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South Dakota Sites for Straw Pulping Plants

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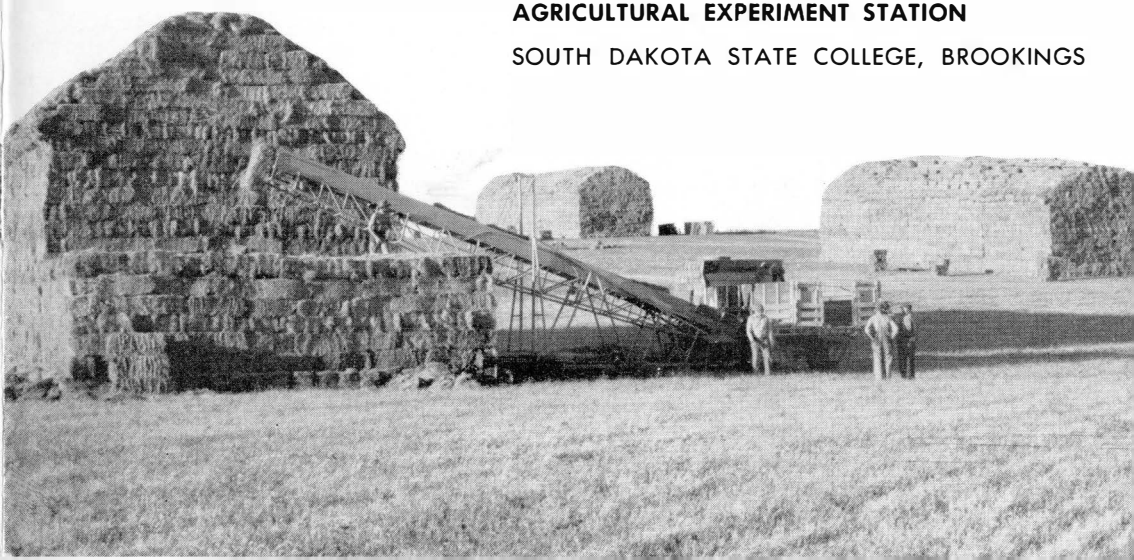
SOUTH DAKOTA SITES FOR **straw pulping plants**

ECONOMICS DEPARTMENT
AGRICULTURAL EXPERIMENT STATION
SOUTH DAKOTA STATE COLLEGE, BROOKINGS



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South Dakota Sites for Straw Pulping Plants[1]

R. L. KRISTJANSON and WINSTON K. ULLMAN[2]

South Dakota is frequently designated as the most agricultural state in the nation. Within its borders there are only two cities—Sioux Falls and Rapid City—whose populations exceed 25,000. Of the total personal income of $895 million earned in South Dakota in 1954, 256 million or 28.7 percent was derived directly from farming.[3] In addition, a substantial part of the business carried on in South Dakota is largely dependent upon the agricultural sector.

This situation poses certain problems. Agriculture in South Dakota suffers from the instability of two factors—price and weather. Because of this instability, when prices are unfavorable or weather is unsuitable, the whole economy of South Dakota suffers. Superimposed on this problem of income instability is the trend toward increased size of farms. Modern farming techniques, which require larger operating units, have contributed to the fact that fewer and fewer people are now living on farms. According to the United States census, the rural population of South Dakota decreased 10 percent in the period from 1940 to 1950. The total population of South Dakota showed an increase of only 1½ percent in the same period, while the population of the nation as a whole increased 14½ percent.[4]

One solution to agricultural income instability and the lack of growth in population is the introduction of industry into the state. A recent industrial conference at Huron, April 13 and 14, 1955, launched a program to encourage all industrial development in South Dakota.

[1]This publication contains information developed under a contract of the U. S. Department of Agriculture and authorized by the Research and Marketing Act. The contract provided for determination of available surplus wheat, rye, and flax straw in South Dakota for industrial utilization and sites for possible processing plants. It was supervised by the Northern Utilization Research Branch of the Agricultural Research Service.

[2]Associate Economist and Assistant Economist, respectively, South Dakota Agricultural Experiment Station.

[3]*Survey of Current Business,* U. S. Dept. of Commerce, Washington, D. C., September 1955, pp. 15, 21.

[4]Johanson, John P., *The Influence of Migration Upon South Dakota's Population, 1930-1950.* Bulletin 431, South Dakota Agricultural Experiment Station, Brookings, South Dakota, p. 6.

Purpose of Study

There are, of course, many possible types of industries that might locate in South Dakota. This study is designed to examine the economic feasibility of operating one type of industrial plant—a plant that uses straw as a basic raw material or ingredient in the production of insulating and/or structural board, box board, and corrugating paper. More specifically, this study attempts to determine whether any area or areas in the state have all the necessary requirements for the operation of such a plant.

This work has been made possible by the U. S. Department of Agriculture. The Northern Utilization Research Branch at Peoria, Illinois, has done extensive research in developing and improving the commercial pulping process that uses straw as a basic ingredient. The South Dakota State College Agricultural Experiment Station was selected to undertake a study, under contract, to determine whether conditions are favorable for establishing a plant of this character in South Dakota.

To determine whether any areas in the state are suitable for a plant site, it was necessary to establish the availability in sufficient amounts, above normal requirements, of straw, water, power, fuel, labor, and chemicals, as well as sewage disposal and transportation facilities.

There are several reasons for undertaking this work. First, in recent years the Peoria Laboratory of the U. S. Department of Agriculture has done extensive work on the use of agricultural residues for paper and board and has developed a new pulping process for straw.[5] This process uses a Hydrapulper for the pulping operation. Use of this Hydrapulper has several advantages over the conventional method of pulping straw. These advantages include savings in handling the straw, equipment costs, operating costs, as well as improvement in quality. The value of such advantages has been estimated at approximately $5 per ton of corrugating paper.[6] A new plant using this process would have a manufacturing advantage over existing plants using older processes.

One of the major difficulties that confronts existing strawpulping plants is straw collection. These plants were built when grain harvesting was done by threshing machines. Plants were located close to population centers rather than to areas of heavy straw production. With the change in harvesting methods from threshing machines to combines, these plants have found it more difficult and more costly to obtain their straw supply.

Finally, production and consumption of paper has grown very rapidly in recent years. This in-

[5]Aronovsky, S. I. and Lathrop, E. C., "A New Mechano-Chemical Process for Pulping Agricultural Residuals," TAPPI, Vol. 32, No. 4, pp. 145-149. (Apr. 1949.) Also U. S. Patent 2,708,160, issued May 10, 1955, to same authors. Process for Pulping.

[6]Krancher, Carl G., and Price, Carl E., "Hydrapulper Processing of Straw," published in TAPPI, Volume 33, Number 6, pp. 275-277, June 1950.

creased demand has resulted in rapidly increasing costs of paper made from wood pulp. As a result of pulpwood supply sources receding further and further from the mills, higher transportation costs were incurred causing many American pulp and paper manufacturers to search for other available fibrous raw materials for paper making.[7]

[7]Aronovsky, S. I., "The American Paper Industry Needs Straw and Bagasse," a paper presented at the annual meeting of the American Pulp and Paper Mill Superintendents Association, Detroit, Michigan, July 17-19, 1952.

Straw Production

No data are available on the production of straw in South Dakota. However, extensive data are available on bushels of grain annually produced and on the relationship between grain production and straw production. From these data it is possible to calculate a grain-straw ratio to convert grain production to straw production.

Table 1 shows the relationship between grain production and straw production. These data were calculated by the Agronomy Department of South Dakota State College from experiments conducted by that department.

For the purposes of this study wheat and rye straw production results were computed from experiments conducted in 1943, 1945, 1948, 1949, and 1952. These years were selected because the use of data from years prior to 1943 would give a distorted picture. These years were considered to be representative by the agronomists. Unfortunately, data on flax straw production were only available for 1952; however, the Agronomy Department considered 1952 a representative year.

Total estimated straw production, as shown in table 1, was reduced 20 percent (column 2) to allow for the difference between the total straw produced and the stubble usually left in the field by the windrower. This 20 percent factor may vary with straw prices and/or harvest conditions of the straw but was considered by the Agronomy Department to be a reasonable average.

Table 1. Relationship Between Grain and Straw Production*

Type of Grain	Total Straw per Bu. of Grain, Lbs.	Lbs. Available for Recovery,† Actual Net	Net Available, % of a Ton	Conversion Factor, Bu. to Tons
Rye	109	87.2	4.36	.0436
Wheat	138	110.4	5.52	.0552
Flax	80	64.0	3.20	.0320

*See also "Harvesting of Small Grains and Utilization of the Straw." U. S. Department of Agriculture, Bureau of Agr. Economics, FM. 66, June 1947.

†20 percent of the total straw was considered left by the windrower.

Total Straw Production

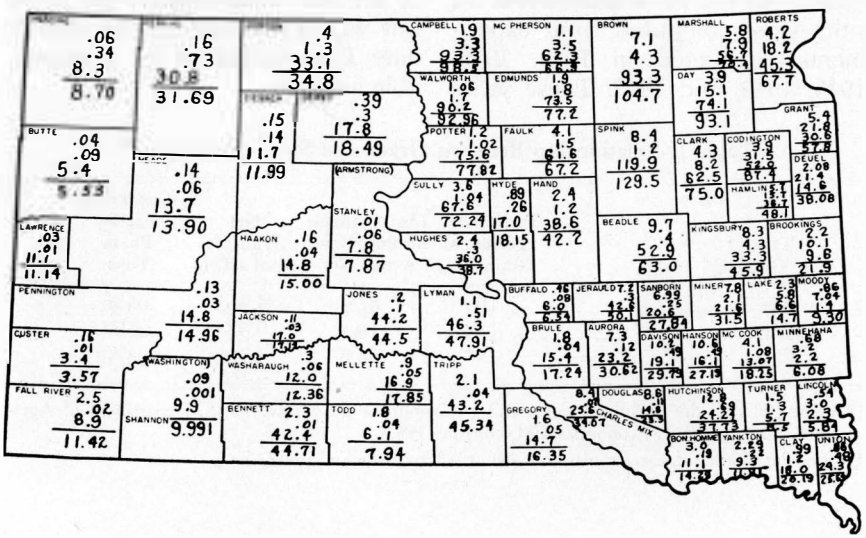
The conversion factors described were applied to grain production in each county of the state for 1934 through 1954. To reflect maximum and minimum production in establishing the frequency of straw crop failures, 21 years were used. However, only the past 10 years were used to obtain average straw production because changes in varieties, fertility levels, and soil management practices would make prior years nontypical.

The basic annual requirements for a minimum-sized economic plant using straw for producing corrugating paper are estimated at 50,000 tons of straw to be available within a 50-mile radius. When converted to production per square mile, this amounts to 6.36 tons per square mile. As shown in figure 1, if all the wheat, rye, and flax straw produced were available for industrial use—less 20 percent left as stubble—all the counties of the state with exception of Butte, Custer, Minnehaha, and Lincoln, produce a straw density per square mile sufficient to support a plant of the designated size.

Concentrated Production Areas

The assumption that all straw produced is available for industrial purposes is unrealistic; wheat and rye straws may be used on the farm or be plowed under. Flax straw, which is difficult to work into the soil satisfactorily, is probably nearly all surplus straw. For this reason flax straw was singled out (see figure 2) to determine whether any area in the state produced enough flax to supply a pulp plant

Figure 1. Total wheat, rye, and flax straw per square mile by counties (10-year average, 1945-54). First figure refers to rye straw production, second to flax, third to wheat, fourth to total rye, flax, and wheat straw production in tons per square mile.



with flax straw only.[8] Ten counties in northeastern South Dakota are shown to produce a flax straw density meeting this requirement. However, some of this flax straw is now being shipped out of the state.

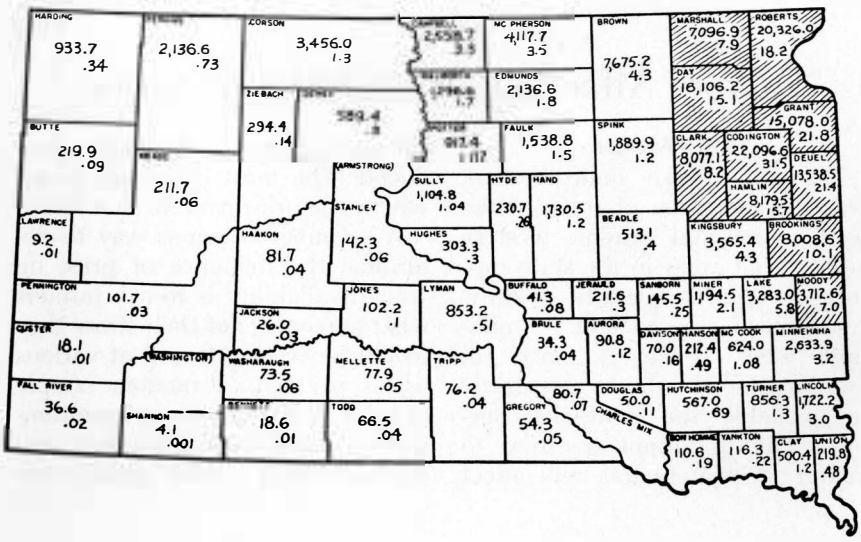
Since all wheat and rye straw produced cannot be classified as surplus straw, assumptions were made as to the amount of straw that might be considered surplus. Assumptions of 20 to 30 percent availability of the total wheat and rye straw were tentatively considered, and figures 3 and 4 were prepared to illustrate each alternative. On the maps illustrating each assumption, all counties with over 7 tons per square mile available wheat and rye straw for a 10-year average are shaded. This serves to illustrate locations of straw production concentration and to locate areas which would be most desirable as plant sites.

Frequency of Straw Production Failures

The number of years, within the past 21 when straw production fell below 7 tons available straw per square mile, was listed within each shaded county. These years might be considered as straw failures. Although the total amount of straw produced would meet the requirements of this study, under the rigid assumptions of only 20 and 30 percent surplus straw, such an amount would not be available.

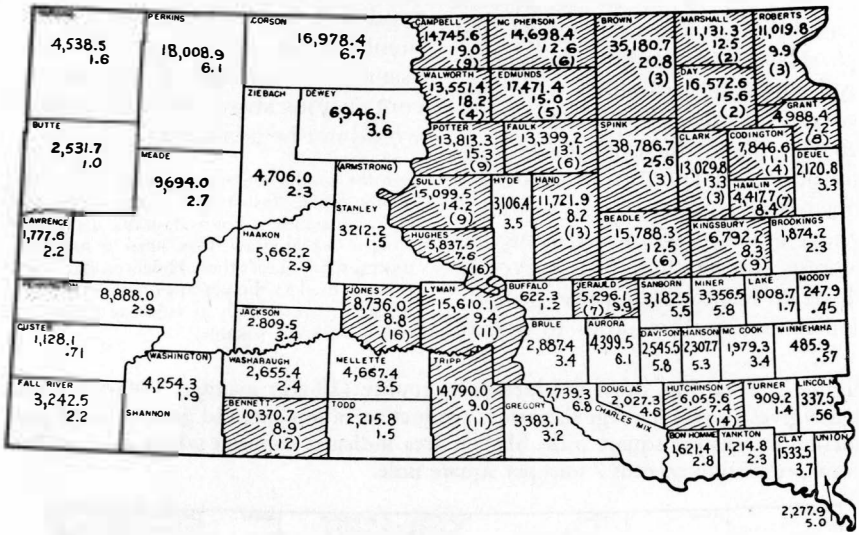
[8]For the production of boxboards and corrugating paper, flax straw, because of its tow fiber, apparently is not as desirable a raw material as wheat straw. Flax straw is harder to process than wheat straw. However, flax straw is being used in the production of high grade specialty papers, such as cigarette paper, for which it is more suitable.

Figure 2. Total flax straw production by county (10-year average, 1945-54). First figure gives 10-year average flax straw production in tons, second gives average production in tons per square mile. Shaded area indicates counties where average flax straw production exceeds 7 tons per square mile.



It is logical to assume that in years of low farm income a larger percentage of the total straw production would be available than normally. In years of extremely low grain yields the grain-straw ratio would have the greatest margin of error in favor of straw production.

Figure 3. Twenty percent available wheat and rye straw production (10-year average, 1945-54). In each county, the first figure represents 20 percent of 10-year average wheat and rye straw production in tons. Second figure gives tons of available wheat and rye per square mile at 20 percent availability. Shaded areas indicate available straw over 7 tons per square mile. Bracketed figures are the number of years in the last 21 when available straw fell below 7 tons per square mile. Flax straw is not included.



Factors Affecting Availability of Straw

Price Factors

The data given indicate that, with the exception of some of the southeastern and extreme western counties, all areas in the state produce a sufficient quantity of straw to supply a paper plant of minimum size. However, since all straw produced will not necessarily be available for industrial purposes, the important question to answer is what factors will affect the availability of the straw produced. The most important factor will be the price paid for that straw.

A seemingly obvious way to determine the influence of price on straw availability is to ask farmers what percentage of their straw they would be willing to sell at various prices per ton. A random sample of farmers was chosen for questioning in a county with high straw production. Their replies quickly re-

vealed that farmers had no idea what they would or should charge for their straw. They had not sold straw in the past (except flax in certain locations) and, therefore, had no information on which to base a reliable estimate. Without asking the question in such a way as to bias the answer received, it was found impossible to obtain reliable information by such techniques.

A second method to determine the influence of price on the availability of straw, is to assume that a farmer will sell his straw if the costs involved are met. Data were then assembled to determine what these costs were.[9]

The process of getting straw from the field to a paper plant would involve at least three operations, and sometimes four, each involving some cost to the farmer. Three steps that always would be involved are baling, handling, and trucking. Raking would be involved only when straw production was light.

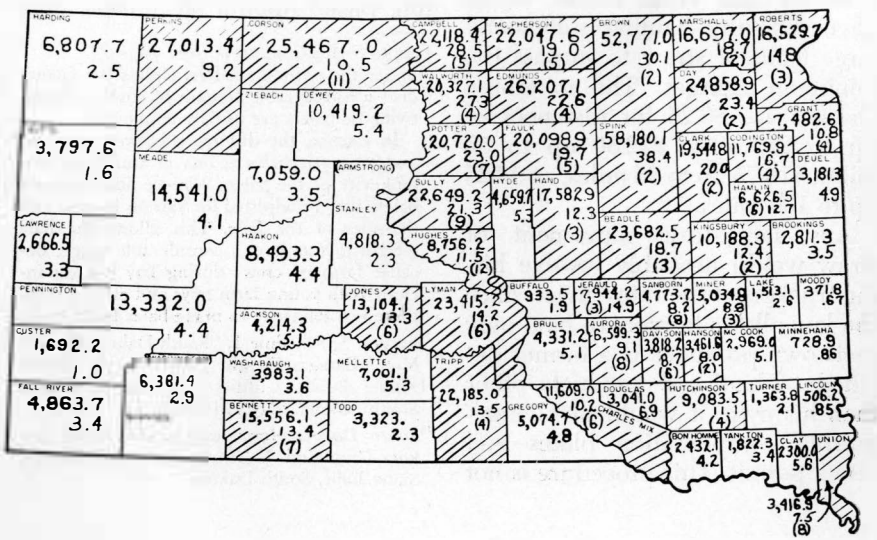
Baling Costs

The average baling cost charged by custom balers during the summer of 1955 was 11 cents per bale for twine-tied bales.[10] The number of

[9]These data were assembled from discussions with county extension agents in the northeastern part of the state. They were checked with a farmer who is engaged in fairly large-scale custom baling for the railroads and has kept detailed cost records.

[10]Some wire-tie balers frequently leave small pieces of wire in or on the bales, creating a hazard in livestock feeding. Because of this danger along with the waste wire disposal problems, farmers in South Dakota generally

Figure 4. Thirty percent available wheat and rye straw production (10-year average, 1945-54). In each county, the first figure represents 30 percent of the 10-year average wheat and rye straw production in tons. Second figures give available wheat and rye straw per square mile at 30 percent availability. Shaded areas indicate available straw over 7 tons per square mile. Bracketed figures are the number of years in the last 21 available straw fell below 7 tons per square mile. Flax straw is not included.



bales per ton varies considerably. Bale weights of 45 pounds were considered average for this area. This would mean that twine-baling would cost $4.89 per ton. Variations in actual weight of the bales could vary this figure from $4.75 to $5.25 per ton. A problem that is likely to arise in South Dakota is that most balers use twine rather than wire for tying the bales. In paper production wire-tied bales are preferred to twine-tied bales, since wire-tied bales can stand storage and transportation better.

Trucking Costs

Custom trucking costs are set by the Public Utilities Commission and are graduated by the distance hauled. The current rates are as follows: $2 per ton up to 25 miles, $3 per ton up to 50 miles, $4.20 per ton up to 75 miles, and $5.25 per ton up to 100 miles. Minimum total charges are also established. Since straw is a bulky product, these minimum charges are important. Standard livestock and grain trucks would have difficulty hauling sufficiently large loads of straw to surpass the minimum charges. The minimum charges are $6.25 for distances of up to 25 miles, $12.50 up to 50 miles, $18.75 up to 75 miles, and $25 up to 100 miles.[11]

Any large-scale movement of straw would probably involve hiring truckers at the rates given, since the law allows farmers to haul only their own products. If a farmer decided to haul any products other than his own, it would involve acquiring compensation plates and also a permit. This procedure is not only costly but also entails obtaining a statement from truckers verifying that they (the truckers) cannot conveniently handle the proposed loads.

Handling Costs

Handling charges were estimated by farmers and county extension agents to be $1.50 per ton of straw. These handling charges cover the labor involved in getting the bales from the field onto the truck that transports them to the plant.

Raking Costs

If straw yields are heavy, raking prior to baling is unnecessary. When the straw yield is light, it is raked before baling. The custom-raking rate varies from 80 cents to $1 per acre. The 10-year average wheat yield per acre is 12 bushels for the north - central district.[12] When converted to equivalent straw yield, the average net straw produced would be 1,325 pounds of straw per acre or 66.25 percent of a ton. Based upon a 90-cent-per-acre

Footnote 10 *(Continued from page 7)*
prefer the twine-tie balers. Unless the farmer does a considerable amount of custom baling, twine-tie balers are usually employed.

In essence, the difference between wire-tie and twine-tie bales is one of sturdiness and longevity of the bales. Wire-tie and twine-tie balers may be adjusted for various lengths and densities of the bale. This allows the bale weight to vary over a considerable range. Because farmers' crews during hay harvest include both young farm boys and elderly men, there is a tendency to make bales fairly light.

[11]Section 3, Schedule 1, "South Dakota Class B Motor Carriers Freight Tariff No. 16," South Dakota Public Utilities Commission, Pierre, South Dakota, May 1, 1956, p. 10.

[12]*South Dakota Agriculture, 1954,* South Dakota Crop and Livestock Reporting Service, Sioux Falls, South Dakota.

charge for raking, the raking cost per ton would be $1.35.

Value of Straw for Purposes of Fertility

Since a large amount of the straw is returned to the soil, the question arises as to whether straw has any value for soil fertility.

Work has been done by the Agricultural Experiment Station at Fargo, North Dakota, on the soil depleting power of flax as compared with hard spring wheat and other small grains. The chemical constituents of the straws and grains were determined, beginning in 1947, at Fargo and Minot, North Dakota.[13]

The North Dakota study included all elements removed from the soil. For the purpose of this study, which is to determine the monetary value of the fertility loss resulting from straw removal, only nitrogen, phosphorus and organic matter should be considered. The addition of nitrogen and phosphorus fertilizers has given significant yield increases on small grain in South Dakota. Agronomists agree that organic matter is valuable for maintaining favorable physical qualities and fertility of the soil.[14] Potassium is not being considered as a cost item here, since it is not a limiting factor in South Dakota crop production. South Dakota soils are derived from parent material high in potassium and it is unlikely a shortage of this element will be experienced in the foreseeable future.[15]

Straw analysis at North Dakota disclosed a relatively low nitrogen and phosphorus content, though the variation was greater for straw than for grain. Wheat straw at Fargo averaged 0.66 percent nitrogen and approximately 0.07 percent phosphorus.[16] In other words, a ton of straw contains 13.2 pounds of nitrogen and 1.4 pounds of phosphorus. Flax straw contained 0.79 percent nitrogen and 0.09 percent phosphorus. This would be 15.8 pounds of nitrogen and 1.8 pounds of phosphorus per ton of flax straw. No data were available on rye straw.

Ammonium nitrate is currently selling for $85 per ton. Since this form contains 33.5 percent nitrogen, 670 pounds of nitrogen costs $85, hence has an approximate value of 12.7 cents per pound. Phosphorus fertilizer in the 0-45-0 form costs $78 per ton. Phosphorus fertilizer percentages are determined on the percent of P_2O_5 rather than on phosphorus. The conversion factor for 0-45-0 fertilizer would be 19.6 percent. This would net 392 pounds of phosphorus for $78. At this price replacement phosphorus would cost almost 20 cents per pound.

Using these costs for nitrogen and phosphorus in wheat straw, the

[13]Claggett, C. O., Stow, T. E., Klosterman, H. J. and others, *The Soil Depleting Power of the Flax Crop Compared with That of Hard Red Spring Wheat, Oats, and Barley,* Bulletin 378, North Dakota Agricultural Experiment Station, Fargo, North Dakota, August 1952.

[14]Puhr, Leo F., and Worzella, W. W., *Fertility Maintenance and Management of South Dakota Soils,* Circular 92, South Dakota Agricultural Experiment Station, South Dakota State College, Brookings, South Dakota, p. 5.

[15]*Ibid.*

[16]Claggett, et. al., op. cit.

element replacement cost of wheat straw would be $1.96 per ton. The element replacement cost for flax would be $2.37 per ton.[17] This does not include application cost, as it is assumed that a continuous grain cropping system would require, sooner or later, some application of fertilizers. However, at present, commercial bulk fertilizer spreaders charge 50 cents per acre for application.

Organic matter loss presents a different problem, as it is not available as a commercial product in quantities large enough for general distribution. It is usually replaced by the addition of grasses or legumes in the crop rotation schedule and this involves the curtailing of grain acreages. While this practice may be good from the soil conservation viewpoint, the price that could be paid for straw would probably not be high enough to encourage this method of operation. It is extremely difficult, therefore, to place a value on organic matter. Some soils have ample supplies; others are lacking in organic matter.

The Agronomy Department at South Dakota State College has found that the addition of 20 pounds of nitrogen fertilizer, while increasing grain yields, will also increase straw yields just over 20 percent.[18] While these tests are inconclusive, it seems reasonable to assume that by following a fertilizer program and normal soil management practices, organic matter deficiency would not occur if not over 30 percent of the total straw was consistently sold from the land. This amount would not be an absolute ceiling but is advanced as a safe long-time average percent if proper soil management is followed. This would allow ample variation in the percent of straw that might be safely sold, so that with a properly planned and located paper plant a consistent annual supply would be available.

Total Costs

The total costs of delivering the straw to the pulping plant, using the cost estimates just discussed, would be $12.20 per ton. This includes: baling $4.89, hauling $2.50, handling $1.50, raking $1.35, and fertility loss $1.96.

The relationship between the price paid for the straw and its probable availability for industrial use is shown in figure 5.

This figure indicates that 20 percent of the total straw produced might be available at a price offer of $12 per ton, and 80 percent might be available at $15 per ton.[19] In other words, four times as much straw might be available at $15 per ton as at $12 per ton. This relationship is based on present costs and average yields.

Nonprice Factors

Price is not the only factor that will affect the availability of straw; numerous nonprice factors also are involved. These include present

[17] These data should be used with great caution. Soil type, weather conditions, etc. would affect the fertility value of the straw.

[18] Based on unpublished results of the Agronomy Department, South Dakota State College, Brookings, South Dakota.

[19] These figures have been verified by interviews with farmers doing custom baling.

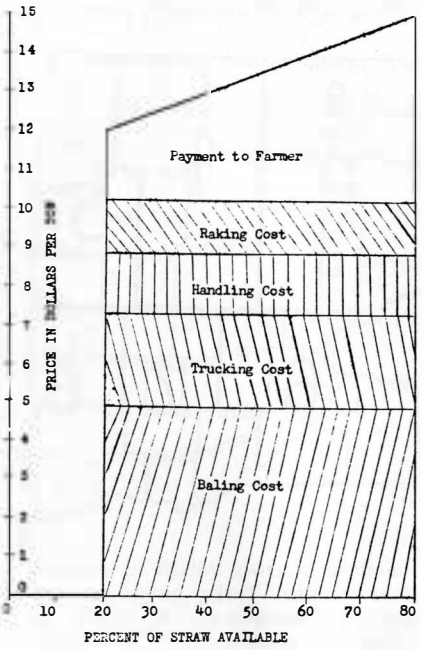


Figure 5. Relationship between price paid for straw and its availability.

farm uses, existing industrial uses, cropping practices, straw contaminants such as weeds, and the methods used in buying.

Present Farm Straw Uses

According to county extension agents and farmers in the straw production areas, most of the wheat and rye straw is spread and remains in the field. Where any such straw is collected, it usually does not exceed 5 or 10 percent of the farmers' production. For livestock purposes, oat straw is usually preferred. Sometimes oat straw has the advantage of being a substitute for some livestock roughage.

There are some livestock feeding operations in the southeastern part of South Dakota that utilize straw for bedding. However, these are not in the area of heavy wheat straw production and hence would not affect the availability of surplus straw for paper production in the designated areas. Figure 6 locates the different types of farming operations carried on in the different areas of the state.

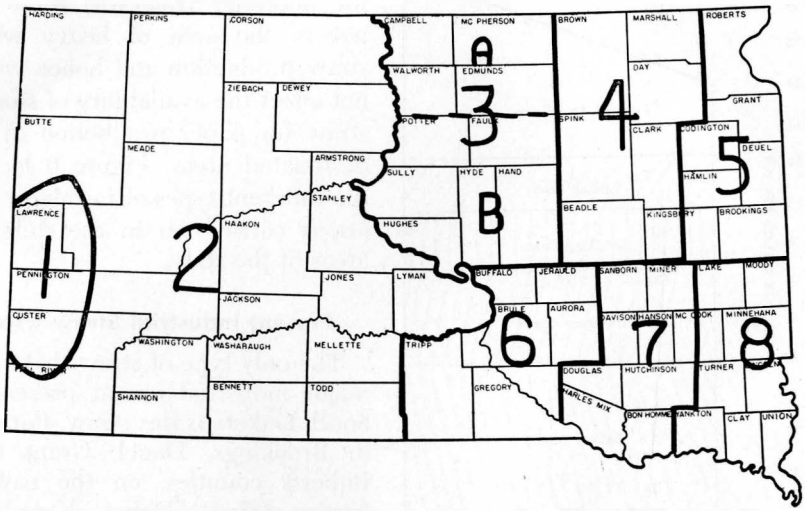
Present Industrial Straw Uses

The only type of straw that has a major industrial use at present in South Dakota is flax straw. Farmers in Brookings, Deuel, Grant, and Roberts counties, on the eastern border of South Dakota, have been selling flax straw to Minnesota buyers for use in paper production. County extension agents in these four counties estimate the amount sold has ranged from 65 to 85 percent of the total available straw. In Clark county only a limited amount of flax straw has been sold in the past. This can be attributed to the added moving and handling cost of obtaining straw from other than the eastern tier of counties in South Dakota.[20]

In addition to the flax straw being used for paper manufacturing, the only other off-farm use for straw in South Dakota is the very small amount of straw used in sales barns, stockyards, and small pack-

[20]According to the Watertown Chamber of Commerce, a flax straw processing plant is being encouraged to locate in Watertown. If a plant locates there, it will undoubtedly increase the size of the South Dakota area supplying flax straw and decrease the amount available for an additional plant such as is being considered in this report.

Figure 6. Types of farming and ranching in South Dakota by areas.



1. BLACK HILLS AREA. Includes Belle Fourche irrigation area, plus irrigated valley and dryland farming adjoining Black Hills. A rather specialized area—sugar beets, fruits, vegetables, lamb and cattle feeding, dairy and mixed farming, and ranching. Alfalfa hay grown extensively.

2. RANGE AREA. Cattle and sheep chief enterprises, particularly in northwest and southwest parts. Considerable amount of mixed livestock and small grain farming in many parts of area. Ranches and farms average well over 1,000 acres, with many ranches covering several thousand acres. Most parts of area best suited to an extensive grass-range livestock system of farming.

3. NORTH CENTRAL AREA. A transitition area between more intensive farming area to east and range area to west. About 60 percent of farmland is grazing and wild hay land. Wheat still an important cash grain crop, particularly in northern part. Beef cattle and sheep production becoming more important with annual hog production fluctuating considerably. Southern and western parts somewhat more rolling and better adapted to ranching. Considerable numbers of cows milked in northern four counties. Turkey production important enterprise, particularly in southern part.

4. NORTH JAMES RIVER AREA. The major wheat and cash grain area of state. Corn occupies less than 25 percent of crop area. Beef cattle, dairying, hogs, sheep, and poultry contribute greatly to cash income of farmers. Turkey production important in some parts. Major portion of small grain harvested by combines.

5. NORTHEASTERN AREA. Wheat, flax, and potatoes important cash crops. Corn, oats, and barley chief feed grains produced. Dairying, hogs, and poultry more important sources of income than in area 4. Beef cattle and sheep production increased in recent years. Production of certified seed potatoes important in Codington and adjacent counties. Higher proportion of hilly land in area makes it important to utilize more of the farmland in pasture and hay crops. Alfalfa production becoming more important.

6. SOUTH CENTRAL AREA. Farming here a transition between moderately intensive crop and livestock area to east and more extensive range area to west. About one-third of farmland

in cropland. Kinds of farming rather varied. Although beef cattle production is major livestock enterprise, hog, sheep, and dairy production also carried on. Turkey production important in some parts. Ranching becoming more important. Corn, sorghum, barley, and wheat sold on many farms.

7. SOUTH JAMES RIVER AREA. A moderately intensive crop and livestock area between intensive production area on east and more extensive farming area on west. Types of farming vary considerably. General livestock-grain farms predominate. Hogs, dairy, beef, livestock fattening, and poultry major sources of income. Corn, barley, oats principal feed crops grown. Most feed crops marketed through livestock.

8. SOUTHEASTERN AREA. Most intensive system of livestock feeding, hog, dairy, and poultry production centered in this area. Beef cattle production important enterprise on many farms. Corn principal crop grown; oats and alfalfa the other major crops. Flax important cash crop on some farms in northern part. Soybeans grown to limited extent. Most crops marketed through livestock. Proportion of farmland in crops highest in state.

ing plants. This straw is used for livestock bedding.

Crop Practices Prevalent in the Area

Wheat is the major crop within the areas considered for wheat straw pulping in South Dakota.

Wheat is combined from the windrow rather than as a standing grain as is common in Illinois, Nebraska, and other states. The height of cut varies with the height of grain and the quantity necessary to make a continuous ribbon for uniform feeding into the combine. It is preferred, when possible, to leave sufficient stubble to keep the grain off the ground and in good condition. Normally, when the straw is tall, a longer stubble is left to lessen the straw load on the combine cylinder. Straw may be spread or left in a windrow for baling at the combine operator's discretion.

Impurities in Straw

Weeds are the most common impurity of straw. The broadleaf weed problem has been almost eliminated in wheat and rye by the use of 2,4-D weed sprays and good management practices. The grass type contaminants, when serious in wheat or rye, are of a local nature. Flax straw is subject to more contamination from both grass type and broadleaf weeds. The use of sprays is effective on the weeds contaminating the stand of flax. However, this often results in damage to the flax. Weed contaminants are the major cause for the rejection of flax straw for industrial use by out-of-state buyers.[21]

County extension agents were concerned about the possibility of an extensive straw movement spreading noxious weeds. One agent cited examples of new leafy spurge patches bordering the roads leading to flax straw storage sites. If the transportation of straw contaminated with noxious weeds is continued, some regulatory measures may be imposed by the State Weed Board.

[21]Based on interviews with county extension agents.

Rust has been a serious contaminant in the durum wheat area, which is also the concentrated flax area in South Dakota. Because of the extensive rust damage in recent years, farmers in these areas are eliminating durum wheat from their cropping systems. This recent shift should be considered more closely, if straw plants are depending on durum wheat from Roberts, Marshall, Grant, Codington, Hamlin, and Deuel counties in northeastern South Dakota.

When rust resistant varieties become available in large quantities, this situation could conceivably be reversed. However, the effect of rust, without available resistant varieties, is to drastically reduce the acreage planted to wheat. Within the spring wheat area rust resistant varieties are available and more resistant ones are in prospect.

Methods Used in Buying

The methods of buying straw will be important if a plant is to be assured of a long-time supply of straw.

Experience in other agricultural processing plants such as dairy and beet sugar plants indicate that a public relations program, carried on through fieldmen who visit farmers, is desirable in maintaining a steady flow of raw materials into the plant.

The buyers for the plant would also profit by working with county extension agents in the area where they are buying straw. Fertilizer application recommendations of the College of Agriculture, if followed, would in many instances result in enough increase in straw production to supply a plant with straw.

Summary on Availability of Straw

The data given indicate that straw is produced in quantities large enough to supply a paper plant in most of South Dakota. However, all straw produced will not be available to a paper plant.

Factors that will affect availability of the straw are prices, present farm uses, existing industrial uses, cropping practices, areas affected by contaminants, and the methods used in buying.

If the price offered is high enough to cover the procurement, and the methods used in buying are such that they take into consideration the effects of straw removal on fertility loss, the northeastern quarter of South Dakota would be capable of supplying straw in sufficient quantities to supply several paper plants.

The important question left to be answered is what area or areas in the state have the other factors necessary for the successful operation of a commercial plant.

Analysis of Possible Straw Pulp Processing Plant Sites

Analysis of Basic Physical Requirements

The basic factors necessary for consideration of a plant site of this nature are: water availability, sewage disposal, electrical power, and fuel for steam.

Water Availability

The most difficult requirement to meet for a straw pulping process is that of water. The size of the plant under consideration here would require 3 million gallons of water per day.

The only known source of this quantity of water in South Dakota is the Missouri River. Other sites may have the necessary water from underground sources, but apparently insufficient knowledge exists about these sources to guarantee this amount on a continuing basis.[22]

Another possible future source of water is the Oahe irrigation development. Figure 7 shows the proposed areas for irrigation. If this plan materializes, sites along the canal line would then have a sufficient supply of water. However, as indicated in the preceding paragraph, lack of water negates further consideration of any sites that are not located along the Missouri River.

[22]Underground water supplies are known to exist. However, interviews with the State Geologist and representatives from the Industrial Development Expansion Agency, the Water Resources Commission, and the Bureau of Reclamation disclosed that very little is known about these aquifers either with regard to their extent or their potential usefulness.

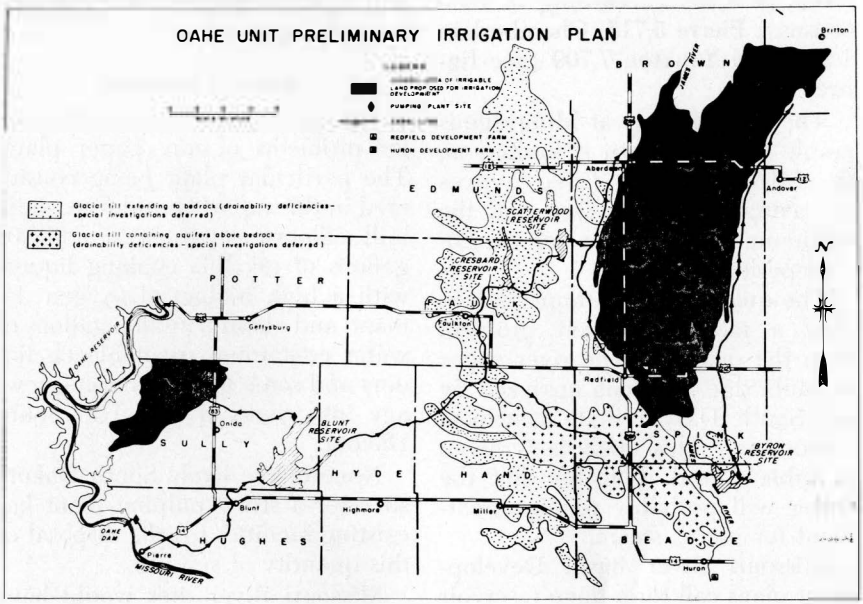


Figure 7. Preliminary irrigation plan for the Oahe unit.

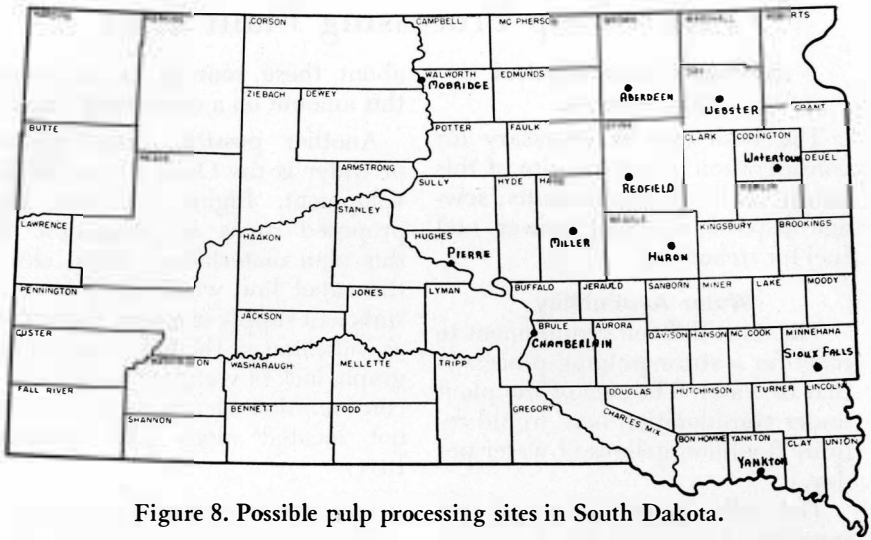


Figure 8. Possible pulp processing sites in South Dakota.

There are only four towns along the Missouri River in South Dakota, whose sizes warrant consideration. They are Mobridge with a population of 3,753 (according to 1950 census); Pierre 5,715; Chamberlain 1,912; and Yankton 7,709 (see figure 8).

The water supply at Mobridge is ample, and the town is located on the Missouri River. Table 2 gives the average monthly flow and the minimum monthly flow for the 20-year period 1929-49.

The quality of the water is probably a more important problem than the quantity. The river water at Mobridge has been analyzed by the South Dakota State Chemical Laboratory. This analysis is given in table 3 and indicates that the water will probably require treatment for use as steam.

Missouri River Basin Development plans call for a huge reservoir to extend from Pierre, South Dakota, to Bismarck, North Dakota. When this development is completed the reservoir will act as a settling basin for the river water. This water will then be considerably improved for pulping purposes.

Sewage Disposal

Sewage disposal is one of the major problems of any paper plant. The particular plant being considered in this report would have daily mill effluents (waste) of 300,000 gallons of alkaline cooking liquors with a high biological oxygen demand and about 2 million gallons of water containing spent bleach liquors and some filler. Dumping sewage into rivers is illegal in South Dakota.

None of the likely South Dakota sites for a straw pulping plant has existing facilities for the disposal of this quantity of sewage.

Missouri River sites would have advantage over some areas for sew-

Table 2. Average and Minimum Monthly Flow of Missouri River

Month	Near Mobridge, S. D. (1929-49)			At Pierre, S. D. (1930-49)		
	Average (000,000 Gal.)	Minimum (000,000Gal.)	Year	Average (000,000Gal.)	Minimum (000,000Gal.)	Year
January	165,637	67,954	1940	161,112	65,340	1940
February	161,717	84,942	1940	168,692	83,635	1940
March	458,033	120,552	1940	477,472	128,720	1940
April	612,236	246,659	1938	665,439	276,388	1938
May	512,266	273,775	1945	535,625	272,141	1945
June	1,064,062	545,916	1934	1,023,682	536,441	1934
July	705,019	246,005	1934	758,516	294,357	1934
August	374,398	132,314	1934	395,781	146,035	1934
September	332,253	89,516	1934	343,623	92,456	1934
October	335,194	147,342	1935	345,436	152,896	1935
November	263,974	111,078	1936	269,446	109,445	1936
December	164,003	87,556	1932	162,272	86,576	1935

Source: Guy C. Stevens and Clayton H. Hardison, *Monthly and Annual Discharge of Missouri River Between Fort Benton, Montana, and Herman, Missouri, and Principal Tributaries,* Geological Survey Circular 108, Department of Interior, 1951.

age disposal because land prices are relatively low. Because of limited rainfall, the land is used for grazing. If a lagoon system of sewage disposal is at all feasible, the land for such a disposal system would be relatively cheap.

Electric Power

The power requirements for a pulping plant investigated in this report is 25,000 kilowatt hours per day. An important part of the Missouri River Basin Development Program is the generation of electric power. Plans call for the generation of 3.5 billion kilowatt hours of annual firm power when all the main stem projects are completed. Oahe, Fort Randall, and Gavins Point dams in South Dakota, and Garrison Dam in North Dakota are in various stages of construction. Big Bend Dam, south of Pierre, South Dakota, is the only one on which construction has not begun.

Mailed inquiries were made to power companies in the state to determine whether they could supply the necessary power and what rate

Table 3. Analyses of Missouri River Water at Mobridge

Component	ppm
Total solids	492
Silica (SiO_2)	17
Sulfate (SO_4) as ions	233
Chloride (Cl) as ions	7
Fluoride (F) as ions	0.8
Calcium (Ca) as ions	62
Magnesium (Mg) as ions	20
Iron (Fe) as ions	18
Manganese (Mn) as ions	0.4
Hardness as $CaCO_3$	237
Alkalinity-Methyl Orange	118
Alkalinity-Phenolphthalein	00

Source: William Drake, Jr., *Pulp and Paper Possibilities in South Dakota,* South Dakota Resources Commission, State Capitol, Pierre, November, 1953.

they would charge for such power. All companies indicated that this amount of power could be supplied.[23]

At present, the rates for this power cannot be determined as the power load is unique in South Dakota and offers no means of comparison. If a plant is built in South Dakota, the owners would have to determine rates through a bargaining process with existing power companies or consider as an alternative the feasibility of installing a private generating system. With a relatively constant power load, and such a tremendous quantity of electric power to be consumed, this situation would be very appealing to any existing power company. However, both possibilities should be studied intensively before any decision is made.

Fuel for Steam

A natural gas line was completed the last of January 1957 which is serving Sioux Falls, Mitchell, Madison, Brookings, Huron, and Aberdeen. Two natural gas lines existed prior to this in South Dakota—one in the southeastern part of the state and the other on the western border.

Low-cost lignite is available in great abundance in western North Dakota and northwestern South Dakota. This lignite is to be found in Harding, Perkins, northern Meade, Dewey, and Corson counties (see figure 9). It has been estimated that more than 1 billion tons of lignite are present in the area, in

[2] From correspondence with Northwestern Public Service, Northern States Power, Black Hills Power and Light, and Otter Tail Power Company.

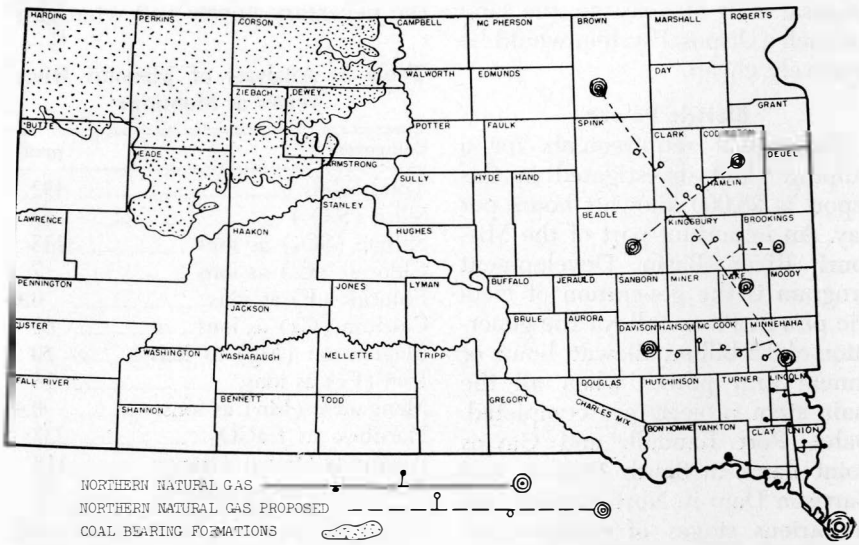


Figure 9. Existing and proposed natural gas lines in eastern South Dakota, September 1956. Coal-bearing formations are also indicated.

beds over 2.85 feet thick. However, the estimate did not cover the entire area in which lignite deposits are known to exist, and it is probable that the total estimated reserve would reach 2 billion tons if this were taken into account.[24]

Table 4. Composition and Heat Value of South Dakota Lignite

Moisture	36.65%
Volatile Matter	25.87%
Fixed Carbon	28.68%
Ash	9.50%
Sulphur	0.93%
Heating Value	6855 B.T.U.

Source: *South Dakota Coal,* South Dakota State Planning Board, Brookings, South Dakota, 1936.

The cost of the lignite would range between $4.80 per ton, freight included, to Mobridge and $5.70 to Pierre.[25]

This lignite can be shipped by rail and the possibility exists that when the Missouri River Program is completed this lignite could be shipped down the river by barge. Analysis of this lignite is shown in table 4.

[24] *Mineral Resources of South Dakota,* South Dakota Natural Resources Commission, Pierre, South Dakota, April 1952, p. 22.

[25] William Drake, Jr., *Pulp and Paper Possibilities in South Dakota,* South Dakota Natural Resources Commission, State Capitol, Pierre, November 1953, p. 18.

Analysis of General Requirements

Straw Supply

The best site, from a straw production standpoint, is Mobridge. Campbell, Walworth, Potter, McPherson, Edmunds, and Faulk counties are heavy straw production areas (see figure 4). Straw production in Corson County, although relatively light, is concentrated in the eastern portion of the county, which is closest to Mobridge. Emmons, Logan, and McIntosh counties in North Dakota also would be a source of supply.

Labor Supply

As stated in the introduction, South Dakota is primarily an agricultural state. This means two things with regard to labor. First, labor is plentiful. The agricultural industry has within it a great deal of "disguised" unemployment. This "disguised" unemployment exists wherever a farm is too small to adequately utilize the family labor living on it for a full year.

Experience in other areas in the country indicates that, when an industry is introduced into a primarily rural area, labor to work in that industry is plentiful.This labor may come from farms where the head of the household goes to work in the industry and the family takes over the responsibilty of running the farm. The workers for an industry also come from the excess of population in agriculture. Farm people tend to have larger families than urban people and there is always a migration of people from farm to industry.

Table 5. Wages of South Dakota Farm Labor

Year and Month	Quarterly Wage Rates (as of first day of month shown)				
	Per Month		Per Day		Per Hour
	With Board	Without Board	With Board	Without Board	Without Board
1948					
January	$ 99.00	$137.00	$5.10	$7.00	—
April	108.00	146.00	5.30	6.80	—
July	118.00	157.00	5.70	7.60	—
October	124.00	164.00	6.80	8.70	—
1949					
January	111.00	140.00	5.60	7.30	$ .96
April	117.00	142.00	5.60	7.20	.95
July	118.00	144.00	5.70	7.40	.97
October	113.00	138.00	5.80	7.70	.98
1950					
January	106.00	126.00	4.95	6.60	.91
April	106.00	131.00	5.00	6.60	.88
July	111.00	136.00	5.50	7.30	.91
October	117.00	140.00	6.10	7.80	.98
1951					
January	109.00	130.00	5.40	6.80	.95
April	128.00	151.00	6.00	7.40	.99
July	133.00	154.00	6.60	8.30	1.05
October	137.00	160.00	7.30	8.90	1.05
1952					
January	120.00	149.00	5.80	7.20	.98
April	134.00	165.00	6.20	8.00	.99
July	138.00	161.00	6.80	8.60	1.00
October	136.00	164.00	7.10	8.70	1.05
1953					
January	118.00	149.00	5.70	7.40	1.01
April	135.00	163.00	6.40	8.10	1.02
July	137.00	160.00	6.80	8.70	1.03
October	135.00	160.00	6.90	8.70	1.03
1954					
January	123.00	154.00	6.00	7.40	1.03
April	131.00	162.00	6.00	7.80	1.00
July	138.00	161.00	6.80	8.30	1.02
October	131.00	160.00	6.60	8.20	1.02
1955					
January	114.00	152.00	5.70	7.20	98

Source: *South Dakota Agriculture, 1954,* South Dakota Crop and Livestock Reporting Service, Sioux Falls, South Dakota.

In addition to this surplus agricultural population, Mobridge and Pierre both are located on the eastern edge of Indian reservations. Unskilled labor would be plentiful from this source. However, some training would be necessary to utilize this source for mechanical work. Skilled labor would probably have to be imported into the state.

The existing labor rates in South Dakota are given in tables 5 and 6.

Community Labor Situations

South Dakota communities, with the exception of Sioux Falls and Rapid City, do not have any sizeable industries and do not have a skilled labor pool on which to draw.

However, South Dakota is a surplus labor area. The rural population is declining. Many young people are trained in South Dakota's educational institutions and then leave the state to seek employment.

The people of South Dakota are becoming extremely aware of this migration of the younger generation. Through their state government, local chambers of commerce, and other civic groups they are actively promoting industrial development in the state. Any industry locating in South Dakota could expect a very favorable attitude toward its location in this state.

Transportation Facilities

Mobridge is located on a hard-surfaced road, U. S. Highway 12, and on a main line of a transcontinental railroad, the Chicago, Milwaukee, St. Paul, and Pacific. There is excellent rail service east and

Table 6. Measurement of Hours and Earnings for Selected Industry Groups in South Dakota, July 1953

Industry	Av. Weekly Earnings	Av. Weekly Hours	Av. Hourly Earnings
All Manufacturing	$63.38	42.9	$1.48
Food and Kindred Products	63.27	42.7	1.48
Meat Packing	71.03	43.9	1.62
Dairy Products	39.01	39.7	1.20
Bakery Products	61.11	45.2	1.35
Other Foods	60.50	45.2	1.34
Lumber and Wood Products	54.11	40.4	1.34
Printing and Publishing	77.16	41.5	1.86
Stone, Clay and Glass Products*	66.58	50.2	1.33
Metal Products	66.35	46.5	1.43
Chemical and Allied Products	64.30	42.5	1.51
Mining and Quarrying	75.26	46.7	1.61
Public Utilities†	59.68	40.3	1.48
Contract Construction	85.54	46.3	1.85

Source: Employment Security Department of South Dakota in cooperation with the Bureau of Labor Statistics.
*In South Dakota, principally cement products.
†Except transportation.

west from Mobridge and excellent roads for truck service in or out of Mobridge.

Pierre is located at the junction of U. S. Highway 83 running north and south and U. S. Highway 14 running east and west. Pierre is also located on an east-west line of the Chicago and Northwestern railroad.

Figures 10, 11, and 12 show the primary highways, railroads, and air routes in South Dakota as of 1956.

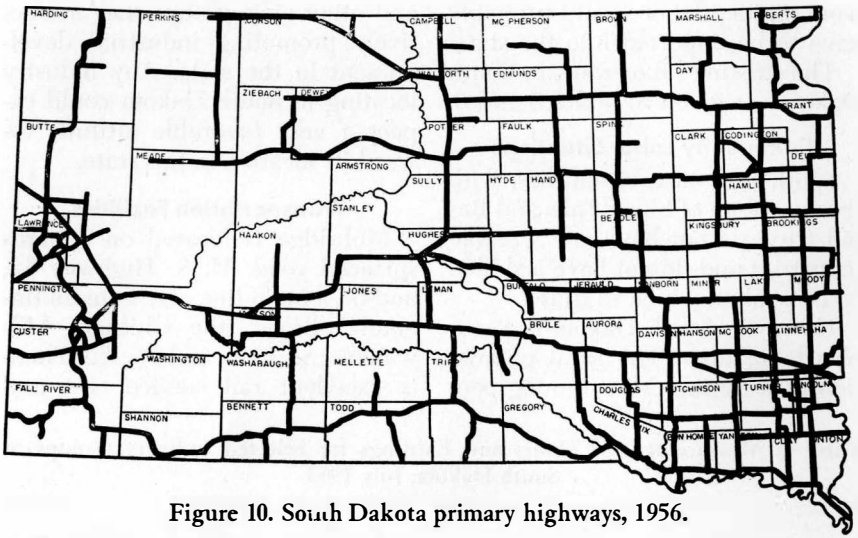


Figure 10. South Dakota primary highways, 1956.

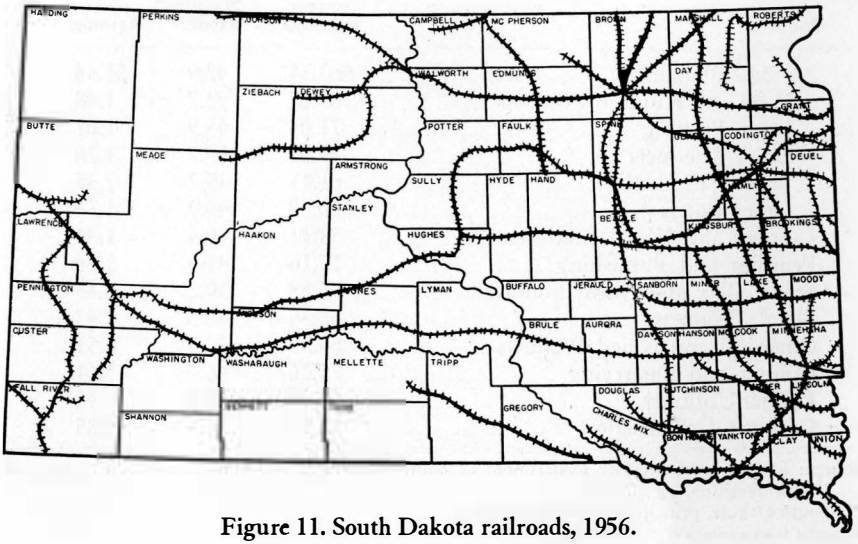


Figure 11. South Dakota railroads, 1956.

Chemical Requirements

Virtually none of the chemicals necessary for the pulping process are available in South Dakota.. A list of most of the chemicals needed for paper making, as well as the delivered price to Mobridge and Pierre and the location of the supplier are to be found in a recent publication of the South Dakota Resources Commission.[26]

[26] *Ibid.*, p. 24.

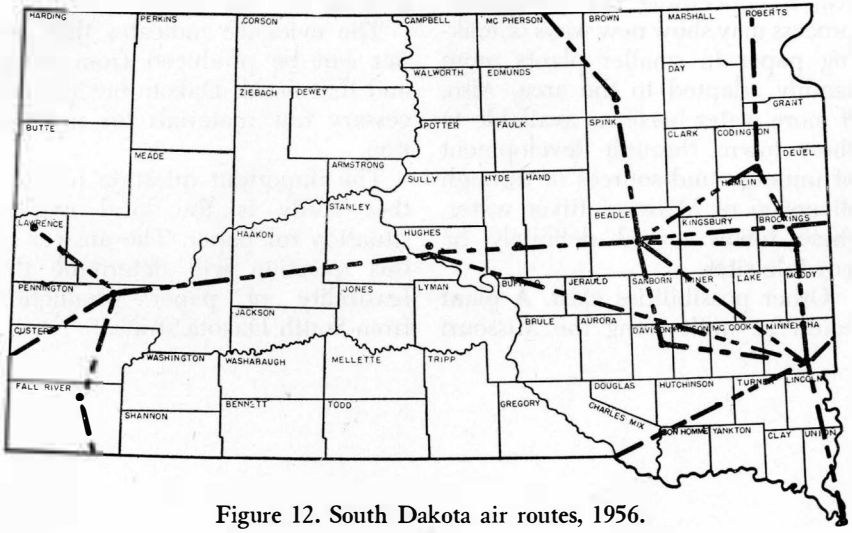


Figure 12. South Dakota air routes, 1956.

Conclusions

The purpose of this study was to determine which areas in the State of South Dakota have the necessary requirements for a paper plant using straw as a basic ingredient.

Water is the limiting factor as far as raw materials are concerned. The only sites in South Dakota that have a known water supply of 3 million gallons of water a day are along the Missouri River.

The best site along the Missouri River as far as raw materials are concerned is the town of Mobridge. At this site, straw and water are plentiful and the other raw materials are readily available. Pierre and Chamberlain are less favorable sites in terms of straw production.

The conclusions given are warranted with respect to a hypothetical plant using 50,000 tons of straw a year and 3 million gallons of water a day.

If the water requirement is decreased through changes in the technical process or if the water could be reused, then the whole northeastern quarter of the state could be considered for possible

plant locations. This would include such towns as Aberdeen, Webster, Watertown, Redfield, Miller, and Huron. Further research is needed on the industrial process to determine the feasibilty of the reuse of water in this process. Further research concerning the production process may show new ways of making paper in smaller plants more readily adapted to the area. Also, if more water becomes available to these towns through development of underground sources or through diversion of Missouri River water, these towns would definitely be possible sites.

Other possibilities exist. A plant could be built along the Missouri River (Mobridge, Pierre, Chamberlain, Yankton) to use straw produced east of the river and wood pulp produced in the Black Hills. This possibility would depend on the technological feasibility of a plant using both straw and wood pulp as raw materials.

The evidence indicates that paper can be produced from straw and that South Dakota has the necessary raw materials for production.

The important question for further study is the local market situation for paper. The answer to this question will determine the feasibility of paper production from South Dakota straw.