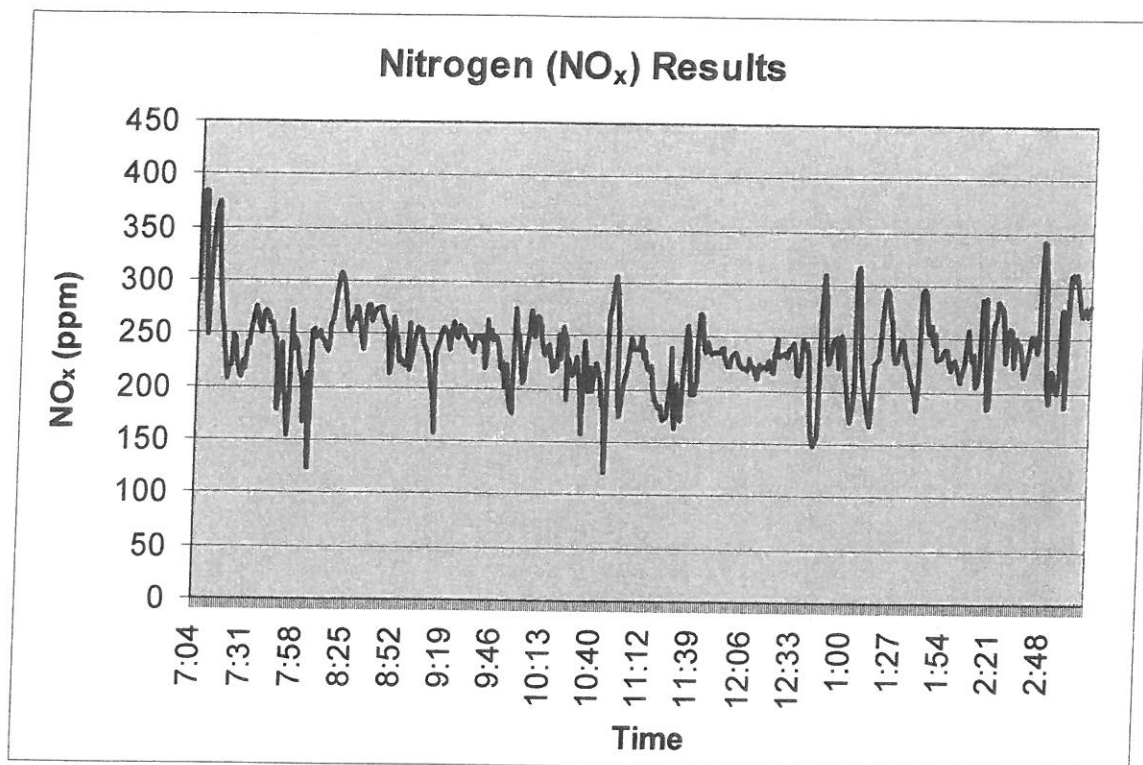


Figure 3.--Nitrogen emissions during the August 19, 2010 biomass cofiring trial.

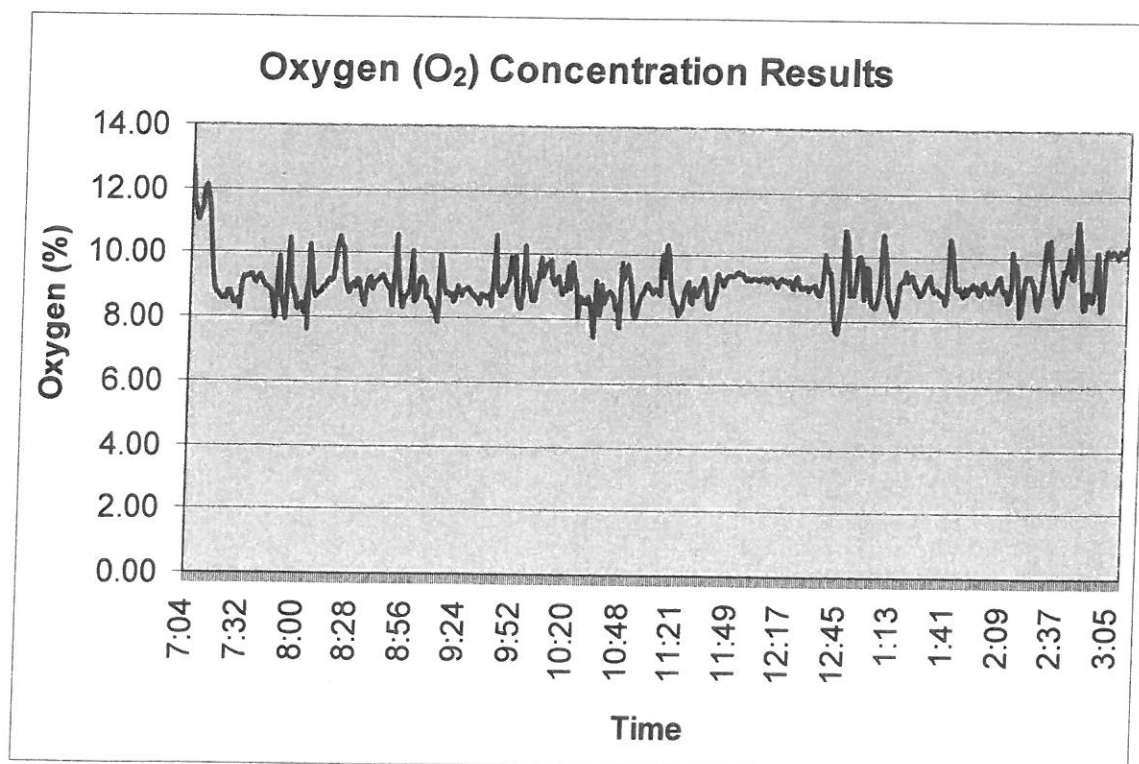


Figure 4.--Oxygen emissions during the August 19, 2010 biomass cofiring trial.

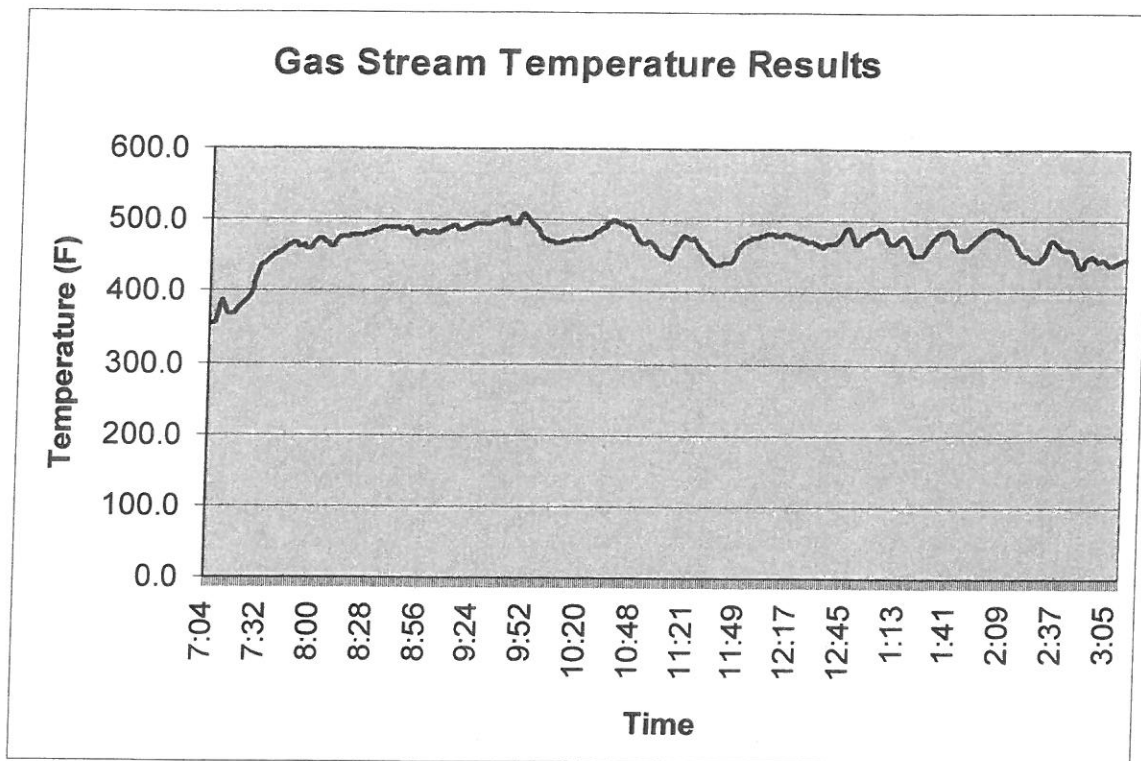


Figure 5.--Gas stream temperature results during the August 19, 2010 biomass cofiring trial.

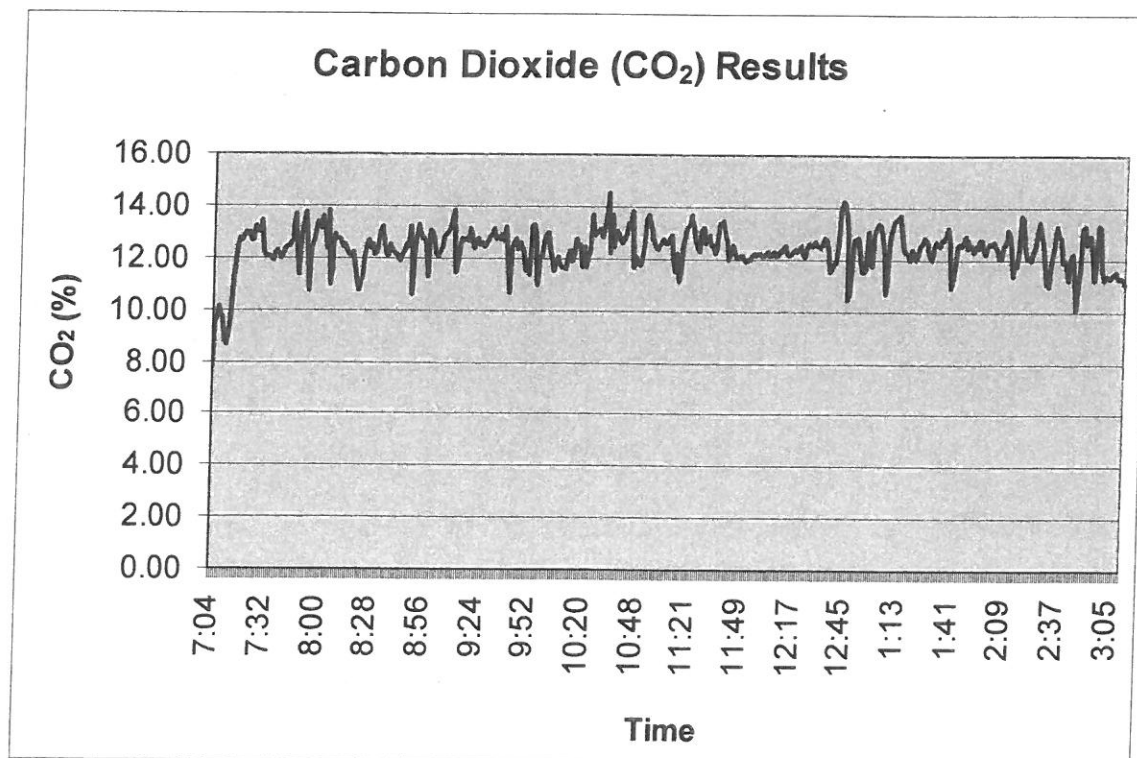


Figure 6.--Carbon dioxide emissions during the August 19, 2010 biomass cofiring trial.

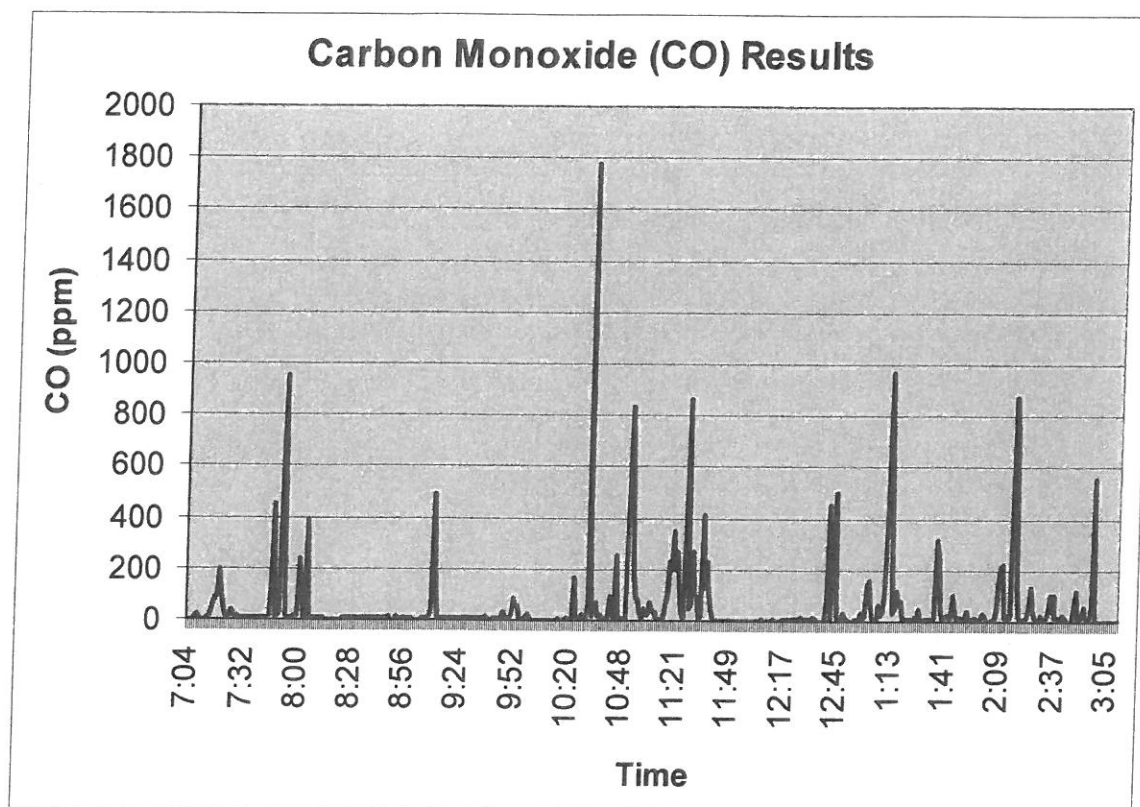


Figure 7.--Carbon monoxide emissions during the August 19, 2010 biomass cofiring trial.

1269 Premier Way, Thunder Bay, ON P7B 0A3

Telephone: 807-625-6700 ~ Fax: 807-623-4491 ~ www.wspgroup.com

MEETING DATE:	March 18, 2014		
MEETING PLACE:	Duluth Steam Plant		
PROJECT NO.:			
PROJECT NAME:	Biomass Handling Study		
	Name	Company	e- mail address
PRESENT:			
	Jim Green	Duluth Steam	Jim.Green@ever-greenenergy.com
	Bacon Reuille	Duluth Steam	bacon@DuluthSteam.com
	Barry Brooks	WSP	
DISTRIBUTION:	All Present		

NOTES:

Item #	Topic	Discussion	Action
1	Study Scope	The study will focus only on the present needs of the plant to burn 25% biomass on a BTU basis annually. Steam Load: - 200 KPH winter - 30 KPH summer	
2	Existing System	(4) Boilers c/w manual ash removal (2) of (4) boilers gas natural gas burners All boiler has fuel oil guns for start-up Western Coal is typically used with 4% ash, eastern coal is occasionally used Each boiler has its own roller type pulverizer	Jim will forward info on existing silo, pulverizer, boilers and steam production
3	Potential Biomass Fuels	The study will be limited to woody biomass, hog fuel, dust and pellets (white or dark) will be investigated. Hog Fuel would require re-hogging and would be introduced prior to the pulverizer Pellets would be introduced prior to the pulverizer. Dust could be introduced either before or after the pulverizer	Barry will contact biomass suppliers to investigate the difference in pricing between biomass dust and pellets
3.1	Biomass Fuel Requirements	Moisture content of less than 15% Volatile Matter of greater than 35%	

4	Biomass Burning limit	The amount of biomass to burn will be limited by the carry-over to the bag house. As steam demand increases the biomass burning will decrease in order to avoid carry-over to the bag house. Material Handling Equipment Design Capacity of 2.75 tph, which includes 15% for surge capacity and 10% contingency	
5	Biomass Delivery	24/7 enclosed trucks or container, must not be dust generating	
6	On-site Storage	An existing silo may be utilized for storage, otherwise the trailers or container will be the only storage with metering bins on the operating floor level	

Disclaimer:

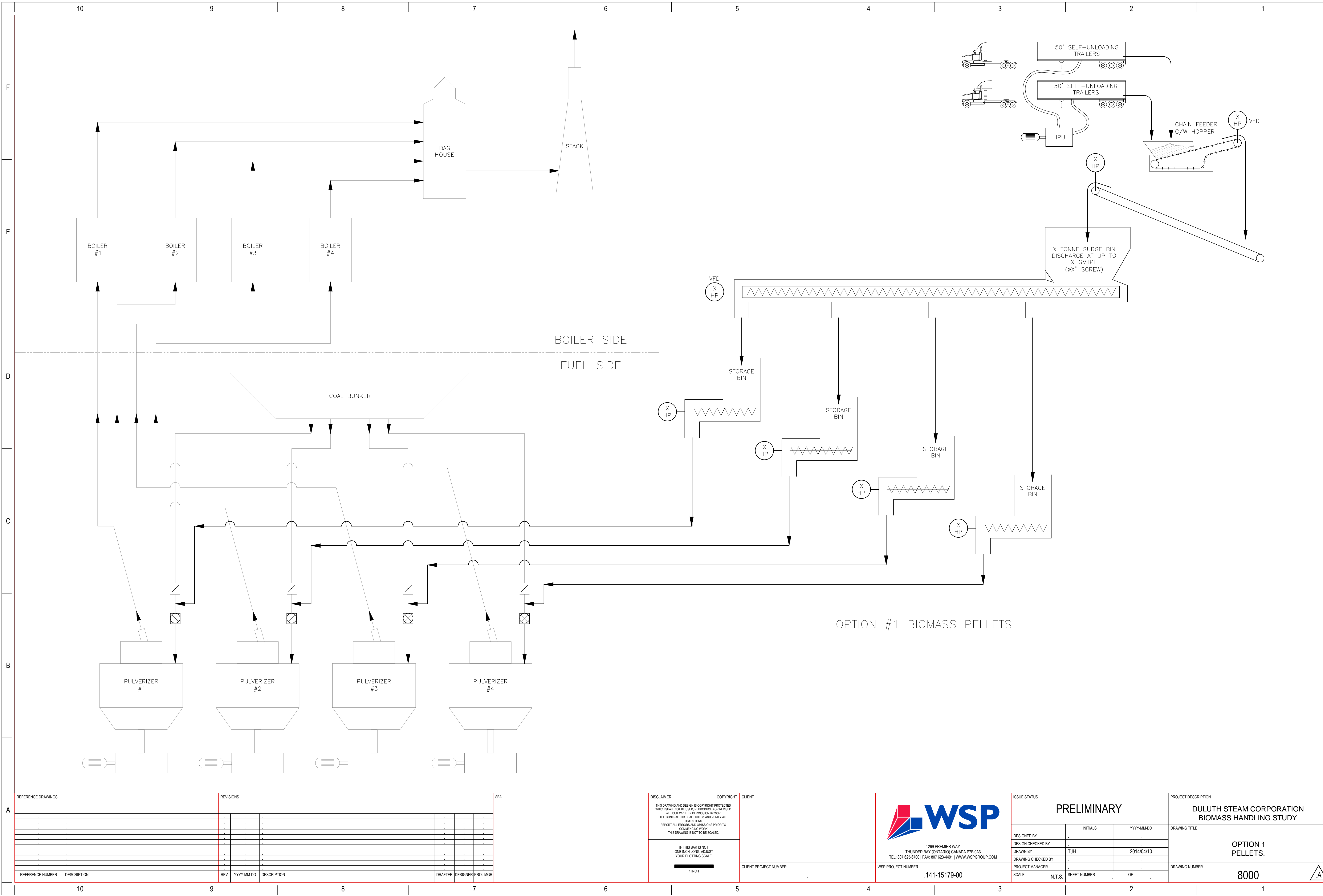
Any Discrepancy in these minutes must be brought to the attention of the recorder, in writing, within 7 days of issue date. If none are received, the minutes will be adopted.



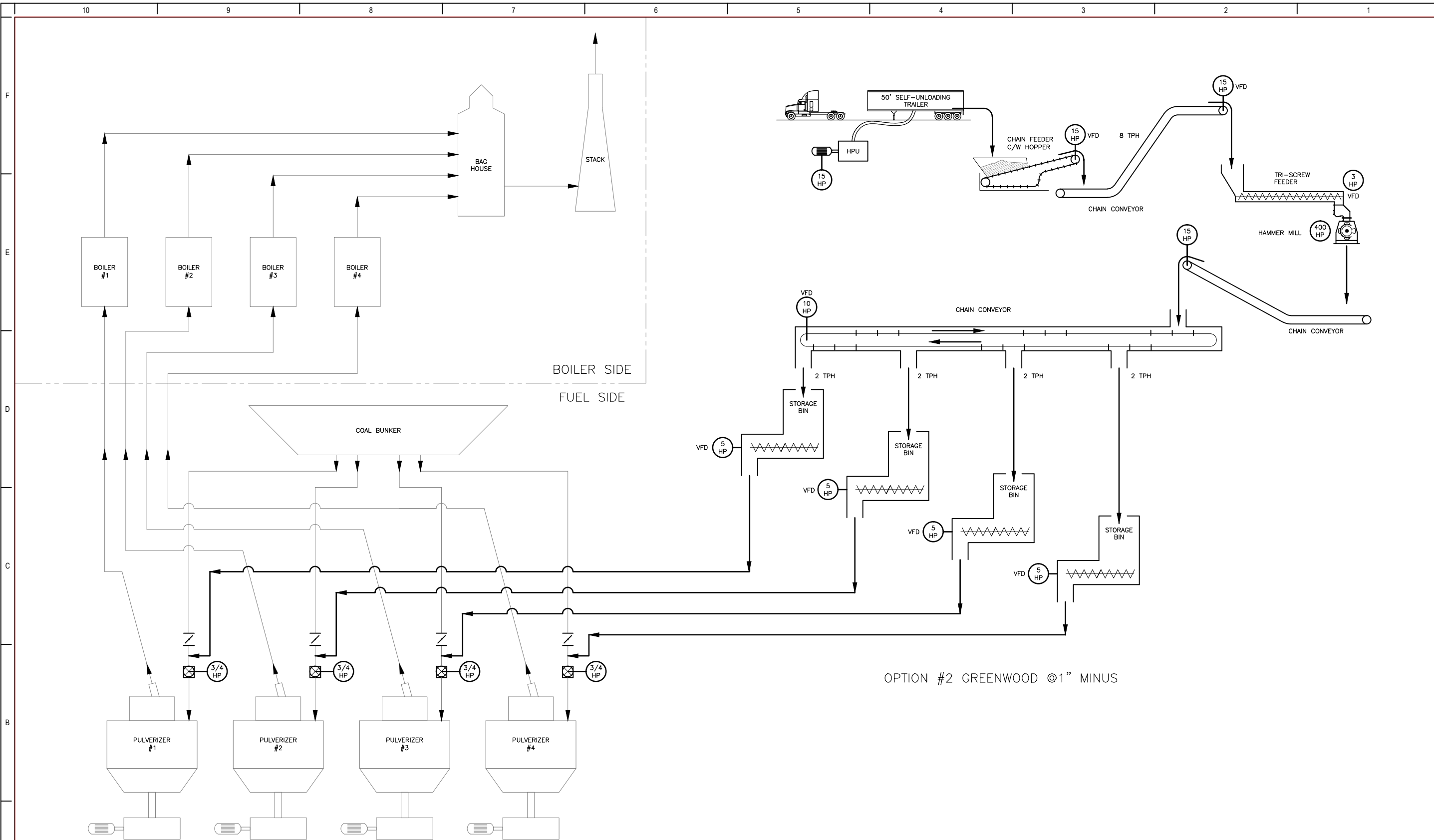
WSP Group


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 Telephone: 807-625-6700 ~ Fax: 807-623-4491 ~ www.wspgroup.com

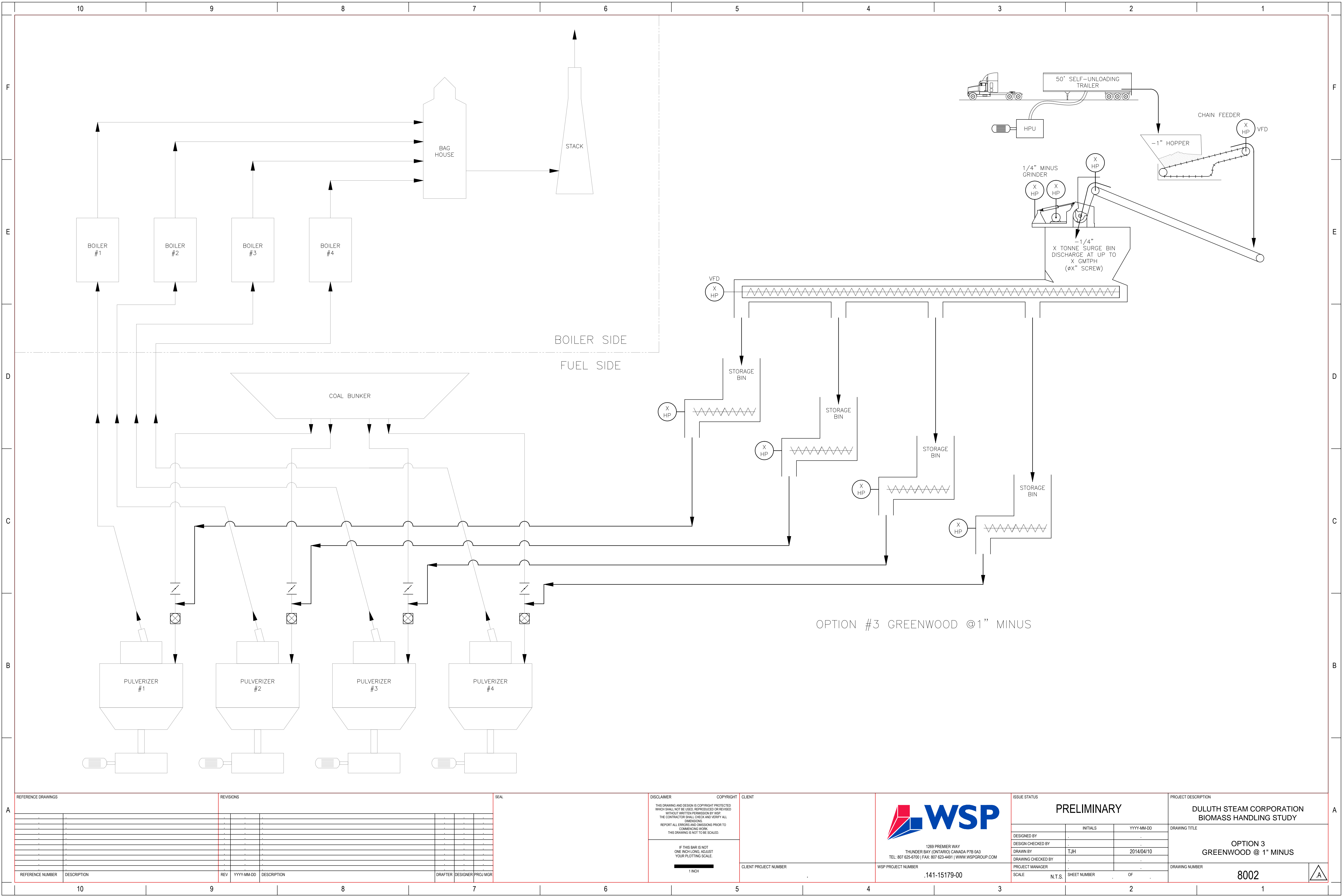
PROJECT NAME:	Duluth Steam Biomass Handling Study		
PROJECT NO.:	141-15179-00		
SUBJECT:	Fuel Option Comparison		
PREPARED BY:	Barry Brooks		
Item	Option #1, Biomass Pellets,	Option #2, Biomass Dust,	Option #3, Wood Chips,
Heating Value	8,200 BTU/LB	6,000- 6500 BTU/LB	4,300- 4800 BTU/LB
Bulk Density	40 LBS/CU FT	25 LBS/CU FT	20 LBS/CU FT
Moisture Content	6%	25 - 30%	45 – 50%
Estimated fuel cost (not confirmed, dust price is based on pellet suppliers information)	\$150/ton	\$75/ton	\$40-50/ton
Fuel Handling System	See Flow Diagram No.8000	See Flow Diagram No.8001	See Flow Diagram No.8002
Fuel Storage	Receiving Hopper, Surge Bin, and (4) Storage Bins	No on-site storage with the exception of the two (2) transport trailers, this will reduce the risk of silo explosions	Receiving Hopper, Processed Material Surge Bin, and (4) Storage Bins
Operating Issues	Easiest to control and monitor. Cleanest fuel.	Will require controlling pneumatic blower and rotary feeder by boiler load and coal/biomass mix ratio.	An additional process for the operators to monitor and control. Potential noise source.
Dust Explosion Risk	Low to Mid Risk	Mid Risk	Low
Fuel Supply	Pellet suppliers would welcome the summer business.	Fuel sourcing of the required tonnage may be an issue.	Most flexible for fuel sourcing.



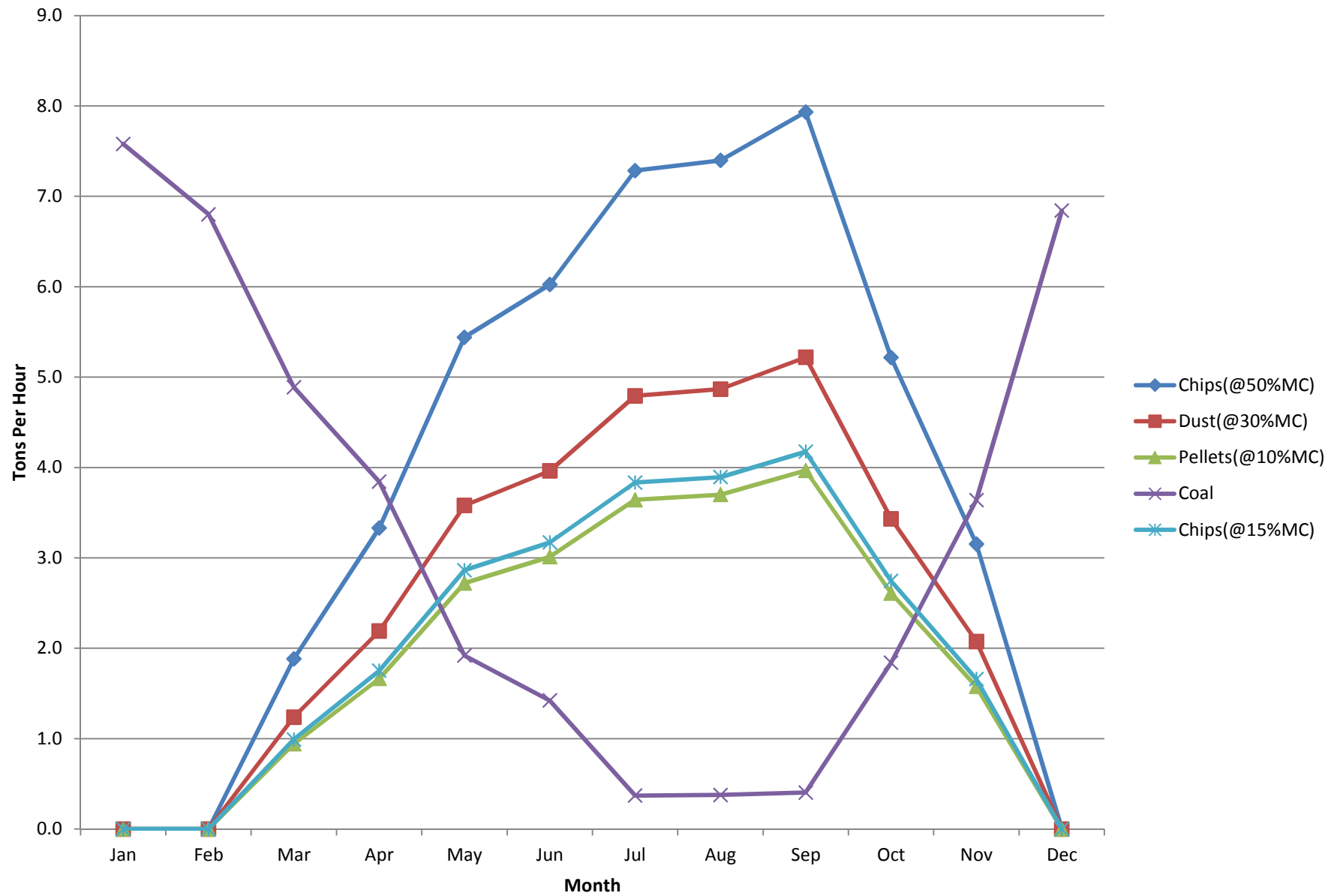
A	REFERENCE DRAWINGS				REVISIONS				SEAL			DISCLAIMER				COPYRIGHT				CLIENT				<div><div><div><div></div><div></div></div><div><div></div><div></div></div></div><div><div>WSP</div><div>1269 PREMIER WAY THUNDER BAY (ONTARIO) CANADA P7B 0A3 TEL: 807 625-6700 FAX: 807 623-4451 WWW.WSPGROUP.COM</div></div></div>				ISSUE STATUS				PROJECT DESCRIPTION					
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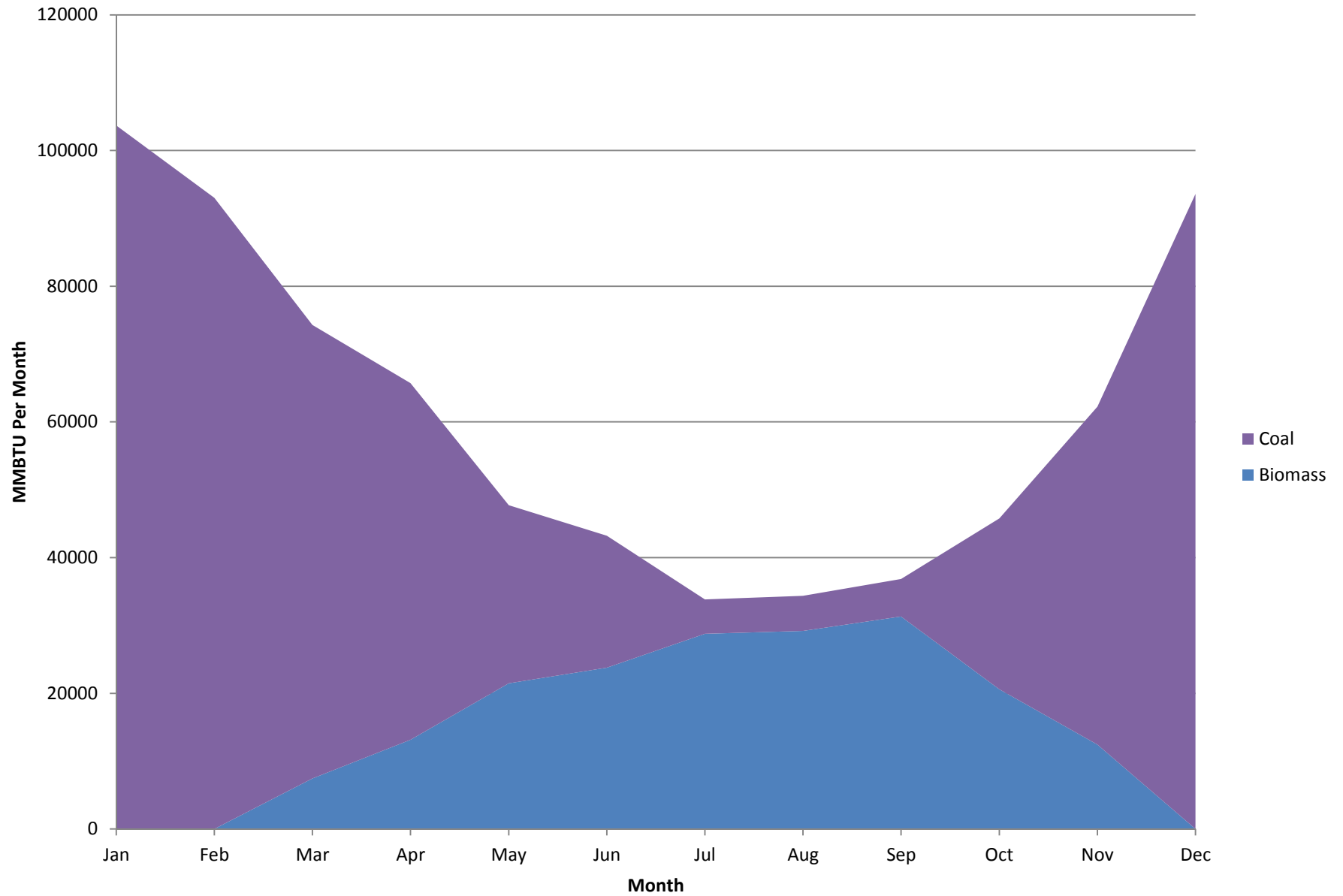
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															DRAWING TITLE					
															DESIGNED BY		INITIALS		YYYY-MM-DD	



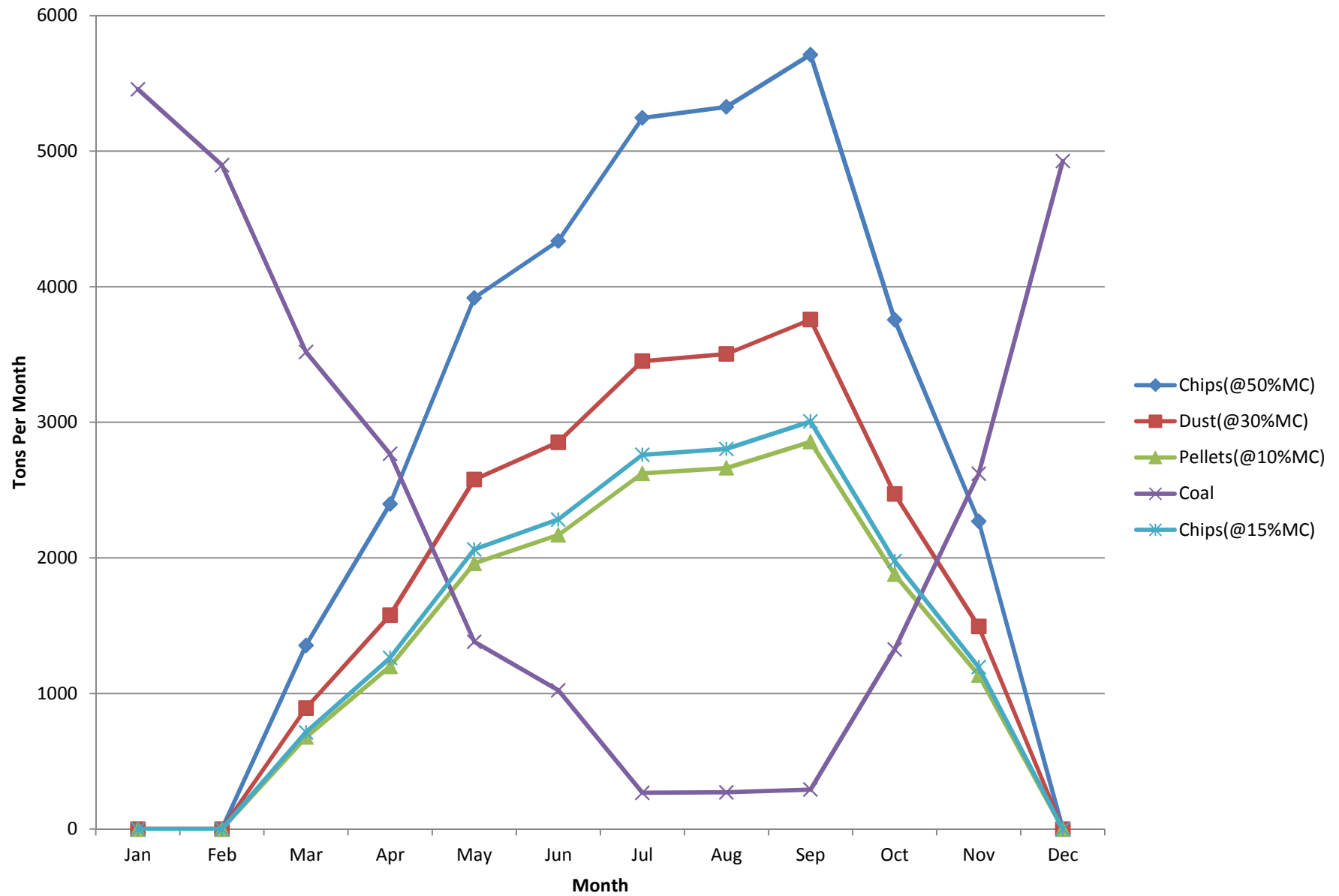
25% Biomass By BTU/Annum Average

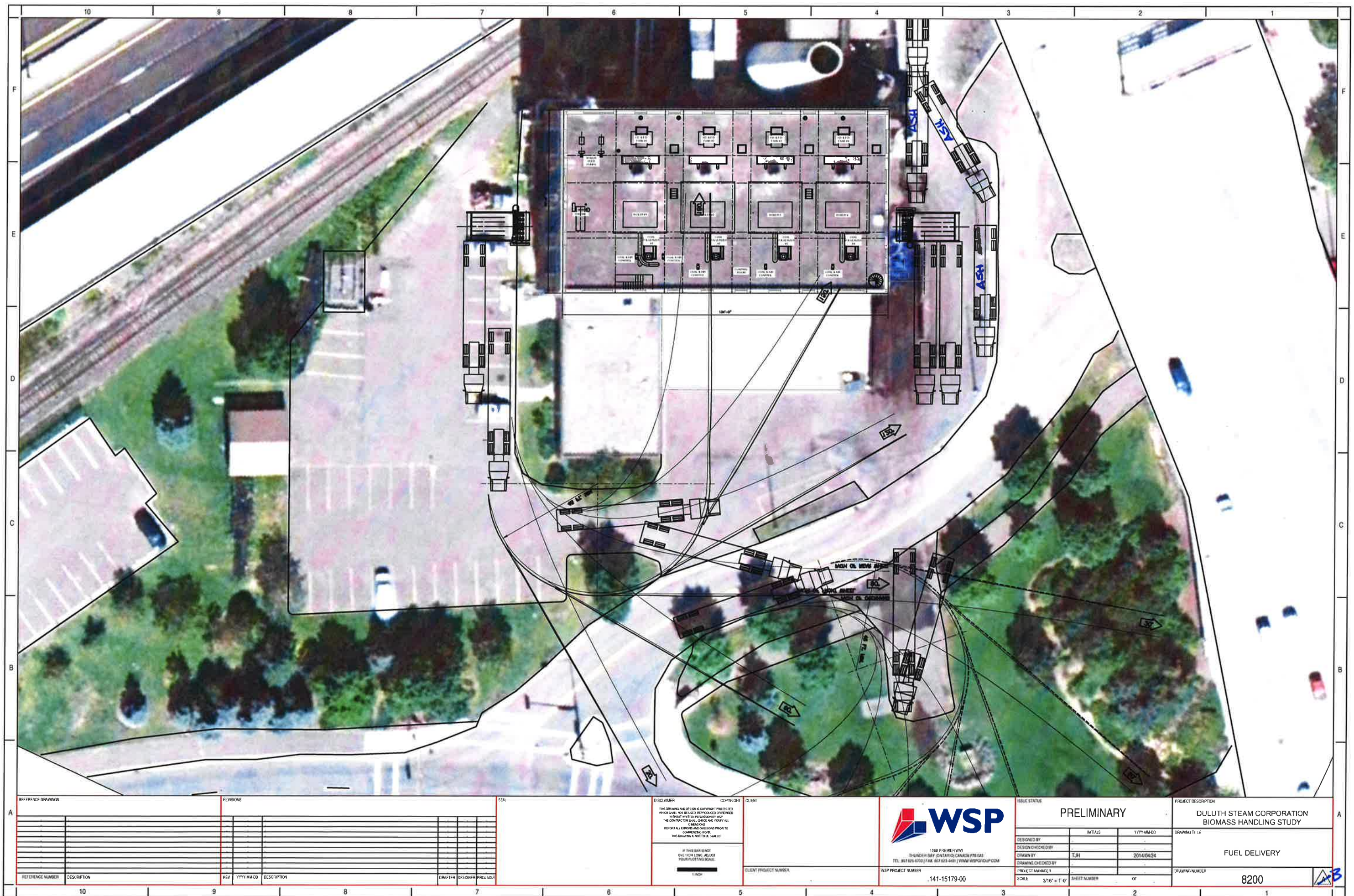


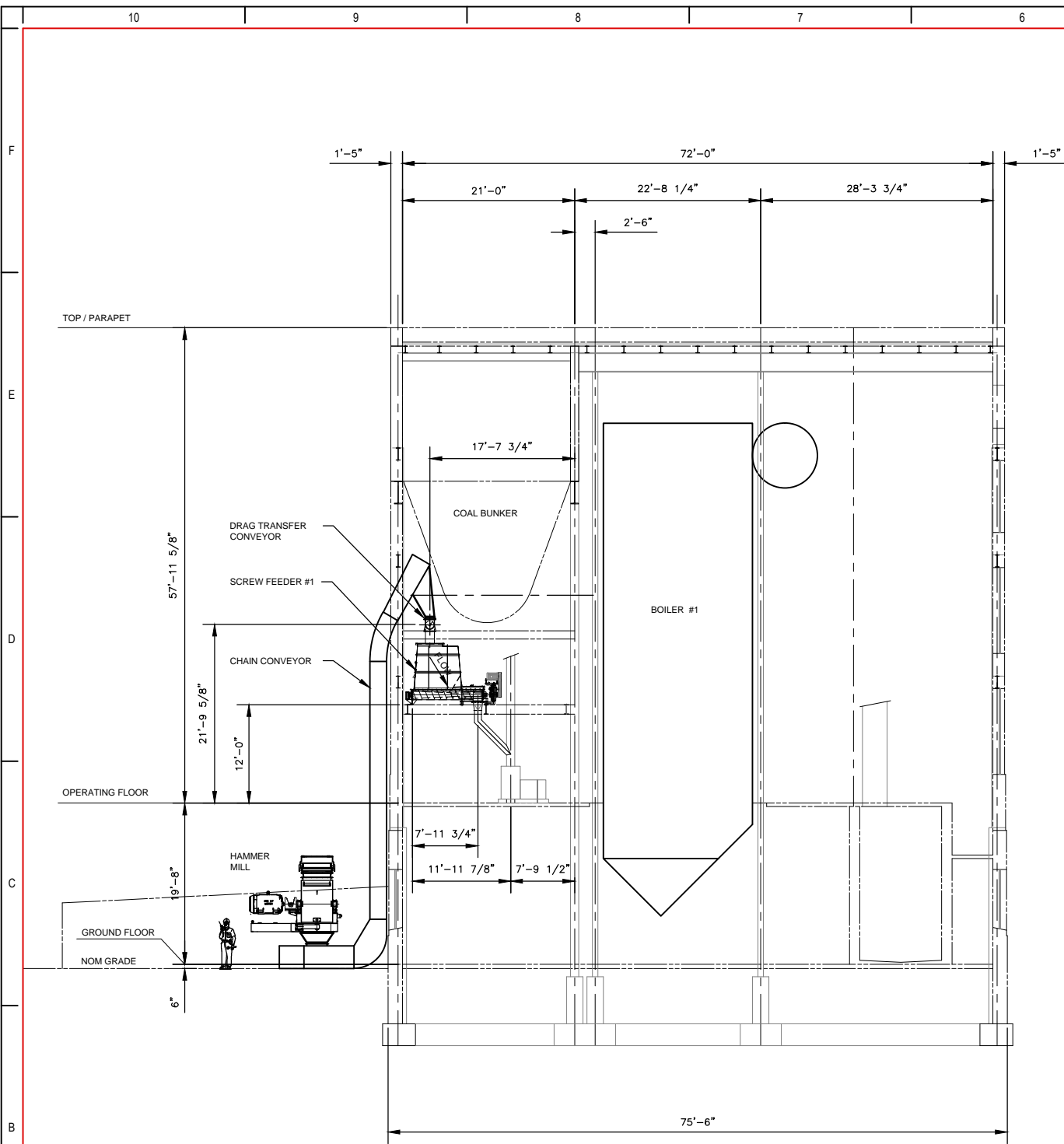
25% Biomass By BTU/Annum Average



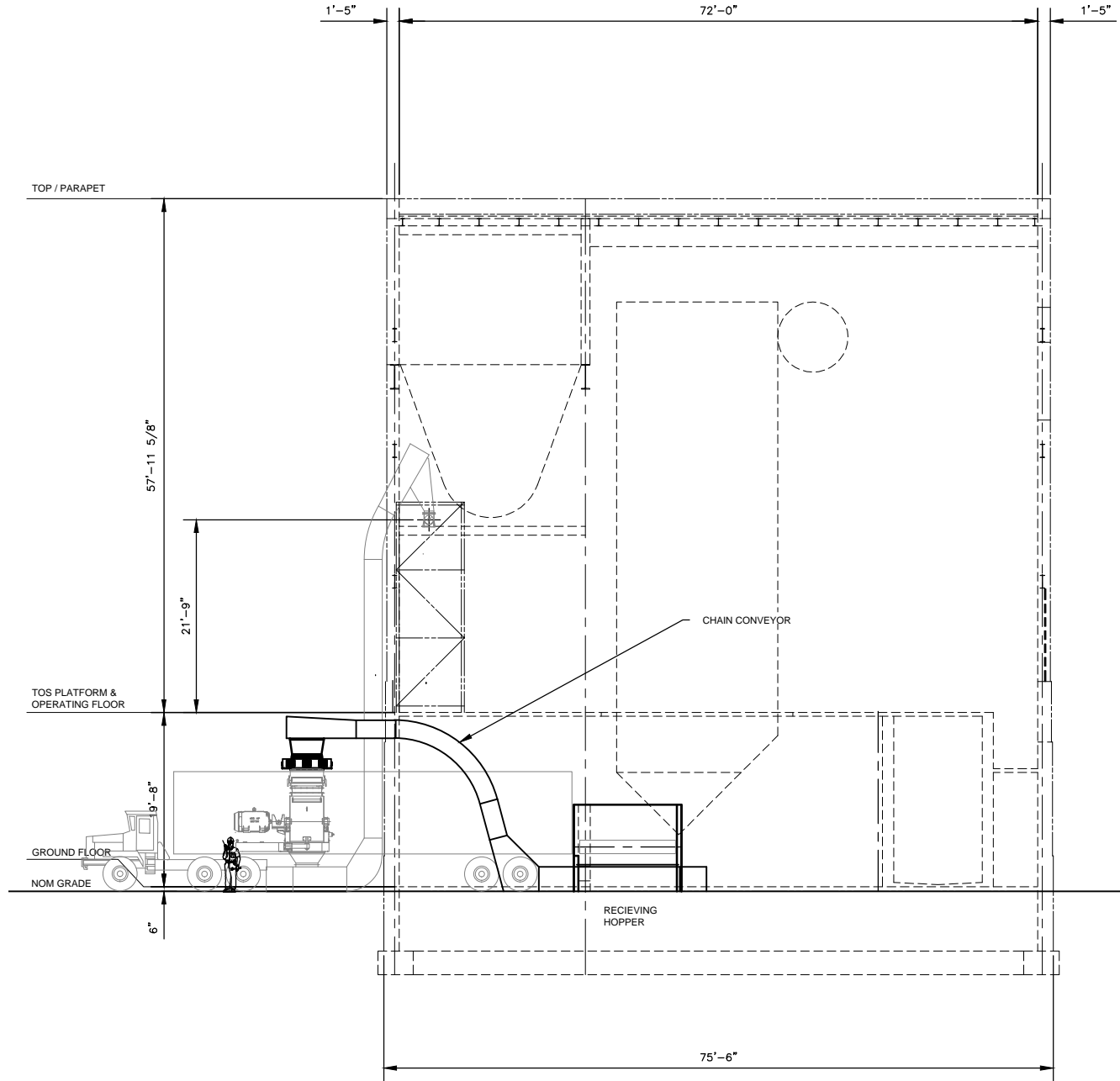
25% Biomass By BTU/Annum Average





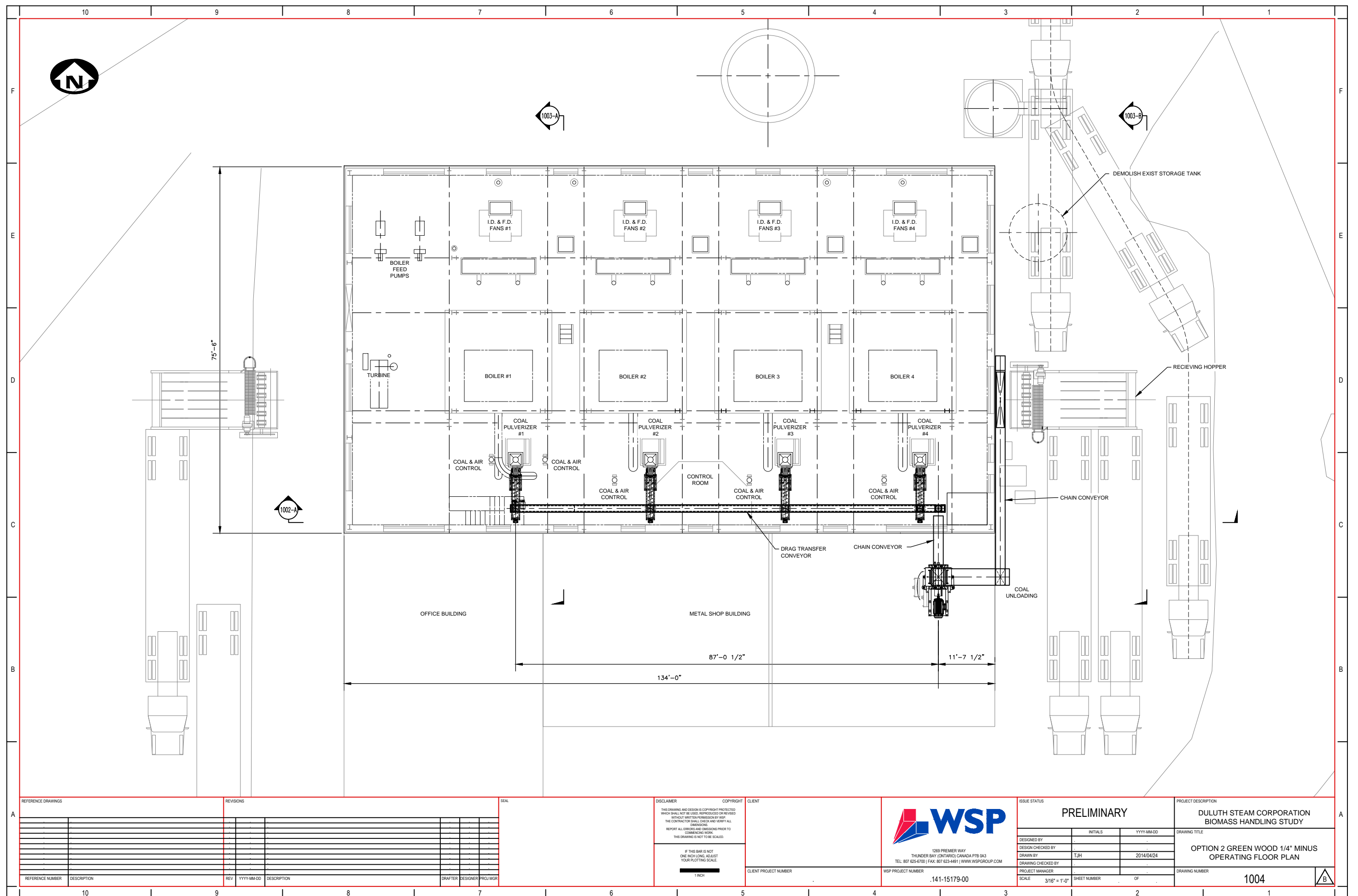


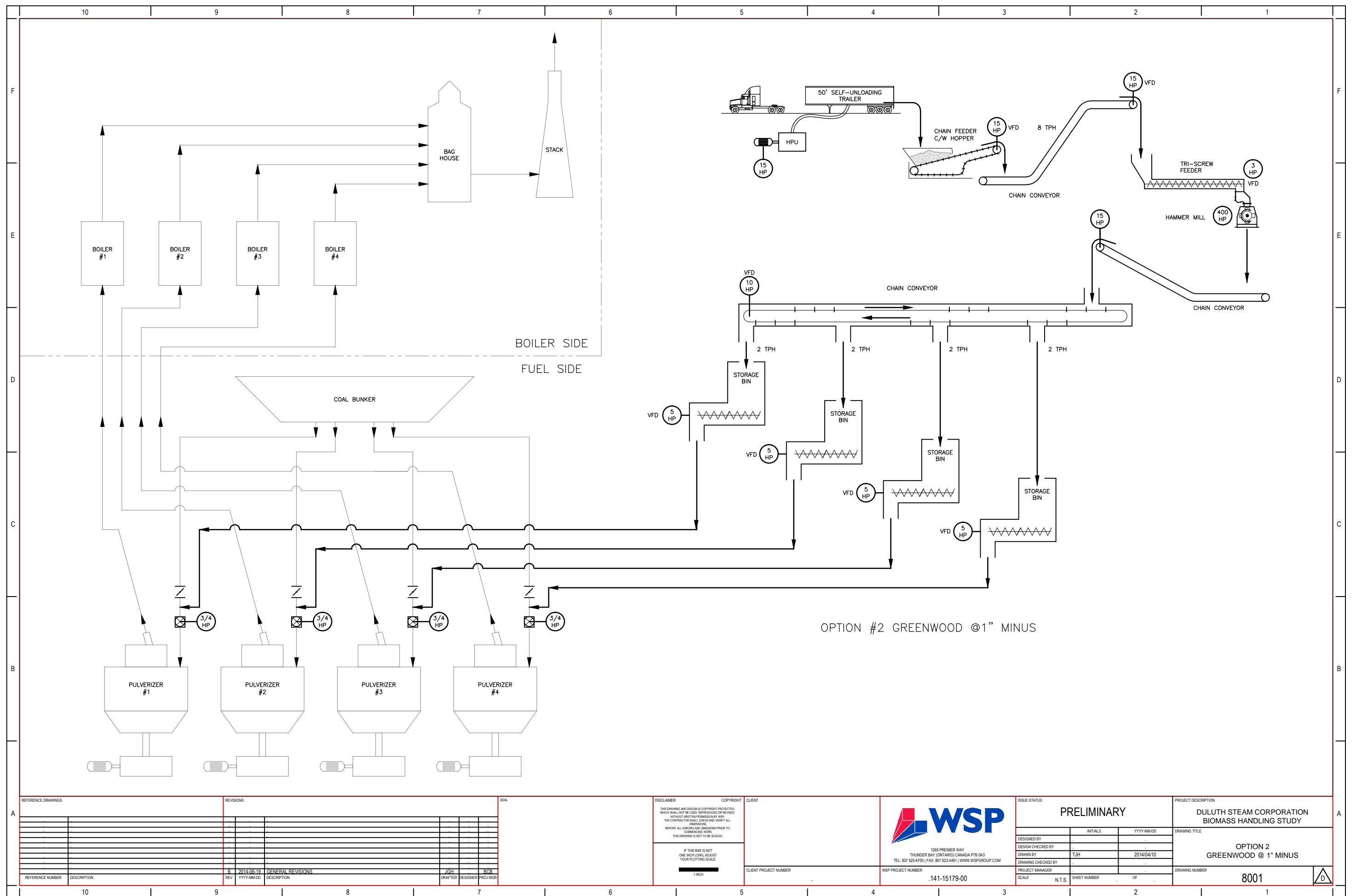
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1001
SECTION LOOKING WEST
1/8"=1'-0"



1003-B
1001
SECTION LOOKING WEST
1/8"=1'-0"

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Jim Green

From: Tom Warne <Warne@hammermills.com>
Sent: Thursday, January 15, 2015 3:44 PM
To: Robert White; Jim Green
Subject: photos
Attachments: HPIM3809.jpg; HPIM3807.jpg; HPIM3806.jpg

Hi again guys:

Here are three photo's showing our testing on the green material (no drying):

1. As received.
2. Through a ¼" screen.
3. Through a 1/8" screen.

I am not overly confident that we could process this material long term through the 1/8" screen given the moisture level. I do not think we would have difficulty with the ¼" as long as what we tested was representative of what we could expect in the field under normal operating conditions. You will need a lot of air suction to keep this material moving down and through the screens and help mitigate the issues of material clinging to the screen openings.

Sample should reach you early next week and I look forward to your feedback.

Thanks again,

Thomas E. Warne, President



Thomas E. Warne
Schutte Buffalo Hammermill, LLC
61 Depot Street, Buffalo, New York 14206
Corporate office: (716) 855-1555
Toll-free: (800) 4 Grind 4 (or 800-447-4634)
Fax: (716) 855-3417
My email: warne@hammermills.com
Website: <http://www.hammermills.com>
(click logo above to connect to our website)



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Jim Green

From: Tom Warne <Warne@hammermills.com>
Sent: Thursday, January 15, 2015 3:41 PM
To: Robert White; Jim Green
Subject: testing
Attachments: HPIM3801.jpg; HPIM3803.jpg; HPIM3804.jpg

Bob & Jim:

The samples are headed back to you Jim to evaluate. Here are three photos that show how fine we could grind down to once the material was dried in our oven:

1. As received material.
2. Run through a 1/8" screen
3. Run through a 1/16" screen

Once dried we experienced no screen blinding whatsoever. I do not know what particle size you consider acceptable but this is about as fine as we can grind practically and still maintain a decent throughput. Let me know your thoughts after reviewing the samples which left today.

Thanks again.

Thomas E. Warne, President



Thomas E. Warne
Schutte Buffalo Hammermill, LLC
61 Depot Street, Buffalo, New York 14206
Corporate office: (716) 855-1555
Toll-free: (800) 4 Grind 4 (or 800-447-4634)
Fax: (716) 855-3417
My email: warne@hammermills.com
Website: <http://www.hammermills.com>
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Wet Sawdust from Pallet Factory



Wet Sawdust 1/4" Hammer Mill Screen



Wet Sawdust 1/8" Hammer Mill Screen



Sawdust from Pallet Factory (dried)



Dry Sawdust - 1/8" Hammer Mill Screen



Dry Sawdust - 1/16" Hammer Mill Screen

DESIGN CONSIDERATIONS AND TECHNICAL SPECIFICATIONS

1. INTRODUCTION

This project is intended to substitute locally available woody biomass for at least 25 percent (on a fuel energy input basis) of the 50,000 tons of coal consumed at DES annually

Previously completed design and research indicates co-firing biomass with pulverized coal in the existing boilers is not likely to be cost effective. This project will instead, install biomass-fired Hot Gas Generator(s) (HGG) just outside the existing plant. The flue gasses from the HGG will be ducted into the existing boiler firebox and through the boiler generating bank to produce steam. Two of the plants four boilers will be re-configured to use heat generated by the HGG(s).

The deliverables for this project include design of, and / or specification development for:

1. A building or enclosure as required to allow year-round operation of the biomass HGG system.
2. Biomass (green wood chips) receiving, storage and HGG feed systems.
3. Biomass - fired Hot Gas Generator(s) (HGG).
4. Duct(s), dampers between HGG(s) and existing boilers.
5. Modifications to existing boiler(s) required to accept flue gas from HGG(s).
6. Remote control and monitoring system so that the HGG operation can be accomplished from the plant's existing control room.
7. Biomass ash collection, conveyance and storage.
8. Interfaces with existing boiler and HGG automatic combustion control systems.
9. Biomass dust capture, fire detection and suppression system(s) as required.
10. Civil, structural, electrical and architectural modifications to existing plant property as may be required.

2.0 OPERATIONAL REQUIREMENTS

2.1 Approach

- a. The desired outcome is the capability to burn biomass fuel in the form of green, locally derived woodchips in a HGG located on the West side of the existing heating plant. No onsite processing of fuel other than the removal of tramp metal will be accomplished.

HGG flue gas will be ducted into two of the plant's four existing boilers. Boilers 1 and 4, located at the West and East ends of the plant respectively will be configured to accept HGG flue gas. When the district heating system demand is low, the biomass-fired hot gas generators will supply the total heat required to generate steam. During winter months when steam demand is higher, the heat from the biomass fired hot gas generator will augment the simultaneous combustion of coal in Boilers 1 and 4.

Flue gas from the biomass-fired hot gas generators will flow through boilers, and the plant's existing fabric filter baghouse and smokestack.

Ash from the biomass fired hot gas generators will be conveyed to a storage silo or tank and periodically offloaded into trucks for disposal. Use of the plant's existing coal ash vacuum conveyance system and ash silos should be considered by designers.

2.2 General Design Requirements

- a. The following assumptions shall be used for design:
 - i. Green wood chip moisture content: 45%
 - ii. Wood chip heating value: 4,500 Btu/lb
 - ii. Wood chip bulk density: 20 lbs/ft³.
 - iii. One truckload of biomass fuel, as delivered has a volume of 2,500 ft³ or a net weight of 25 tons.
 - iv. Existing boilers currently generate 700 lbs of steam per MMBtu heat input (coal).
 - v. For the purpose of this project, the maximum expected generating capacity of each boiler shall be 55,000 lbs steam/hr (55 klb/hr/boiler).
 - vi. Based on the assumptions above, the maximum biomass throughput will be just under 9 tons per hour per boiler.
- b. The system shall be designed for a minimum service life of 25 years.
- c. No new air emission sources shall be added to those currently included in the plant's Title V permit.
- d. The system shall be designed to comply with applicable fire detection, fire suppression and dust control code requirements.

- e. Those portions of the system located outside of the existing plant shall be enclosed in a structure designed to:
 - i. Provide adequate protection from the weather to allow for year-round operation.
 - ii. Contain all fugitive biomass and ash dust which may be generated by the system.
 - iii. Suppress additional noise created by the system's operation to a Maximum level of 85 dB as measured at the plant's property boundaries.
 - iv. Be compatible or complementary, in appearance, with the Canal Park setting.
- f. The system shall be capable of being operated and monitored from the plant's existing control room without the need for continuous DS operating staff presence in the HGG structure.

2.2 Fuel Delivery

- a. Green woodchips will be delivered to site in live-bottom, moving floor, push-off or end-dump 42' trailers (fuel supplier provided). The fuel receiving area shall be located on the West side of the plant. Onsite truck traffic patterns and maneuvering areas shall be designed to minimize traffic disruptions on adjacent city streets while the same time providing sufficient space for unloading of trucks.
- b. Receiving area and equipment shall be configured to allow for offloading of just one trailer at a time but with sufficient capacity in the receiving area for at least two truckloads of fuel.
- c. Receiving area and equipment shall be designed to prevent biomass freezing, bridging, clogging or other fuel flow interruptions.

2.3 Fuel Storage

- a. Biomass fuel shall be conveyed from the receiving area to Ready Service Storage with capacity sufficient, when combined with Receiving Area storage capacity to allow for six (6) hours of 2-boiler operation at full load (104 tons).
- b. Ready Service Storage shall be designed with a First-In, First-Out operating scheme.
- c. If advantageous, a design which combines receiving and storage functions while meeting the individual requirements of Sections 2.2 and 2.3 is acceptable.
- d. The Ready Service Storage design shall include a means to be emptied (by some means other than feeding biomass to the HGG).

2.4 Hot Gas Generators (HGG)

- a. The HGG shall be located to the West of the existing plant building near the fuel delivery and storage equipment.

- b. The HGG shall have sufficient capacity to simultaneously deliver hot flue gas with a total heat content of 157 MMBtu/hr to the plant's boilers (78.5 MMBtu/hr per boiler).
- c. The HGG shall have a turndown ratio of at least 3:1 (rate of heat delivered to existing plant boilers).
- d. HGG flue gasses shall be ducted into the plant to Boilers 1 and 4. Existing window openings may be used for ductwork penetration(s) through plant walls if possible. The system shall be configured to allow hot gas to be supplied to Boilers 1 and 4 individually or simultaneously. The design shall provide for complete isolation of HGG flue gas from one boiler while the other boiler is being supplied with flue gas. The design shall also provide for complete isolation of the HGG while boiler(s) are being fired with coal.
- g. Hot gas from the biomass furnace shall be introduced into the existing boiler fireboxes in a manner which optimizes heat transfer to the existing boilers' generating tubes while not interrupting proper combustion when "cofiring" with coal.
- h. The combined biomass – coal fired system must be capable of meeting air emission limits specified in the plant's existing Air Emissions Permit.

2.4 Ash Handling

- a. Ash generated by the biomass furnace shall be conveyed to a location where it can be collected and loaded into trucks for disposal.
- b. If advantageous for any reason, the design may incorporate use of the existing vacuum ash collection system and the existing steel ash silo for biomass ash storage. If this option is chosen, the design shall include required modifications to the existing steel ash silo and unloading system. Note: This silo was originally designed for dry ash unloading and is not currently configured with an ash-water mixer / unloader.
- c. If the design will combine coal and biomass ash storage and unloading using the existing brick ash silo and unloading systems, any required modifications to either shall be included in the scope of this project.

3.0 EXISTING CONDITIONS AND IMPACT on DESIGN

3.1 Exterior Plant Arrangement

- a.. Hot gas duct(s) could potentially be routed from the HGG into the plant through existing 10 ft x 10 ft window openings on the West end of the plant. See Figure 3.



Figure (3) – West elevation of plant.

3.2 Interior Plant Arrangement

- a. The upper (Operating) floor of the plant is arranged as indicated in Figure 5. The HGG ductwork from the HGG to the fireboxes of Boilers 1 and 4 is indicated in red. This duct would be installed under the coal bunker, above the boiler wind boxes. See also Figure 6.

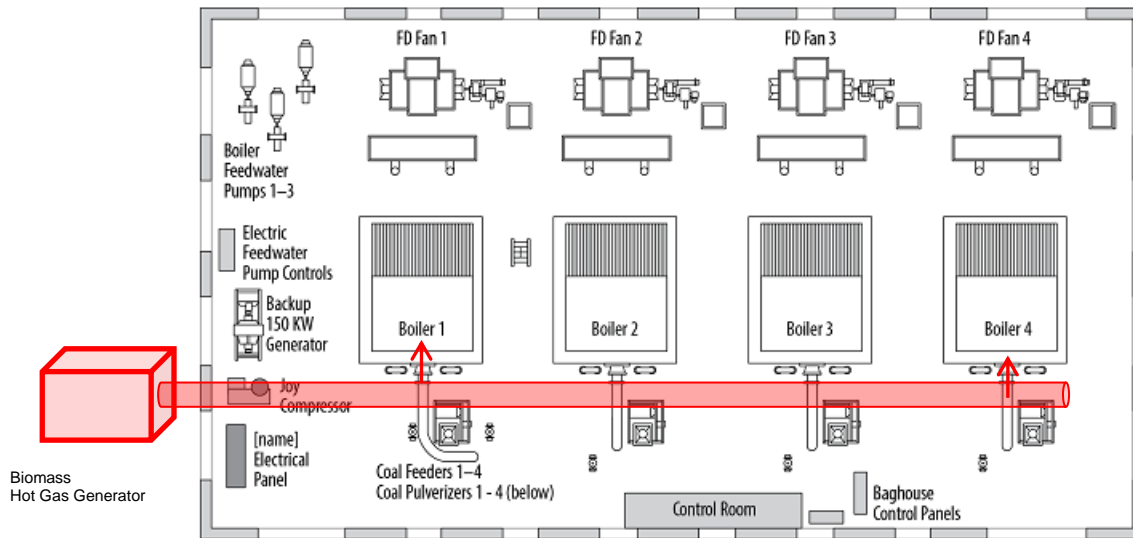


Figure 5 – Plant upper (Operating) level

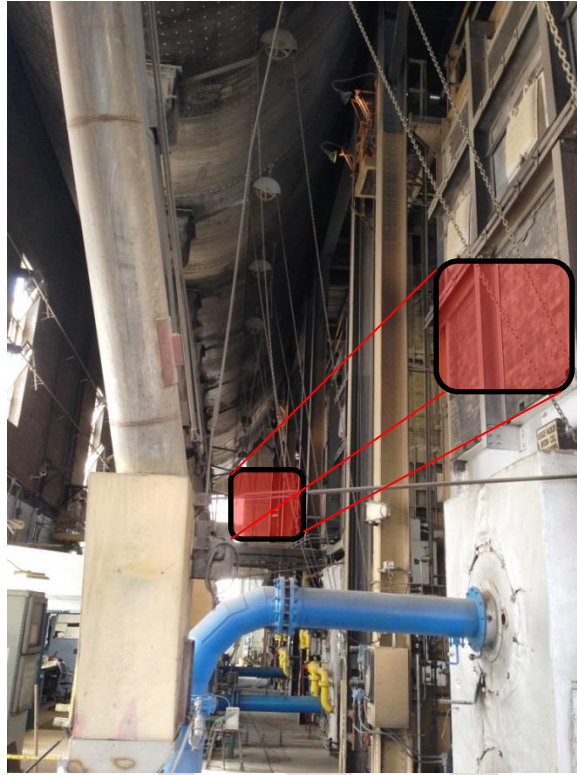


Figure 6 – Plant upper (Operating) level in front of Boiler #4 looking to the east towards Boilers 3, 2 and 1. HGG flue gas duct shown in red.

- c.** The envisioned modification to Boilers #1 and #4 will be to introduce hot gas from the biomass fired HGG into the boiler above the firebox as shown in Figures 8 and 9. The hot gas will flow through the generating bank and air preheater. At low boiler loads, the HGG gasses ducted into the boiler will provide the only heat required to generate steam. At higher loads, the boilers will be “co-fired” with coal, the heat from the HGG combining with the heat of coal combustion.

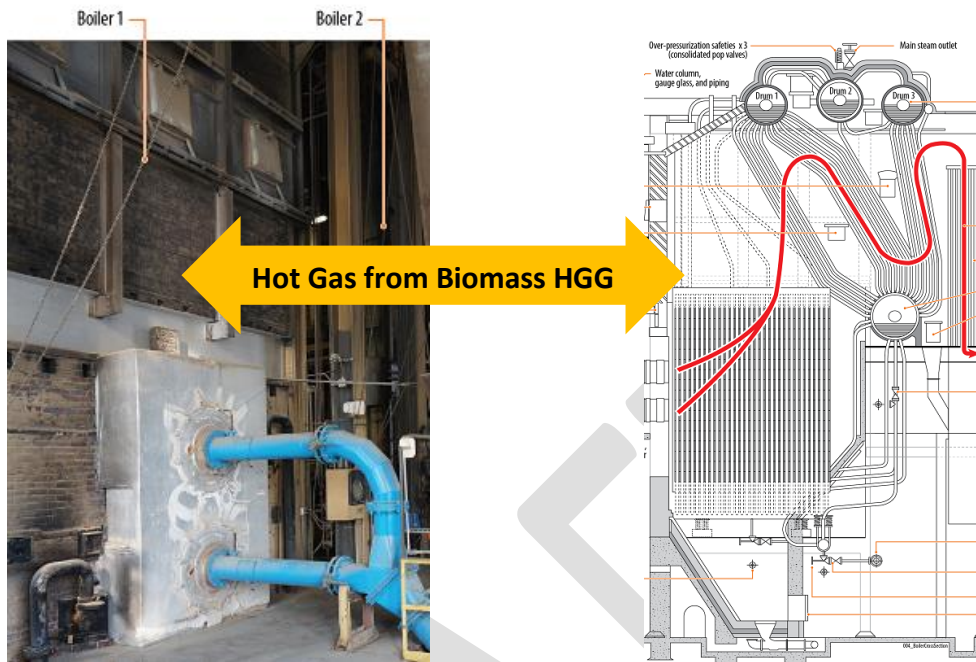


Figure 8 – Boiler location where hot gas will be introduced.



Figure 9 – Interior of firebox where hot gas will be introduced to boiler (left) and corresponding locations on exterior of boiler (right).

3.4 Existing Boiler Controls

- a. Six (6) Moore 353 (Siemens) controllers are installed for each boiler to automatically achieve boiler set point (225 psi) while maintaining proper boiler water level and firebox combustion. The six controllers are shown in Figure 10.



Figure 10 – Six controllers are installed for each boiler. The controllers are (clockwise from top left): Boiler Sub-Master; Coal Pulverizer, Forced Draft Fan; Drum Water Level; Induced Draft Fan; and Oxygen. Boilers 2 and 3 also have natural gas controllers as these two boilers are configured for gas operation.

- b. Each boiler control system also includes a fuel selector switch which adjusts control system parameters to optimize combustion for the particular fuel in use: bituminous (Eastern) coal or sub-bituminous (Western) coal. See Figure 11.



Figure 11 – Fuel Selector Switch.

- d. The general control logic interface envisioned between the biomass hot gas generator and the existing controls for boilers 1 and 4 is as follows:
- i. The preferred mode of operation will allow each boiler to generate between 25,000 and 55,000 lbs steam / hr using only the heat introduced from the biomass fired hot gas generator. If this can be achieved, the demand signal from the existing control system will be used to control the HGG firing rate and whatever dampers or other devices are employed to control the rate of heat input into each of the two boilers.
 - ii. If 55,000 lbs steam / hr cannot be achieved with HGG generated heat alone, a coal – HGG cofiring control scheme will be required. The current minimum sustainable firing rate while burning coal is 25,000 lbs steam / hour (below this firing rate, the coal flame is unstable). This minimum coal firing rate must be considered in the cofire control sequence.
 - iii. The safety logic described in Section 3.4.d. shall be incorporated so that heat input from the HGG is also stopped in the event of boiler low water level or high pressure.

FOUNDATION ANALYSIS

DULUTH STEAM - AQC

CITY OF DULUTH

FEBRUARY 12, 1979

SUMMARY OF IMPORTANT INFORMATION

The following foundation systems were evaluated for the support of the fabric filter addition, ash silo, and start-up oil tank.

- a. Mat or spread foundations in existing fill
- b. Mat or spread foundations in controlled compacted backfill after removal of fill
- c. Mat or spread foundations supported by friction piles or piers
- d. Mat or spread foundations supported on friction and end bearing piles
- e. Mat or spread foundations supported on end bearing piers

A mat or spread foundation supported on H-piles driven to bedrock is the recommended system for the fabric filter addition and ash silo structures. A mat foundation established in the existing fill is the recommended system for the start-up oil tank.

SUBSURFACE INVESTIGATION

A subsurface investigation program consisting of four rotary wash borings and associated laboratory testing was performed for the Duluth Steam - AQC site. The field investigation took place from November 13, 1978, through November 17, 1978. The borings were drilled and logged by Soil Exploration, Inc., under the supervision of Black & Veatch. The locations of the borings are shown on Figure 1, Plot Plan, and were located in the field by Black & Veatch. A summary of the information obtained from the borings is provided in Table 1. The boring logs and all laboratory test results are presented in the report "Soil Exploration - Duluth Steam - AQC" by Lakehead Testing Laboratory, Inc.

SUBSURFACE CONDITIONS

The borings at the site were drilled to 52.5 feet to 65.5 feet below the existing ground surface and penetrated four geologic units. The surficial unit is a man-made fill which blankets the site. Underlying the fill is a lacustrine deposit, the upper layer of the deposit consists of a coarse sand and gravel, and the lower layer consists of a fine sand. Beneath the lacustrine unit is a silt glacial till layer which directly overlies the

bedrock. The bedrock consists of amygdaloidal basalt. Water was present in all the borings at a depth of approximately 5 feet, coinciding with the level of Lake Superior. A cross section of subsurface conditions beneath the site is shown on Figure 2. A description of the stratigraphic unit beneath the site is presented in the following sections.

Fill - The fill material consists of a brown, dark brown and black very soft to stiff silty sand and lean clay, with some gravel, ashes, glass, wood chips, and sawdust. The thickness of the fill varies from 9.0 feet in Boring 3 to 10.5 feet in Boring 1. Borings 1 and 2 were drilled through Railroad Street which had a thin layer of asphalt and concrete surfacing. Boring 2 had a 2-foot layer of fibrous peat at the base of the fill.

Lacustrine Deposit - The fill is underlain by a sequence of sands and gravels thought to have been deposited as part of the Lake Superior shoreline. The upper layer consists of a dense to very dense, brown, medium to coarse-grained sand and gravel with a trace of organics and a few cobbles. The thickness of this layer varies from 10.5 feet to 13.9 feet. It appears that the upper layer varies laterally in composition. In Borings 1 and 4, this layer consists predominantly of gravel with a few cobbles and organics. In Boring 3, it is medium to coarse-grained sand with gravel with layers of organics and peat below 21 feet. In Boring 2, the layer consists of a 5-foot thick layer of loose, medium-grained sand with some gravel and organics that overlies 5.5 feet of dense to very dense gravel.

Below the coarse sand and gravel layer lies a brown, very dense fine-grained sand with traces of gravel and organics. The thickness of this layer varies from 24.1 feet to 27.0 feet. The bottom 4 feet to 8 feet of this layer above the glacial till is dense.

Glacial Till - Underlying the lacustrine unit and overlying the bedrock is a grayish-brown, very stiff silt with some gravel and a few cobbles. The thickness of the till varies from 1.5 feet to 5.0 feet.

Bedrock - The bedrock is a slightly weathered to fresh, dark gray, hard amygdaloidal basalt with olivine filled vesicles and occasional calcite veins. It is moderately close to widely jointed, and slopes towards Lake Superior.

ENGINEERING PROPERTIES

The purpose of the subsurface investigation was to analyze and evaluate the capability of the geologic units to support the proposed structures. On the basis of the drilling results and laboratory testing, the engineering properties of the geologic units are summarized in the following sections. A typical subsurface profile with engineering properties used in the engineering analysis is presented on Figure 3.

Fill - The fill is made up of material of variable nature and consistency. The unconfined compressive strength of the two samples tested varied from 1.3 ksf to 2.3 ksf, the stress-strain plots of these tests indicate that this material is highly compressible. The modulus of elasticity for the fill is 115 ksf calculated from the SPT blow counts and unconfined compressive tests. On the basis of the SPT blow counts and compressive strength, the fill is not adequate for direct bearing material for heavy or settlement sensitive structures.

Lacustrine Deposit - The initial 5.0 feet to 10.0 feet and bottom 4.0 feet to 8.0 feet of the unit is medium dense to dense, and the rest of the unit is very dense. The modulus of elasticity values calculated from the SPT blow counts for this unit are 300 ksf, 550 ksf, and 400 ksf for the top, middle, and bottom of the unit. The angle of internal friction was calculated to be 30° for the upper 10 feet and 35° for the rest of the unit.

Glacial Till - The glacial till consists of a very stiff non-plastic silt with some gravel and a few cobbles. The modulus of elasticity for the glacial till was calculated as 450 ksf.

Bedrock - The bedrock consists of a very competent slightly weathered to fresh basalt. The allowable bearing capacity of the bedrock is estimated to be 100.0 ksf.

FOUNDATION RECOMMENDATIONS

Five types of foundation systems were evaluated for the fabric filter addition, ash silo, and start-up oil tank. The foundation systems are:

- a. Mat or spread foundations in existing fill
- b. Mat or spread foundations in controlled compacted backfill after removal of fill
- c. Mat or spread foundations supported by friction piles or piers
- d. Mat or spread foundations supported on friction and end bearing piles
- e. Mat or spread foundations supported on end bearing piers

System (b) was eliminated because it was determined it was not economical or practical to remove and replace the 10-foot thick layer of fill, of which 5 feet is below the water table with controlled compacted backfill. System (c) and (d) were limited to low displacement H-piles because of the possibility of affecting existing structures by driving high displacement piles close by. System (c) was ruled out because of the low allowable frictional capacities available above the bedrock. System (e) was ruled out because it was not economical, there was a possibility of undermining the existing structures during drilling, and the difficulty in drilling the shafts in submerged sands and gravels with cobbles.

Fabric Filter Addition - An H-pile foundation founded on bedrock is recommended to be used for the support of the fabric filter addition. A pile foundation founded bedrock is required to avoid excessive total and differential settlements. Total and differential settlements will be less than 1/4-inch.

Allowable single pile end bearing capacities have been calculated for three H-pile sizes, based on 12,000 psi allowable stress in the pile with the soil providing adequate lateral support.

<u>Pile</u>	<u>Allowable Pile Capacity (tons)</u>
HP 8 x 36	60
HP 10 x 42	70
HP 12 x 53	90

Ash Silo - An H-pile foundation founded on bedrock is recommended to be used for the support of the ash silo, if it is to be relocated. A pile foundation founded on bedrock is required to avoid excessive differential settlement. Total and differential settlements will be less than 1/4-inch.

Allowable single pile capacities are the same as those presented for the fabric filter addition.

Start-up Oil Tank - A mat foundation founded on the fill material is recommended for the start-up oil tank, if it is to be relocated. If the tank is to be founded on the existing pavement of Railroad Street, no foundation preparation is required. If the pavement is removed and the tank is not located over the pavement, the existing fill should be stripped for a minimum of 2 feet, and replaced with controlled compacted granular backfill. The mat foundation for the start-up oil tank will settle up to 1.5 inches under the center of the tank, and have a maximum differential settlement on the order of 1 inch between the center and the edge.

TABLE 1
BORING SUMMARY

BORING NO.	SURFACE ¹ ELEV. (ft)	THICKNESS OF FILL (ft)	ELEV. OF TOP OF UPPER SAND AND GRAVEL (ft)	THICKNESS OF UPPER SAND AND GRAVEL (ft)	ELEV. OF LOWER SAND (ft)	THICKNESS OF LOWER SAND (ft)	ELEV. OF TOP OF TILL (ft)	THICKNESS OF TILL (ft)	ELEV. OF TOP OF BASALT (ft)
1	99.3	10.5	88.8	10.5	78.3	25.0	53.3	1.5	51.8
2	99.7	10.0	89.7	11.0	78.7	24.5	54.2	2.5	51.7
3	99.2	9.0	90.2	13.9	76.3	24.1	52.2	4.5	47.7
4	99.6	9.5	90.1	12.0	78.1	27.0	51.1	5.0	46.1

¹Datum is assumed to be 100.0 and referenced to the floor of the existing building at the northeast entrance.

 BORING LOCATION

RAILROAD STREET



AREA AVAILABLE
FOR FABRIC
FILTER ADDITION

CHIMNEY



ASH
SILO

GARAGE

START UP
OIL TANK

CITY OF DULUTH STEAM PLANT

20' 10' 0 20' 40'
SCALE: 1" = 20'

PLOT PLAN



FIGURE 1

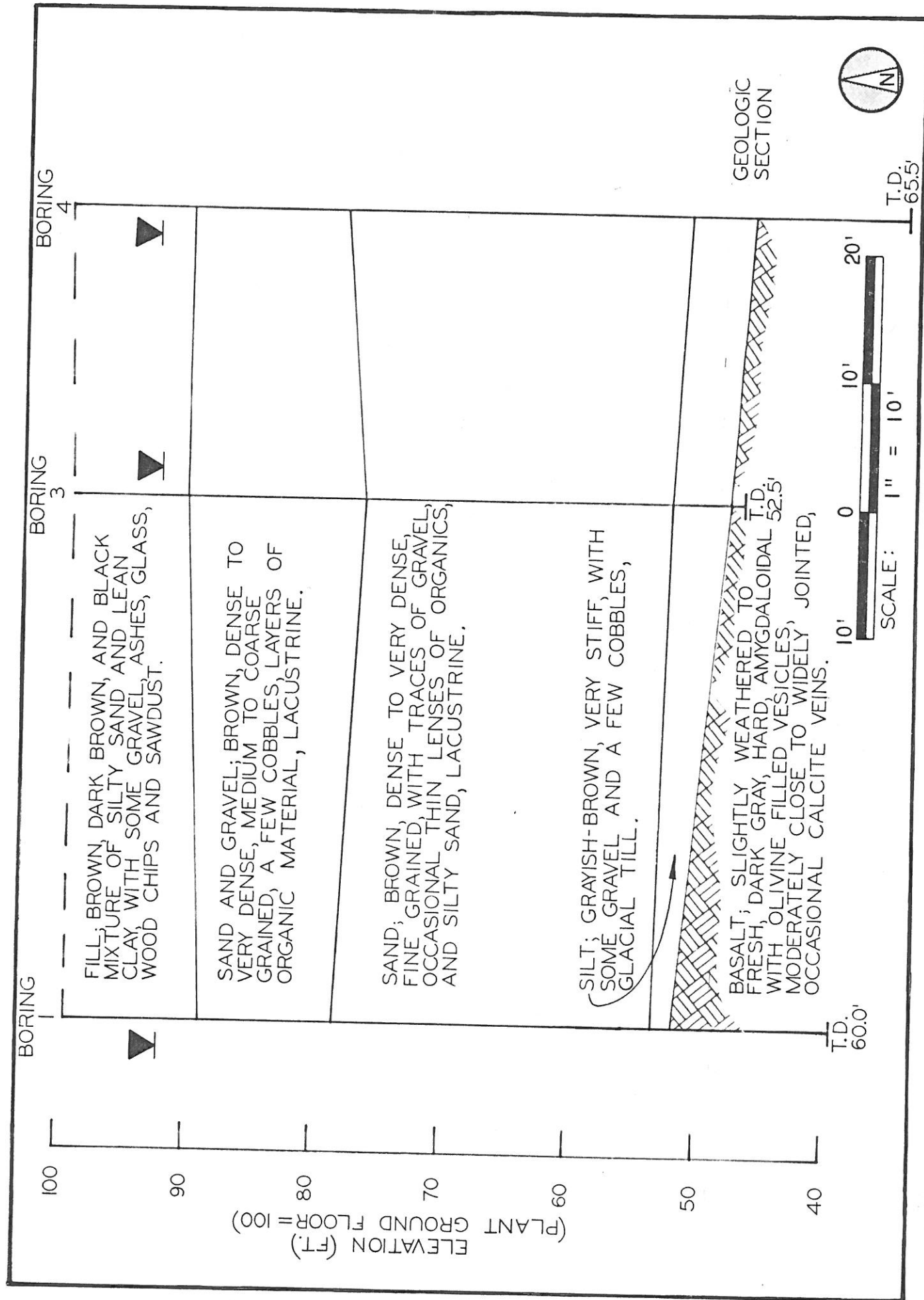
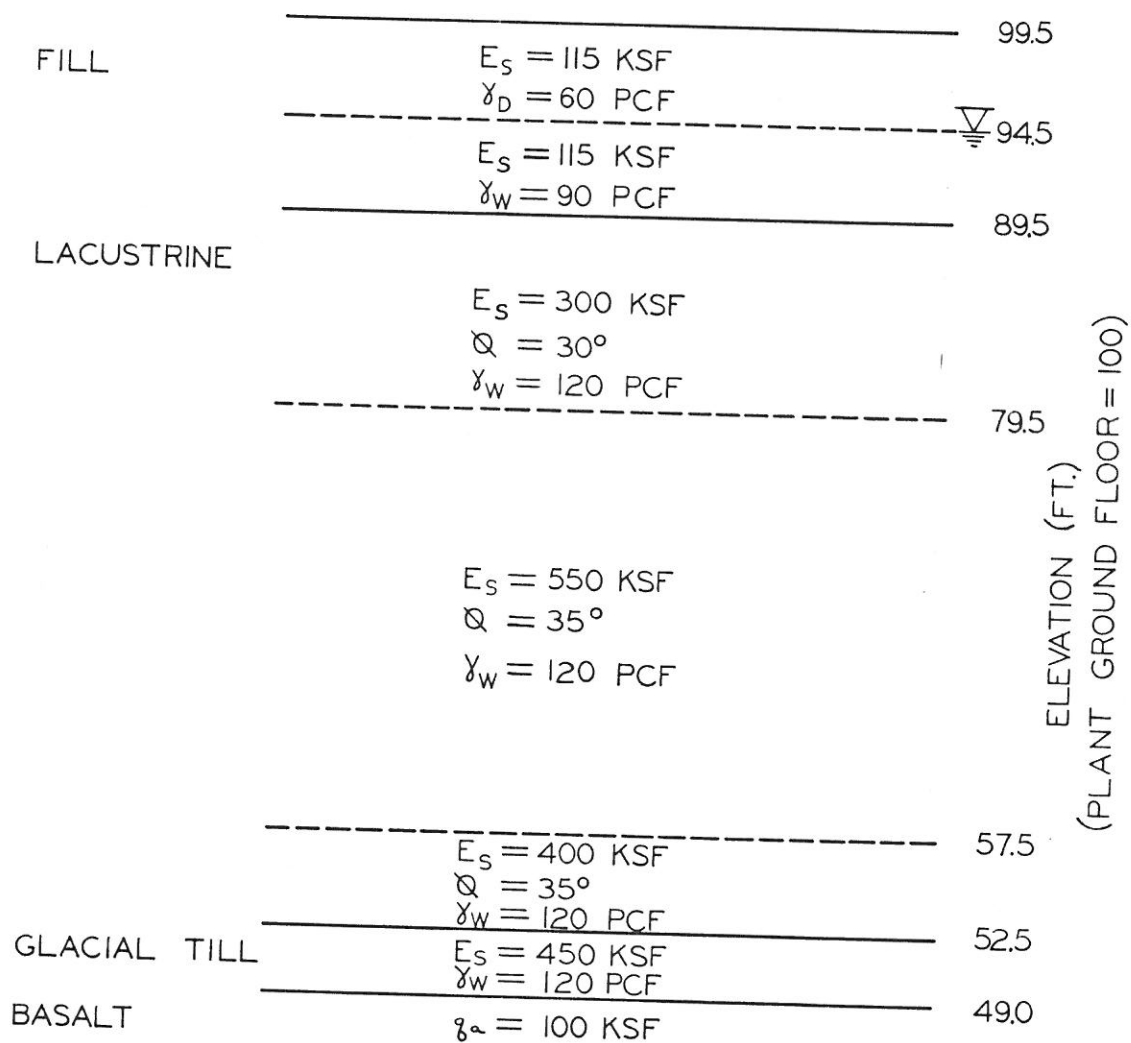


FIGURE 2



LEGEND

E_s = MODULUS OF ELASTICITY
 γ_D = UNIT WEIGHT OF DRY SOIL
 γ_W = UNIT WEIGHT OF MOIST SOIL
 ϕ = ANGLE OF INTERNAL FRICTION
 γ_a = ALLOWABLE BEARING CAPACITY

TYPICAL SUBSURFACE PROFILE

FIGURE 3

**REPORT OF
GEOTECHNICAL EXPLORATION/REVIEW
FOR
PROPOSED NEW COAL PULVERIZER
DULUTH STEAM COOPERATIVE PLANT
DULUTH, MINNESOTA**

AET #94-7588

PREPARED FOR:

**DULUTH STEAM COOP ASSOCIATION
1 LAKE PLACE DRIVE
DULUTH, MINNESOTA 55802**



**AMERICAN
ENGINEERING
TESTING, INC.**

CONSULTANTS
• GEOTECHNICAL
• MATERIALS
• ENVIRONMENTAL

February 28, 1994

Mr. Gerald W. Pelofske
Duluth Steam Coop Association
1 Lake Place
Duluth, Minnesota 55802

Re: Geotechnical Exploration/Review
Proposed New Coal Pulverizer
Duluth Steam Cooperative Plant
Duluth, Minnesota
AET #94-7588

Dear Mr. Pelofske:

The following report contains the findings of our subsurface exploration program and geotechnical engineering review for the above referenced project. We are sending you three copies of our attached report. This report documents the exploration/test results and provides our opinions and recommendations to aid you and the design team in planning and construction of the project.

American Engineering Testing, Inc. appreciates this opportunity to serve you. As your project proceeds, we remain interested in providing additional consulting or testing services. If you have any questions about the report, or if we can provide additional services to you, please feel free to contact us.

Sincerely,

Kristopher A. Lyytinen, P.E.
Geotechnical Engineer

Thomas G. Krzewinski, P.E.
Principal Engineer

KAL/pam

"AN AFFIRMATIVE ACTION EMPLOYER"

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**REPORT OF
GEOTECHNICAL EXPLORATION/REVIEW
FOR
PROPOSED NEW COAL PULVERIZER
DULUTH STEAM COOPERATIVE PLANT
DULUTH, MINNESOTA
AET #94-7588**

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REPORT OF
GEOTECHNICAL EXPLORATION/REVIEW
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DULUTH STEAM COOPERATIVE PLANT
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AET #94-7588

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APPENDIX

- Boring Location Sketch
- Logs of Test Borings
- Results of Sieve Analysis Tests
- Results of Atterberg Limit Tests
- Results of Unconfined Compression Tests
- Field Sampling and Testing Methods
- Boring Log: Abbreviations, Notations and Symbols
- Identification of Soils
- Soil Identification and Description
- Geologic Terminology
- Boring Logs: Ground Water Information

**REPORT OF
GEOTECHNICAL EXPLORATION/REVIEW
FOR
PROPOSED NEW COAL PULVERIZER
DULUTH STEAM COOPERATIVE PLANT
DULUTH, MINNESOTA
AET #94-7588**

SUMMARY

Purpose

The Duluth Steam Coop Association is proposing to add a new Coal Pulverizer at the Duluth Steam Cooperative Plant in Duluth. The purpose of our work on this project is to obtain subsurface information, and based on this data, prepare a geotechnical engineering report presenting comments and recommendations to assist you and the design team in the planning and construction of the project.

Scope

To accomplish the above purpose, you have authorized our firm to drill three test borings, perform laboratory tests, and furnish a geotechnical exploration report for the proposed construction.

Findings

The borings encountered 8 to 9.5 feet of fill consisting primarily of sand with gravel with some cinders, coal, bricks, glass and other debris overlying the native soils. Beneath the fill the borings encountered medium dense to dense, fine to medium grained sand beach deposits which extended to the boring termination depths. Two of the borings encountered peat between the fill and the natural inorganic soils. This organic layer extended to depths of up to 14.5 feet.

Recommendations

These recommendations are in condensed form for your convenience. It is important that you study our entire report for detailed recommendations.

- We recommend that the proposed new pulverizer be supported on timber piles driven approximately 15 to 20 feet into the dense beach deposits or on 12 to 14 inch auger cast piles bearing on the dense beach deposits. These types of deep foundations are capable of developing allowable capacities of up to 30 to 40 tons per pile. The piles will have lengths of 25 to 35 feet and 15 to 20 feet for the timber piles and auger cast piles, respectively.

INTRODUCTION

The Duluth Steam Coop Association plans to construct a new coal pulverizer at the Duluth Steam Cooperative Plant in Duluth. You have authorized American Engineering Testing, Inc. (AET), to conduct a subsurface exploration program and provide geotechnical engineering recommendations for the project. This report presents the field information we obtained at the site, and also our engineering recommendations.

To protect you, AET, and the public, we authorize use of opinions and recommendations in this report only by you and your project team for this specific project. Contact us if other uses are intended. Even though this report is not intended to provide sufficient information to accurately determine quantities and locations of particular materials, we recommend that your potential contractors be advised of the availability of the report.

Scope of Services

Our scope of services for this project was presented to you in our written proposal dated December 20, 1993. A review of our agreed-upon scope of services is as follows:

- Drill three standard penetration test (SPT) borings at the site to an anticipated depth of 30 feet. The borings were located within the existing steam plant in the footprint of the planned new coal pulverizer foundation. The soils were sampled by the split spoon method in accordance with ASTM:D1586.
- Perform a limited number of geotechnical laboratory tests to aid in classifying the soil types and predicting their soil properties.
- Prepare a formal engineering report including logs of the test borings, a sketch indicating boring locations, presentation of soil and ground water conditions, the laboratory test results, and our geotechnical opinions and recommendations regarding the following:

- Site preparation
- Foundation types and depths, including allowable soil bearing pressure and estimated settlement
- Construction and post construction groundwater control

The scope of our work is intended for geotechnical purposes only. This scope is not intended to explore for the presence or extent of environmental contamination at the site.

PROJECT INFORMATION

We understand that the Duluth Steam Coop Association plans to add a new coal pulverizer at the Duluth Steam Cooperative Plant in Duluth. We understand that a pile foundation is anticipated but acknowledge that access is limited and that low headroom conditions may impair pile installation. The new pulverizer will weigh approximately 22 tons and will be supported on a 20 by 20 foot concrete slab. The existing structures at the site are supported on timber and/or auger cast piles. No additional loading conditions were available at the time that this report was written.

The presented project information represents our understanding of the proposed construction. This information is an integral part of our engineering review. It is important that you contact us if there are changes from that described so that we can evaluate whether changes in our recommendations are appropriate.

SITE CONDITIONS

Surface Observations

The site is located at the Duluth Steam Cooperative Plant in Duluth. The area planned for the foundation is located within the existing plant building and has approximately 15 feet of

clearance. The borings were drilled at locations determined by Duluth Steam personnel. Elevations were determined by an AET drill crew and are referenced to the existing floor. We assigned an assumed elevation of +100.0 feet to this benchmark. A sketch showing the boring locations is included in the Appendix of this report.

Subsurface Soils/Geology

We have included the logs of the test borings and a boring location sketch in the Appendix of this report. We refer you to these logs for specific information concerning soil layer depths, soil/geology descriptions and density/consistency, based on the penetration resistance. It is important to note that the subsurface conditions only indicate the material classification/properties at the sampled locations and variations do occur between and beyond borings.

Based on our interpretation of the available boring information, it is our judgment that the generalized soil profile consists of 8 to 9.5 feet of fill consisting primarily of sand with gravel with some clay and other miscellaneous debris, overlying the native soils. Beneath the fill, the borings encountered medium dense to dense, fine to medium grained beach deposited sands and gravel extending to the boring termination depths. Two of the borings encountered a layer of peat extending to depths of up to 14.5 feet.

Ground Water

During our drilling operations, we probed the boreholes for the presence of free ground water. The results of these measurements are noted on the attached boring logs and indicate that free water was encountered in all of the borings at depths ranging from 6 to 8.5 feet. The water levels noted correspond to the level of Lake Superior. The water table should mirror variations in the level of Lake Superior.

The attached Appendix sheet entitled "Boring Logs: Ground Water Information" provides additional information on ground water level measuring.

LABORATORY TESTS

Recovered samples were selected for laboratory testing which consisted of three sieve analysis tests. The results of the laboratory tests which were used to aid in classifying and judging the engineering properties of the soils, are indicated on the boring logs opposite the samples upon which they were performed and on separate sheets following the boring logs.

ENGINEERING CONSIDERATIONS

Review of Soil Properties

- Strength - The fill layer encountered at the site is judged to have a variable strength due to its loose uncontrolled nature and the presence of the miscellaneous debris. The underlying beach deposit is judged to have a high strength. We estimate an angle of internal friction exceeding 30° for these soils.
- Compressibility - The fill layer and the organic soils are judged to have a high compressibility due to its loose uncontrolled nature and the nature of organic soils. The underlying beach deposits are judged to have a very low compressibility.

RECOMMENDATIONS

Site Preparation

To prepare the area for construction, we recommend removing the existing floor and any other structures (foundations, utilities, etc.). We do not recommend removal and replacement of the

organic soils with engineered fill as damage to the existing structure may occur as well as being below the water table making construction extremely difficult.

Where fill is required to attain or reattain grade, we recommend bringing the site up to grade with clean granular (NFS) material. We recommend that sand or sand and gravel material meeting the following gradation requirements be used:

Sieve Size	Percent Passing
4"	100%
2"	80 to 100
#4	60 to 100
#200	0 to 10

All fill should be placed in relatively thin, loose lifts and should be compacted to a minimum of 95% of maximum Modified Proctor Density (ASTM:D1557).

Pile Foundations

Based on our review of the available subsurface data and our understanding of the proposed construction, we recommend that the proposed machinery be supported on relatively short pile foundations. If limited headroom access is not a problem, we recommend that Class B treated timber piles with a minimum tip diameter of 7 inches be used to support the new pulverizer. It is our opinion that piles of this type driven 15 to 20 feet into the dense beach deposits will develop allowable capacities of up to 30 tons per pile in compression. This will give pile lengths on the order of 25 to 35 feet. We recommend that this capacity be reduced by 5 tons to account for downdrag loadings due to settlement of the fill and the consolidation of the organics, leaving 25 tons of capacity available for structural support. We recommend that the pile installations

be observed by a Geotechnical Engineer or his representative to verify that design capacities have been met and that embedment is sufficient to develop ultimate loads.

The piles should be installed using a steam, air, or diesel hammer that has an energy rating in the range of 15,000 to 20,000 foot pounds. Pile capacities should be verified during installation using a standard driving formula such as the Minnesota Highway Department relationship.

If limited headroom conditions prohibit the installation of driven piles, we recommend placement of auger cast piles for support of the structure. These piles can be 12 inch, 14 inch, or 16 inch in diameter and should penetrate approximately 5 feet into the dense beach deposits, giving pile lengths of 15 to 20 feet. These piles will develop allowable working loads of 40 tons, 55 tons, and 70 tons, respectively. These piles have an added benefit of providing lateral capacity to the installation. We recommend that the 16 inch diameter auger cast piles be used only if higher lateral capacities are required, as installation costs are significantly higher in low headroom areas.

Another option that can be explored is the use of helical piles, such as those made by CHANCE. These piles consist of steel flights attached to small diameter rods which are screwed into place. These piles should be installed to a depth sufficient to allow the helixes to penetrate the beach deposit, giving pile lengths of 15 to 20 feet. Installing these piles to the anticipated depths will develop allowable capacities of 10 tons per pile. If these piles are installed in a grid pattern with the outside edge piles battered to the outside, additional lateral capacity can be attained. If this foundation system is feasible we would be please to work with you in developing a design.

CONSTRUCTION OBSERVATION AND TESTING

The recommendations in this report are based on the subsurface conditions found at our test boring locations. Since the soil conditions can be expected to vary away from the soil boring

locations, we recommend that on-site observation be performed by a Geotechnical Engineer or his representative during construction to evaluate the effect of potential changes. Soil density testing should also be performed on all new fill placed in order to document that project recommendations or specifications for compaction and moisture have been satisfied. Where fill material type is important, sieve analysis tests should be performed to document that the actual fill material meets the recommended gradation criteria. We also recommend that pile installations and procedures be reviewed and observed by a Geotechnical Engineer.

EXPLORATION PROCEDURES

Boring Location/Elevation Data

Our subsurface exploration program included drilling three standard penetration test borings within the footprint of the new pulverizer foundation. These borings were drilled at the site between February 4 and 8, 1994. The locations of the borings were marked by Duluth Steam personnel. The elevations were determined by an AET drill crew and are referenced to the existing floor. We assigned an assumed elevation of +100.0 ft for the floor. The boring locations and elevations are shown on the sketch included in the Appendix of this report.

Field Sampling/Testing Methods

The field sampling methods for the borings are described on the included data sheet under the subheading "Standard Penetration/Split-Spoon Sampling Method."

Classification Methods

For soil samples in which no sieve analysis or Atterberg Limits tests are performed, soil identifications and descriptions shown on the boring logs are judgments based on ASTM:D2488-90 (Visual-Manual Procedure). Charts taken from ASTM:D2488-90 are shown on the appended sheet entitled "Identification of Soils". Where the classification tests have been performed,

ASTM:D2487-92 is used. The logs also indicate the apparent geologic depositional origin, which is interpretive.

Sample Storage

We will retain representative samples of the soils recovered from the borings for a period of 30 days. The samples will then be discarded unless you notify us otherwise.

EXPLORATION PROGRAM LIMITATIONS

The data derived through this sampling and observation program have been used to develop our opinions about the subsurface conditions at your site. However, because no exploration program can totally reveal what is in the subsurface, conditions at other times and locations on this site, may differ from conditions described in this report. The exploration program which we conducted identified subsurface conditions only at those points where we took samples or observed ground water conditions. Depending on the sampling methods and sampling frequency, every soil layer may not be observed, and some materials or layers which are present may not be noted on the boring logs.

Unless actually observed in a sample, contacts between soil layers are estimated based on the spacing of samples and the action of drilling tools. Thus, most contacts shown on the logs are approximate, with possible upper and lower limits of contacts defined by the overlying and underlying samples.

Cobbles, boulders, and other large objects generally cannot be recovered from test borings, and may be present in the ground even if they are not noted on the boring logs.

If conditions encountered during construction differ from those indicated by our borings, it may be necessary to alter our conclusions and recommendations, or to modify construction procedures.

The extent and detail of subsurface information is directly related to the scope of the exploration. It should be understood, therefore, that additional information can be obtained by means of additional exploration.

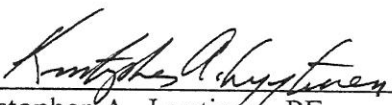
STANDARD OF CARE

Our services for your project have been conducted to those standards considered normal for services of this type at this time and location. Other than this, no warranty, either express or implied, is intended.

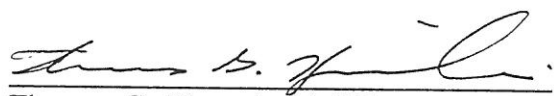
CLOSURE

Report Prepared by:

Under direct supervision of:



Kristopher A. Lyytinen, PE
Geotechnical Engineer



Thomas G. Krzewinski, PE
Principal Engineer





SUBSURFACE BORING LOG

AET JOB NO: **94-7588**

LOG OF BORING NO. **94-1 (p. 1 of 2)**

PROJECT: **PROPOSED COAL PULVERIZER - DULUTH STEAM; DULUTH, MINNESOTA**

DEPTH IN FEET	SURFACE ELEVATION: <u>100.0'</u> MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC. IN.	FIELD & LABORATORY TESTS				
							WC	DEN	LL	PL	%-200
	Concrete Slab - 7" thickness	CONCRETE									
1	Fill - Sand with gravel, some cinders and coal at 6 feet, moist, loose, brown (SP)	FILL	3	M	SS	3					
2			6	M	SS	4					
3											
4											
5			5	W	SS	12					
6	Fill - Clay with some sand, moist to wet, soft, brown (CL)	FILL									
7			2	W	SS	6					
8											
9											
10	Peat, with some fill, wet, soft, organic, black (Pt)	SWAMP DEPOSIT	2	WB	SS	13					
11											
12			7	WB	SS	3					
13											
14	Sand, fine grained, some gravel and cobbles, waterbearing, medium dense to dense, brown (SP)	BEACH DEPOSIT	28	WB	SS	16	17		NP	NP	5
15											
16											
17											
18											
19											
20			50/0.2	WB	SS	6					
21											

DEPTH: DRILLING METHOD		WATER LEVEL MEASUREMENTS							NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG
		DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL	
0-29' 2.25" HSA		2-5-94	2:30	30.5'	29'	29'		6.0'	
BORING COMPLETED: 2/5/94									
CC: LA CA: RW Rig: SKID RIG									






SUBSURFACE BORING LOG

AET JOB NO: **94-7588**

LOG OF BORING NO. **94-1 (p. 2 of 2)**

PROJECT: **PROPOSED COAL PULVERIZER - DULUTH STEAM; DULUTH, MINNESOTA**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC. IN.	FIELD & LABORATORY TESTS				
							WC	DEN	LL	PL	%-200
23	Sand, fine grained, some gravel and cobbles, waterbearing, medium dense to dense, brown (SP)	 BEACH DEPOSIT	28	WB	 SS	6					
24											
25											
26											
27											
28											
29	END OF BORING		33	WB	 SS	3					
30											
	Borehole grouted full with bentonite-cement grout - Surface was patched with concrete										



SUBSURFACE BORING LOG

AET JOB NO: **94-7588**

LOG OF BORING NO. **94-2 (p. 1 of 1)**

PROJECT: **PROPOSED COAL PULVERIZER - DULUTH STEAM; DULUTH, MINNESOTA**

DEPTH IN FEET	SURFACE ELEVATION: <u>1000.0'</u> MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC. IN.	FIELD & LABORATORY TESTS				
							WC	DEN	LL	PL	%-200
	Concrete Slab - 5" thickness	CONCRETE									
1	Fill - Silty Sand with bricks, gravel, glass, loose, moist to wet, brown (SM)	FILL	3	M	SS	5	18		NP	NP	33
2			25	M	SS	6					
3											
4											
5		SWAMP DEPOSIT	4	W	SS	12					
6											
7			2	W	SS	16					
8	Peat, wet, soft, organic, black (Pt)										
9		BEACH DEPOSIT	15	WB	SS	4					
10	Sand with gravel, some cobbles, some silty sand, medium grained, waterbearing (SP)										
11			29	WB	SS	10					
12											
13		BEACH DEPOSIT	36	WB	SS	13					
14											
15											
16											
17		BEACH DEPOSIT	50/0.2	WB	SS	2					
18											
19											
20											
21	END OF BORING Borehole grouted to surface										

DEPTH: DRILLING METHOD		WATER LEVEL MEASUREMENTS							NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG
0-19.5'	2.25" HSA	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL	
		2-5-94	10:30	21'	19.5'	19.5'		6.0'	
BORING COMPLETED: 2/5/94									
CC: LA CA: RW Rig: SKID RIG									




SUBSURFACE BORING LOG

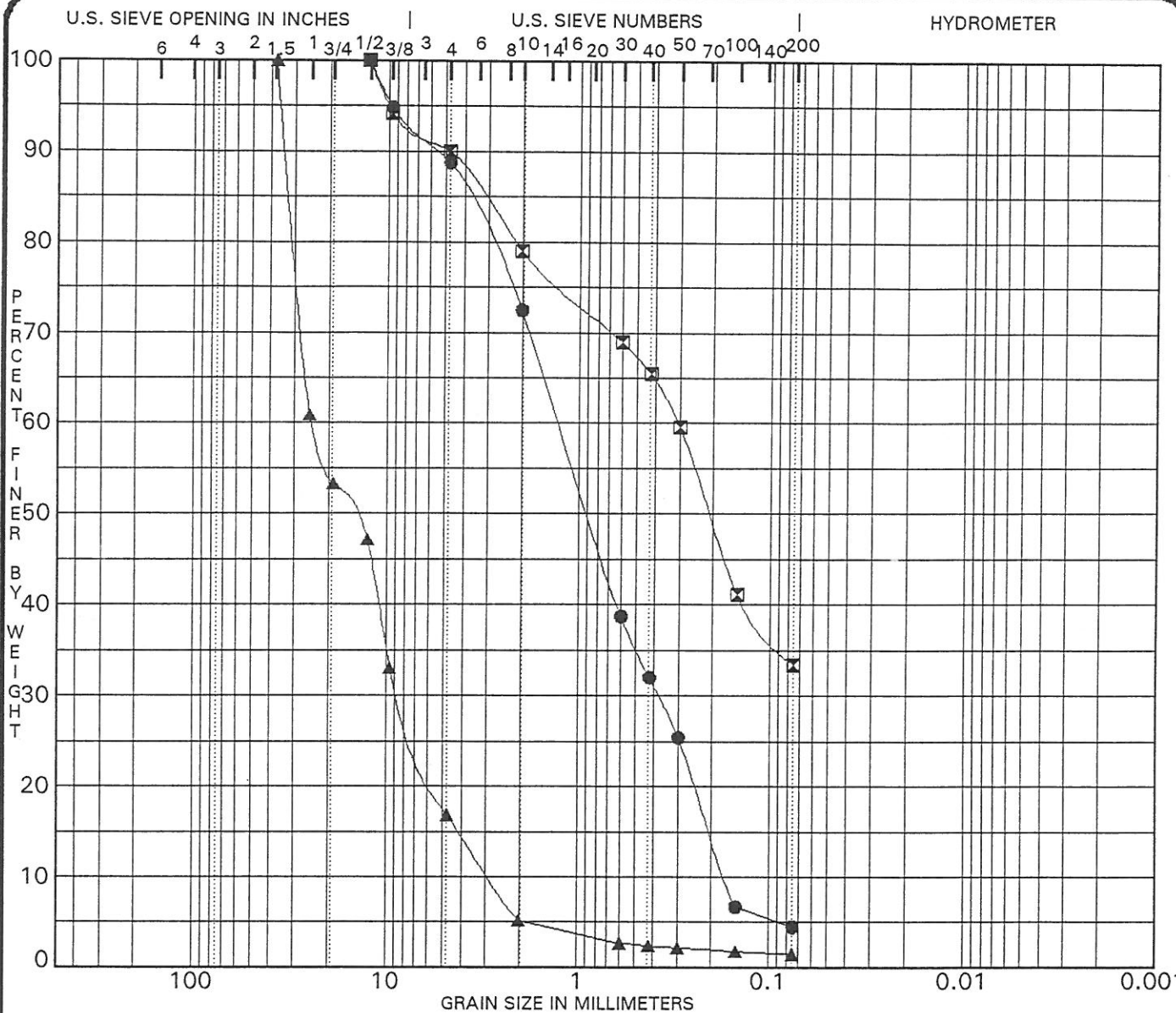
AET JOB NO: **94-7588**

LOG OF BORING NO. **94-3 (p. 1 of 1)**

PROJECT: **PROPOSED COAL PULVERIZER - DULUTH STEAM; DULUTH, MINNESOTA**

DEPTH IN FEET	SURFACE ELEVATION: <u>100.0'</u> MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC. IN.	FIELD & LABORATORY TESTS				
							WC	DEN	LL	PL	%-200
	Concrete Slab - 6" thickness	CONCRETE									
1	Fill - Sand with bricks, gravel, glass, loose, moist to wet, brown (SP)	FILL	7	M	SS	12					
2			2	M	SS	1					
3											
4											
5			2	W	SS	15					
6											
7	Possible Fill - Fat Clay, wet, soft, brown (CH)	POSSIBLE FILL	11	W	SS	13					
8											
9											
10	Gravel with sand, coarse grained, waterbearing, medium dense to dense, brown (GP)	BEACH DEPOSIT	15	WB	SS	10	18		NP	NP	2
11											
12			19	WB	SS	14					
13											
14											
15			35	WB	SS	14					
16											
17											
18											
19											
20			50/0.3	WB	SS	7					
21	END OF BORING Borehole grouted to surface										

DEPTH: DRILLING METHOD		WATER LEVEL MEASUREMENTS							NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG
0-19.5'	2.25" HSA	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL	
		2-8-94	11:30	21'	19.5'	19.5'		8.5'	
BORING COMPLETED: 2/8/94									
CC: LA CA: RW Rig: SKID RIG									



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

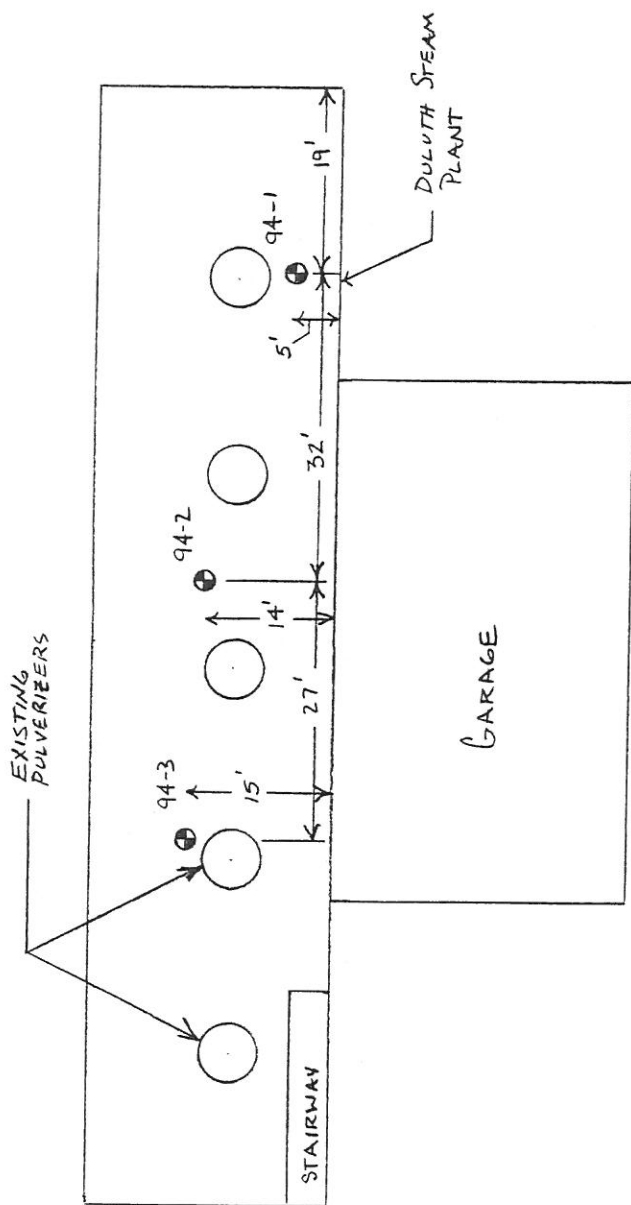
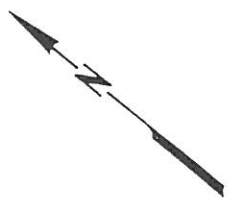
Specimen Identification	Classification		MC%	LL	PL	PI	Cc	Cu
● 94-1 14.5	Sand with gravel, brown (SP)		17	NP	NP	NP	0.67	7.6
☒ 94-2 0.5	Silty Sand with gravel (SM)		18	NP	NP	NP		
▲ 94-3 9.5	Gravel, with sand, brown (GP)		18	NP	NP	NP	1.01	8.5

Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● 94-1 14.5	12.50	1.28	0.382	0.1695	11.3	84.2	4.5	
☒ 94-2 0.5	12.50	0.31			10.1	56.5	33.4	
▲ 94-3 9.5	37.50	24.20	8.356	2.8610	83.2	15.3	1.5	

PROJECT **PROPOSED COAL PULVERIZER - DULUTH**
STEAM - DULUTH, MINNESOTA

JOB NO. **94-7588**
DATE **2-16-94**

GRADATION CURVES
American Engineering Testing
Duluth, Minnesota



SOIL BORING LOCATIONS
PROPOSED COAL PULVERIZER
DULUTH STEAM COOPERATIVE PLANT
DULUTH, MINNESOTA
AET # 94-7588
SCALE 1" = 20'

